Phytoplankton flora of asejire reservoir, Southwest Nigeria

Godwin Asibor and Funso Adeniyi

DOI: https://doi.org/10.22271/23940522.2022.v9.i3a.895

Abstract
An appraisal of the current ecological status of Asejire Reservoir was carried out using the reservoir phytoplankton composition and community structure. Monthly sampling was carried out in nine selected sites for twelve months. Data were analysed using descriptive statistics, analysis of variance, Shannon-Weiner and Evenness indices. One hundred and fifty-four phytoplankton taxa were identified. Taxa dominance was in the following order: Bacillariophyceae > Chlorophyceae > Charophyceae > Euglenophyceae > Ochrophyceae > Dinophyceae. Microcystis sp. were the most abundant species followed by Anabaena sp. and Closterium sp. The riverine zone accounted for 50.8% of the total phytoplankton population. One-way analysis of variance between the zones indicated that there was a significant difference (F=11.41, df=2, p<0.0000146) in the spatial distribution among the stations. Most of the recorded phytoplankton species are cosmopolitan with the presence of the following species: Staurastrum, Closterium, Cosmarium, Anabaena, and Oscillatoria. The presence of some pollution indicator species is a cause of concern and the need to ensure holistic and effective monitoring measure is put in place to safeguard the reservoir.

Keywords: Asejire, reservoir, phytoplankton, community, taxa, cosmopolitan

1. Introduction
The total surface area covered by water in Nigeria is estimated to be 149,919km², constituting about 15.9% of the total area of the country [1]. These water bodies are often used for the disposal of domestic, industrial and other forms of anthropogenic effluents with the wrong assumption that the aquatic ecosystems have self-purifying ability [2, 3]. The primary producers in these waterbodies are the phytoplankton and are usually impacted by these discharges. The phytoplankton are food source for planktonic consumers and other higher organisms in the water and also represent the primary oxygen source in streams, rivers and reservoirs [4]. They number and type of phytoplankton are used as bio-indicators of water quality as they respond very quickly to changes in environmental stress which could result in consequences in their make-up and community structure [5, 6, 7]. Therefore, the composition, population and community structure of plankton are useful in assessing the biological integrity and functioning of aquatic ecosystem [8].

Aside the studies carried out by Egborge between 1972 and 1980 [9] when the reservoir was created; and [10]; most studies on the reservoir has been limited to the ichthyofauna and physico-chemical characteristics of reservoir [11, 12, 13, 14, 15, 16, 10, 17, 18, 19, 20, 21]. Paucity of information on the phytoplankton community especially their biodiversity, population and community structure is a setback to a proper understanding of the life process of the limnology of this vast and important reservoir, hence the need for this study. Therefore, the objectives of this study were to determine the taxonomic composition of the phytoplankton flora of the reservoir with regards to its composition, abundance and community structure. This will aid in updating the status of the phytoplankton community, develop a model for an effective management of the reservoir.

2. Materials and Methods
2.1 Study Area
The study area falls into the equatorial tropical climate [22], characterized by average annual rainfall of 100±40cm and temperature of 28±1.04 °C.

Corresponding Author:
Godwin Asibor
Department of Environmental Management and Toxicology, College of Science, Federal University of Petroleum Resources, P.M.B. 1221, Effurun, Delta State, Nigeria
Relative humidity is usually high ranging from 58% in the dry season to above 80% in the rainy season [23]. The surrounding vegetation is lowland tropical rainforest and dense savannah woodland at the northern fringe, but human interference and persistent annual bush burning for farming have reduced the natural vegetation to one described by [24] as forest regrowth. The Reservoir extend from longitudes 004°00'07"E - 004°08'09"E and from latitudes 07°21'48"N and 07°26'84"N (Figure 1). The reservoir is a manmade lake that was created in 1970 by the impoundment of River Osun to provide potable water for the city Ibadan and environs [11] and officially opened in 1972. Other ancillary benefits such as fishing, transportation, recreation, agriculture, etc. have since emerged after the dam creation [15]. The reservoir receives the bulk of its water input from two rivers, Rivers Osun and its main tributary River Oba. The catchment area of the dam is 7,800 km² and the impounded area is 23.42 km². The surface area of the reservoir is about 24 km². Its gross storage capacity is approximately 7,403.4 million litres per day while its discharge capacity is 136.26 million litres per day with maximum water capacity of about 675 m³. The reservoir supply water to more than two million inhabitants of Oyo and Osun States in the Southwestern part of Nigeria.

2.2 Selection, Description of sampling stations and Sample Collection

After a reconnaissance survey of the Reservoir, nine sampling sites (Stations A, B, C, D, E, F, G, H and I) were established along the course of the Reservoir (three each were along the horizontal axis of the reservoir, covering the upper basin-riverine zone), middle basin - transition zone and lower basin-lacustrine zone) of the lake (Figure 1). A Global positioning system (GPS) handset was used to determine the grid coordinates of the sampling sites. Samples were collected from April 2017 to March 2018. Samples were collected at each station by filtering 100 litres of water through a plankton net of 60 μm mesh size and reducing it to a concentrated volume of approximately 30 ml. The concentrated samples were preserved in 5% formalin solution.

2.3 Laboratory analyses

The 30 ml concentrate volume was further reduced to 5 ml, withdrawn using pipette and observed under the a compound microscope equipped with an ocular micrometer calibrated using a stage micrometer. Phytoplankton organisms were identified using guides by [25, 26, 27, 28, 29, 30, 31, 32, 33]. Species abundance were determined by direct count, aided by a counting chamber whose number of ocular fields had already been determined through calibration. Zooplankton abundance were determined from the count records of the final concentrated volume in relation to the original volume of water strained through the plankton net. Community structure was assessed using the indices of species diversity, Simpson’s dominance index (S). Abundance of each species was estimated based by multiplying the number in the final concentrate volume (30 ml for 30 Litres) by 1000 and expressed as organism/L (Org/L).

2.4 Statistical Analysis

The taxa richness, diversity, and evenness indices were calculated using Berger-Parker, Shannon-Wiener and Simpson and Margalef indices. All the statistical analyses

---

Fig 1: Asejire reservoir showing locations of sampling stations
were carried out using the Paleontological Statistics [34], Statistical Package for Social Sciences Software package and Statistical Ecology [35].

3. Results

3.1 Phytoplankton composition

A checklist of the phytoplankton species identified in Asejire Reservoir are presented in Table 1. A total of one hundred and fifty four (154) phytoplankton taxa were identified belonging to seven groups were recorded during the twelve months study period. This comprises of fifty-one species of Bacillariophyceae, twenty-five species of Charophyceae, twenty-nine species of Chlorophyceae, twenty-one species of Cyanophyceae, five species of Dinophyceae, seventeen species of Euglenophyceae and six species of Ochrophyceae. Taxa of Bacillariophyceae, Charophyceae, Chlorophyceae and Cyanophyceae were found in all the nine sampled locations, while Euglenophyceae, Dinophyceae and Ochrophyceae were found in eight, six and four stations. The order of dominance in relation to species richness in the reservoir was Bacillariophyceae (32.12%), Chlorophyceae (18.83%), Charophyceae (16.23%), Cyanophyceae (13.64%), Euglenophyceae (11.04%), Ochrophyceae (3.90%) and Dinophyceae (3.25%). In terms of abundance, Cyanophyceae recorded the highest with 32.68%, followed by Bacillariophyceae (25.48%), Chlorophyceae (20.59%), Charophyceae (13.81%), Euglenophyceae (5.12%), Dinophyceae (1.69%) and Ochrophyceae (0.64%). Among individual species, *Microcystis* sp. were the most abundant (20.39%), followed by *Anabaena* sp. (6.28%), *Closterium* sp. (5.94%), *Oedogonium* sp. (3.74%) and *Achnanthes* sp. (2.60%). Other phytoplankton species with relatively high abundance were *Synedra* sp., *Flagellaria* sp., *Eunotia* sp. and *Phacus* sp.

| Table 1: Checklists of Phytoplankton recorded from Asejire Reservoir |
| --- |
| **Division** |
| Bacillaceae |
| **Species** | **Stations** | **Total** |
| **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** |
| Achnanthes sp. | 750 | 250 | 400 | 200 | 100 | 50 | 150 | 250 | 2350 |
| Asterionella formosa | 250 | 100 | 550 | 200 | 50 | 25 | 200 | 150 | 50 | 1575 |
| Asterionella gracilina | 100 | 0 | 0 | 100 | 250 | 0 | 0 | 125 | 100 | 675 |
| Bacillaria sp. | 0 | 0 | 0 | 50 | 25 | 50 | 0 | 100 | 100 | 325 |
| Coscinodiscus sp. | 200 | 50 | 100 | 250 | 300 | 150 | 0 | 100 | 100 | 1250 |
| Cyclotella comta | 25 | 175 | 125 | 50 | 25 | 50 | 75 | 0 | 0 | 525 |
| Cyclotella kutzingiana | 0 | 0 | 0 | 50 | 25 | 50 | 0 | 0 | 0 | 125 |
| Cymatopleura solea | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 150 |
| Cymbella affinis | 0 | 0 | 0 | 25 | 50 | 25 | 0 | 25 | 0 | 125 |
| Cymbella lanceolate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 0 |
| Diatoma hiemale | 250 | 100 | 25 | 50 | 0 | 0 | 0 | 25 | 25 | 475 |
| Diatoma sp. | 0 | 100 | 25 | 50 | 0 | 0 | 0 | 0 | 0 | 175 |
| Diatomella balfouriana | 250 | 100 | 25 | 50 | 0 | 0 | 0 | 25 | 0 | 450 |
| Eunothia sp. | 200 | 125 | 25 | 50 | 0 | 0 | 0 | 25 | 50 | 475 |
| Eunotia naegelii | 150 | 100 | 25 | 50 | 0 | 0 | 0 | 25 | 50 | 400 |
| Eunotia obliquestrata | 200 | 50 | 25 | 50 | 0 | 0 | 125 | 50 | 25 | 25 | 550 |
| Eunotia sp. | 250 | 100 | 25 | 50 | 250 | 250 | 200 | 25 | 50 | 1200 |
| Fragilaria construens | 200 | 450 | 25 | 50 | 150 | 25 | 50 | 100 | 0 | 1050 |
| Fragilaria crotonensis | 200 | 150 | 25 | 50 | 250 | 200 | 100 | 150 | 25 | 1150 |
| Gomphomena sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 25 | 75 |
| Guinardia delicatula | 0 | 0 | 0 | 50 | 100 | 0 | 0 | 50 | 25 | 225 |
| Hantzschia amphioxys | 0 | 100 | 25 | 50 | 0 | 0 | 0 | 0 | 0 | 175 |
| Humidophila contenta | 300 | 450 | 150 | 50 | 250 | 250 | 200 | 100 | 125 | 1875 |
| Hyalodiscus radiates | 100 | 125 | 25 | 0 | 0 | 0 | 0 | 0 | 25 | 250 |
| Mastogloia elliptica | 0 | 100 | 25 | 50 | 0 | 100 | 250 | 0 | 25 | 550 |
| Mastogloia sp. | 0 | 100 | 25 | 50 | 0 | 100 | 250 | 0 | 25 | 550 |
| Melosira granulata | 25 | 50 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 175 |
| Navicula capitatoradiata | 125 | 100 | 25 | 50 | 0 | 25 | 0 | 0 | 0 | 325 |
| Navicula cinta | 0 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 75 |
| Navicula cryptocephala | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 |
| Navicula cuspidata | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| Navicula expansa | 0 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 75 |
| Navicula lanceolate | 25 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 75 |
| Navicula mutica | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| Navicula rhynchocep | 50 | 25 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 100 |
| Navicula viridula | 250 | 50 | 100 | 0 | 0 | 25 | 0 | 0 | 0 | 425 |
| Nitzchia sp. | 200 | 50 | 75 | 0 | 0 | 25 | 50 | 25 | 50 | 475 |
| Pinnularia borealis | 0 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 75 |
| Pinnularia brunii | 25 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| Pinnularia gibba | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 |
| Pinnularia nobilis | 0 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 75 |
| Pinnularia sp. | 100 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 175 |
| Pinnularia viridis | 0 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 75 |
| Pinnularia latia | 25 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| Pleurosigma sp. | 100 | 50 | 0 | 25 | 0 | 0 | 25 | 0 | 50 | 250 |
| Charophyceae       |                     |
|--------------------|---------------------|
| Chara sp.          | 250 100 0 100 50 250 100 50 50 50 50 50 50 225 |
| Closterium costatum| 250 100 0 100 50 250 100 50 50 50 50 50 50 950 |
| Closterium ehrenbergii | 100 250 50 100 50 100 100 0 50 800 |
| Closterium gracile  | 300 200 0 50 0 0 100 50 50 50 50 50 50 750 |
| Closterium incurvum | 100 150 50 0 50 100 50 100 25 575 |
| Closterium leibnizii | 0 125 0 0 50 50 100 50 50 425 |
| Closterium lunula  | 0 0 0 0 50 0 0 50 50 150 |
| Closterium moniliferum | 0 100 0 0 50 0 0 50 50 250 |
| Closterium parvulum | 0 0 0 0 50 0 0 50 50 300 |
| Closterium rostratum | 25 0 0 50 50 0 0 50 50 225 |
| Closterium sp.     | 250 100 0 100 50 250 100 50 50 950 |
| Cosmarium obtusatum | 0 0 0 0 0 0 50 0 50 50 |
| Cosmarium quadratum| 0 200 550 75 100 200 75 25 0 1225 |
| Cosmarium speciesm | 0 0 0 50 0 250 300 25 0 625 |
| Desmidium coerctatum| 0 0 0 0 0 25 0 25 0 25 |
| Gyalecta undulata  | 0 0 100 50 100 50 25 0 25 0 350 |
| Microsterias foliacea | 25 150 100 350 200 100 50 50 0 1025 |
| Microsterias moebii | 100 0 250 50 0 0 50 25 0 475 |
| Pleurotium trabeccula| 200 100 350 0 50 25 25 0 0 750 |
| Spirogyra borgeana | 100 50 0 100 50 0 0 100 50 450 |
| Spirogyra californica| 100 150 0 0 50 0 0 0 300 |
| Spirogyra flavivitilis| 125 50 0 0 0 0 0 50 225 |
| Spirogyra sp.      | 200 125 100 0 50 0 0 0 0 475 |
| Staurostrum triangularis | 0 100 50 0 0 25 50 0 225 |
| Staurodesmus convergens | 100 150 50 0 0 0 50 300 |
| Ankistrodesmus falcatus | 100 75 100 75 50 25 75 75 100 675 |
| Asterionella formosa | 150 100 50 50 50 100 0 0 50 550 |
| Chlamydomonas sp.  | 50 150 200 50 0 0 25 0 475 |
| Chlorella sp.      | 200 0 50 0 0 0 150 0 0 400 |
| Chlorosarcina minor | 100 50 50 0 0 0 0 0 200 |
| Coelastrum microsporum | 50 100 250 0 0 50 50 50 50 500 |
| Coelastrum sphaericum| 100 100 250 0 0 50 50 50 550 |
| Eudorina sp.       | 150 100 200 0 0 50 25 0 325 |
| Gonatocystis mononoumenium | 250 450 200 50 75 125 50 25 0 1225 |
| Hantzschia amphioxys | 25 0 0 0 50 0 0 0 100 175 |
| Micrasterias sp.   | 25 0 0 0 0 0 0 0 25 0 25 |
| Microspora floccosa | 125 100 25 75 0 0 25 75 100 585 |
| Oedogonium capillare| 25 0 0 0 50 0 0 50 250 300 100 725 |
| Oedogonium sp.     | 750 500 300 0 50 300 250 100 400 2650 |
| Oocystis crassa    | 50 100 50 25 0 0 0 200 75 500 |
| Oocystis elliptica | 100 100 0 25 0 0 0 50 100 375 |
| Pediastrum duplex  | 0 0 0 100 0 0 0 50 100 250 |
| Rhizoclonium hieroglyphicum | 100 100 0 25 75 100 200 250 300 1150 |
| Scenedesmus bijuga  | 25 125 175 75 100 25 50 100 50 725 |
| Scenedesmus quadricauda | 100 25 100 75 50 125 200 25 0 700 |
| Sphaeroystis scholteri | 50 0 100 0 50 0 100 0 0 300 |
| Stauroastrum leptocladium | 150 300 200 0 50 75 0 0 0 775 |
| Stauroastrum limneticum| 50 200 0 0 50 0 0 0 0 300 |
| Stauroastrum trifidum | 200 150 100 50 75 50 25 0 50 700 |
| Tetraedron minimum | 0 100 150 0 50 100 0 0 0 400 |
| Trebriaria crassipina | 150 250 150 125 50 100 50 25 0 900 |
| Ulothrix sp.       | 100 250 50 200 150 100 0 0 50 900 |
| Volvox aureus      | 200 100 50 150 50 100 0 0 25 50 725 |
| Volvox globulus    | 100 150 50 100 150 100 0 0 50 700 |
| Anabaena circularis| 200 100 50 100 50 75 100 25 800 |
| Anabaena constricta| 25 75 100 25 125 50 100 50 125 675 |
| Anabaena subcylindrica | 750 250 100 100 50 200 250 100 75 1875 |
| Anabena circinalis  | 200 25 25 150 75 250 150 100 125 1100 |
| Anabena sp.        | 100 75 150 125 75 150 200 250 100 725 |
| Aphanocapsa delicatissima | 125 75 100 125 75 75 200 100 100 975 |
| Chromococcus cohaerens | 100 125 150 100 75 150 200 250 100 1250 |
The highest number of individuals for phytoplankton was recorded in the riverine zone (upper reach) of the reservoir in stations A (19075), B (15025) and C (11775) followed by the transition zone in stations F (8675) and D (7975), while the location with the least number of individuals was stations I (5650) and H (6750) in the lacustrine region of the reservoir. In summary the riverine zone accounted for 50.77% of the total phytoplankton population, while the transition and lacustrine zone accounted for 26.81% and 22.41% respectively (Tables 2, 3 and 4). The highest Margalef (d) value (0.672) was recorded for Station E followed by Station A (0.609) while the lowest Margalef was recorded in Stations G, H and B with the values of 0.446, 0.454 and 0.520. The highest Shannon index values of 1.646, 1.593 and 1.577 were recorded in Stations C, A and B all in the riverine zone of the reservoir, while the lowest Shannon index was recorded Stations H, G and D in the lacustrine and transition zones of the reservoir. The Equitability shows that the highest values of 0.919 and 0.880 was recorded in Stations C and B; all in the riverine zone of the reservoir, while the lowest value of 0.774 was recorded in the transition zone of the reservoir.

Table 5 shows the relationship between the individual phytoplankton species in the reservoir. The highest Shannon index values of 4.39, 4.32 and 4.19 were recorded in Stations B, A and C all in the riverine zone of the reservoir, while the lowest Shannon index was recorded Stations D, E and G in the transition and lacustrine zones of the reservoir. This similar trend was also by the Simpson, Menhinick and Margalef, Fisher alpha and Berger-Parker indices. One-way analysis of variance of between the zones indicated that there was a significant difference (F=11.41, df=2, p=0.0000146) in the spatial distribution of the organisms among the stations. A similar trend was also observed in the one-way analysis of variance between the zones with regards to species occurrence as there was a significant difference (F = 12.53, df = 2, p = 0.00000501) between the stations.

| Species                        | Stations | Total | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|--------------------------------|----------|-------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gloeotrichia echinulata        |          |       | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 25 | 0 | 325|
| Lyngbya martensiana            | 100      | 50    | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 175|
| Microcystis aeruginosa         | 750      | 850   | 300 | 750 | 650 | 450 | 400 | 550 | 50 | 4750|
| Microcystis flos aquae         | 850      | 950   | 550 | 650 | 750 | 750 | 575 | 750 | 100 | 5925|
| Microcystis turrigis           | 1550     | 750   | 850 | 1050 | 750 | 850 | 650 | 550 | 750 | 7750|
| Oocystis eremo phera          | 125      | 50    | 100 | 75 | 75 | 25 | 0 | 0 | 25 | 25 | 425|
| Oocystis solitaria             | 100      | 200   | 0 | 0 | 0 | 50 | 25 | 0 | 25 | 75 | 475|
| Oscillatoria aghardii          | 150      | 50    | 75 | 75 | 25 | 0 | 50 | 25 | 75 | 75 | 475|
| Oscillatoria limnosa           | 50       | 100   | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 150|
| Oscillatoria tenuis            | 100      | 50    | 0 | 0 | 0 | 50 | 25 | 0 | 0 | 0 | 175|
| Rivularia sp.                  | 0        | 25    | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25|
| Spirulina platensis            | 100      | 50    | 150 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 350|
| Dinophyceae                    | 100      | 150   | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 350|
| Peridiniopsis thompsoni        | 100      | 25    | 150 | 0 | 0 | 0 | 0 | 25 | 25 | 325|
| Peridinium sp.                 | 50       | 50    | 100 | 0 | 0 | 0 | 0 | 25 | 25 | 225|
| Peridinium bipes               | 100      | 25    | 75 | 0 | 0 | 0 | 0 | 25 | 25 | 250|
| Didinium bolbiani              | 25       | 75    | 50 | 0 | 25 | 0 | 0 | 0 | 25 | 25 | 225|
| Oodinium limneticum            | 125      | 100   | 75 | 0 | 125 | 0 | 50 | 25 | 50 | 500|
| Euglena acus                   | 0        | 0     | 0 | 25 | 50 | 75 | 100 | 0 | 100 | 350|
| Euglena cardinal               | 100      | 75    | 150 | 0 | 0 | 0 | 0 | 0 | 50 | 375|
| Euglena gracilis               | 50       | 75    | 0 | 0 | 0 | 0 | 0 | 0 | 50 | 175|
| Euglena oxyaris                | 100      | 75    | 150 | 0 | 0 | 0 | 0 | 0 | 50 | 375|
| Euglena viridis                | 100      | 50    | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 150|
| Lepocinclis ovum               | 0        | 50    | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50|
| Phacus curvicauda              | 175      | 0     | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 225|
| Phacus longicauda              | 200      | 125   | 175 | 100 | 25 | 50 | 0 | 0 | 0 | 675|
| Phacus orbicularis             | 150      | 175   | 200 | 75 | 50 | 50 | 25 | 0 | 0 | 725|
| Phacus suecicus                | 175      | 0     | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 225|
| Trachelomonas enzera           | 150      | 50    | 25 | 0 | 25 | 0 | 25 | 0 | 275|
| Trachelomonas hispida          | 125      | 50    | 25 | 0 | 0 | 0 | 0 | 0 | 200|
| Trachelomonas hordida          | 50       | 75    | 25 | 0 | 0 | 0 | 0 | 0 | 150|
| Trachelomonas lacustris         | 100      | 50    | 25 | 0 | 0 | 0 | 0 | 0 | 175|
| Trachelomonas oblonga           | 0        | 50    | 0 | 0 | 0 | 0 | 0 | 0 | 50|
| Trachelomonas similis           | 75       | 50    | 25 | 0 | 0 | 0 | 0 | 0 | 150|
| Trachelomonas tambowica         | 100      | 50    | 125 | 25 | 0 | 0 | 0 | 0 | 0 | 300|
| Encyonema auerswaldii           | 0        | 0     | 0 | 25 | 50 | 50 | 0 | 0 | 0 | 125|
| Encyonema sp.                  | 0        | 0     | 0 | 0 | 0 | 50 | 50 | 0 | 0 | 50|
| Geissleria sp.                 | 0        | 0     | 0 | 0 | 50 | 0 | 0 | 0 | 50|
| Gyrosigma acuminatum           | 100      | 0     | 0 | 25 | 50 | 50 | 0 | 0 | 0 | 225|
| Gyrosigma sp.                  | 0        | 0     | 0 | 25 | 50 | 50 | 0 | 0 | 0 | 75|
| Luticola sp.                   | 0        | 0     | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 50|
### Table 2: Phytoplankton abundance among the sampled locations

| Taxa                | Stations | A   | B   | C   | D   | E   | F   | G   | H   | I   | Total |
|---------------------|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|--------|
| Bacillariophyceae   |          | 5800| 3925| 2600| 2050| 2075| 1675| 1925| 1550| 1425| 23025  |
| Charophyceae        |          | 2075| 2100| 1700| 1075| 1000| 1675| 1250| 1025| 575 | 12475  |
| Chlorophyceae       |          | 3475| 3675| 2850| 1250| 1225| 1725| 1600| 1175| 1625| 18600  |
| Cyanophyceae        |          | 5575| 4050| 3150| 3325| 2850| 3125| 2925| 2875| 1650| 29525  |
| Dinophyceae         |          | 400 | 275 | 450 | 150 | 0   | 0   | 125 | 125 | 1525| 575    |
| Euglenophyceae      |          | 1650| 1000| 1025| 200 | 175 | 175 | 150 | 0   | 250 | 4625   |
| Ochrophyceae        |          | 100 | 0   | 75  | 100 | 300 | 0   | 0   | 0   | 575 |        |
| **Total**           |          | 19075| 15025| 11775| 7975| 7575| 8675| 7850| 6750| 5630| 90350  |

### Table 3: Phytoplankton occurrence among the sampled locations

| Taxa                | Stations | A   | B   | C   | D   | E   | F   | G   | H   | I   |
|---------------------|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Bacillariophyceae   |          | 34  | 41  | 35  | 30  | 17  | 22  | 18  | 22  | 24  |
| Charophyceae        |          | 15  | 17  | 11  | 11  | 15  | 12  | 15  | 19  | 12  |
| Chlorophyceae       |          | 27  | 23  | 22  | 16  | 18  | 16  | 15  | 16  | 14  |
| Cyanophyceae        |          | 19  | 20  | 18  | 12  | 14  | 14  | 13  | 13  | 12  |
| Dinophyceae         |          | 05  | 05  | 05  | 0  | 0   | 0   | 0   | 0   | 04  |
| Euglenophyceae      |          | 14  | 14  | 12  | 03  | 05  | 03  | 03  | 03  | 04  |
| Ochrophyceae        |          | 01  | 0   | 03  | 02  | 06  | 0   | 0   | 0   | 0   |

### Table 4: Diversity between the major divisions in the Stations (abundance)

| Taxa                | Station | A   | B   | C   | D   | E   | F   | G   | H   | I   |
|---------------------|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Individuals         |         | 19075| 15025| 11775| 7975| 7575| 8675| 7850| 6750| 5650|
| Dominance           |         | 0.231| 0.225| 0.209| 0.283| 0.261| 0.246| 0.266| 0.288| 0.244|
| Shannon index       |         | 1.593| 1.577| 1.646| 1.411| 1.506| 1.519| 1.405| 1.366| 1.320|
| Simpson index       |         | 0.769| 0.775| 0.791| 0.717| 0.739| 0.755| 0.734| 0.712| 0.756|
| Menhinick           |         | 0.051| 0.049| 0.055| 0.067| 0.080| 0.064| 0.056| 0.061| 0.080|
| Margalef            |         | 0.609| 0.520| 0.533| 0.357| 0.672| 0.551| 0.446| 0.454| 0.579|
| Equitability        |         | 0.819| 0.880| 0.919| 0.787| 0.774| 0.848| 0.873| 0.849| 0.848|
| Fisher alpha        |         | 0.684| 0.592| 0.608| 0.636| 0.760| 0.630| 0.520| 0.529| 0.663|
| Berger-Parker       |         | 0.304| 0.270| 0.268| 0.417| 0.376| 0.360| 0.373| 0.426| 0.292|

### Table 5: Diversity between individuals in the stations (abundance)

| Taxa                | Station | A   | B   | C   | D   | E   | F   | G   | H   | I   |
|---------------------|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Individuals         |         | 0.013| 0.0195| 0.0223| 0.043| 0.0388| 0.0334| 0.031| 0.038| 0.037|
| Shannon index       |         | 4.320| 4.389| 4.189| 3.768| 3.78 | 3.829| 3.780| 3.785| 3.849|
| Simpson index       |         | 0.9787| 0.981| 0.978| 0.957| 0.961| 0.967| 0.969| 0.962| 0.963|
| Menhinick           |         | 0.327| 0.979| 0.949| 0.840| 0.838| 0.784| 0.722| 0.901| 0.945|
| Margalef            |         | 11.570| 12.37| 10.88| 8.237| 8.06 | 7.94 | 7.025| 8.279| 8.102|
| Equitability        |         | 0.9014| 0.917| 0.904| 0.873| 0.881| 0.892| 0.909| 0.879| 0.903|
| Fisher alpha        |         | 16.27| 17.81| 15.53| 11.46| 11.2 | 10.93| 9.531| 11.62| 11.44|
| Berger-Parker       |         | 0.0813| 0.063| 0.072| 0.132| 0.099| 0.098| 0.083| 0.111| 0.133|

### 4. Discussion
The different divisions of phytoplankton namely: Bacillariophyceae, Charophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, Ochrophyceae and Cyanophyceae identified in Asejire Reservoir were to an extent similar to assemblages of some previously identified species from different Nigerian aquatic environment [11, 36, 37, 38, 39, 40, 10, 41, 42, 43].

Phytoplankton of the Cyanophyceae (blue-green algae) group was found to be the most abundant phytoplankton group in the reservoir during the study period. This agrees with the observations of [44, 45] who worked in Aawba Lake (Nigeria) and Lake George (Uganda). *Microcystis* spp. have been reported to dominate the phytoplankton group in Awba Lake in Nigeria according to [44] and an earlier study in Asejire Reservoir by Egborje [12], while *Anabaena* sp., a filamentous form of blue-green algae was reported to dominate phytoplankton in Lake Rudolf (Kenya) and Lake Albert [46]. Contributions to the group were mainly from *Microcystis*, *Anabaena*, *Aphanacapsa*, *Chroomococcus*, *Oscillatoria* and *Spirulina*. A similar observation made by [47] in a freshwater in Uyo. The second dominant group was Bacillariophyta with 23,025 species and 51 taxa. Species numbers of Bacillariophyta were high in all the locations. *Euotia*, *Synedra*, *Achnanthes*, *Asterionella*, *Flagillaria*, *Nitzschia* and *Cyclotella* were the
dominant genus and were widely found in all the locations. [30] remarked that *Fragilaria* and *Nitzschia* species are known indicators of eutrophic lakes, while [48] stated that *Cylotella* species are bioindicators of transient phase from oligotrophic to eutrophic conditions. [30] also observed that *Asterionella* formosa is the characteristic species of mesotrophic lakes. The third dominant group was Chlorophyceae taxa with 18625 individuals, but with the second most occurring species (29). The occurrence maybe due to high oxygen level and mixing as noted by [49, 50] who observed that diatoms green algae dominate the phytoplankton community of many tropical African lakes.

The occurrence of *Microcytis*, *Anabaena* and *Aphanocapsa* is a clear indication anthropogenic pollutants into the reservoir as observed by [30] in Awba Reservoir at the University of Ibadan. The anthropogenic activities could be as result of laundry wastewater, chemicals, agricultural run-off and wastes washed into the reservoir from communities around the upper reach the reservoir. [51] reported that reservoirs where domestic, agricultural and industrial pollution is accelerated, growth of blue-green algae results in noxious bloom of such form as *Microcytis* and *Anabaenata*. A similar observation was made by Egborje [11] that *Anabaena* and *Microcytis* are indication of eutrophication following upwelling in Lake Kainji in Nigeria. The presence of *Oscillatoria* indicates the presence of high concentrations of organic matter and low oxygen content. However, these plant nutrients may be derived from fertilized farm lands at upper sections of the reservoir. This phenomena has also been reported by [32].

The Euglenophyceae taxa identified in the Asejire Reservoir were generally low (5.12%) compared to the Cyanophyceae (32.7%), Bacillariophyceae (25.5%), Chlorophyceae (20.6%) and Charophyceae (13.8%). Euglenoids species can tolerate various levels of organically polluted waters and therefore can be used as indicators of organic pollution [30, 53, 54, 55]. Pollution indicator species like *Euglena*, *Phacus*, *Lepocinclis* and *Trachelomonas*, *Navicula*, *Melosira*, *Pinnularia*, *Synedra*, *Oscillatoria*, *Spirulina*, *Fragilaria* and *Nitzschia* were encountered during the study. The presence of these Euglenoid species encountered in some of locations this may indicate the presence of anthropogenic influence on the reservoir. Egborje [14] pointed out that the euglenoids are good indicators of polluted or meso and eutrophic freshwater bodies. Therefore, there is a possibility of algal bloom formation if there is excessive nutrients enrichment of the water by the presence of human habitations around the reservoir.

In Asejire Reservoir, most of the recorded phytoplankton species are cosmopolitan. One of the most used methods for the codification of trophic state of lake is phytoplankton indexes, though these indexes may not totally reliable due to the short period of water retention time in reservoir systems [56]. It is quite tasking to understand the trophic status of the lake using only species composition results, but [57, 55] stated that *Staurastrum*, *Closterium* and *Cosmarium* (Chlorophyceae), *Anabaena* and *Oscillatoria* (Cyanophyceae) are found; *Peridinium* and *Ceratium* (Dinophyceae), *Cyclorella*, *Stephanodiscus* and *Asterionella* (Bacillariophyceae) are dominant in eutrophic and mesotrophic water. Based on these findings, Asejire Reservoir can be termed a productive eutrophic reservoir.

5. Conclusion

This study on phytoplankton of Asejire Reservoir is considered important and can be utilized as a basis for impact assessment, planning and implementation. Development of policies for monitoring and effective development of the reservoir should incorporate phytoplankton indices. The phytoplankton community structure to an extent have great impact on reservoir survival on the long run. Their presence provide suitable conditions for micro habitats and other grazers within the lake.

6. References

1. Ita EO. Inland Fishery Resources of Nigeria. CIFA Occasional paper No 20. F.A.O, 1993, 120p.
2. Fakayode SO. Impact assessment of Industrial effluent on water quality of the receiving Alaro stream in Ibadan, Nigeria, J Ajem-Ragee. 2005:10-1-13.
3. Adeogun AO, Fafioye OO. Impact of effluents on water quality and benthic macroinvertebrate fauna of Awba Stream and Reservoir. Journal of Applied Science and Environmental Management. 2011;15(1):105-113.
4. Wehr JD, Descy JL. Use of phytoplankton in large river management, J Psychol. 1998;34(5):741-749.
5. Meybeck M, Friedrich A, Thomas R, Chapman D. Rivers in Water quality assessment; A guide to use of biota, sediments and water in environmental monitoring chapman. D.E.D, Chapman and Hall. London, 1992, 239p.
6. Bahura CK. Phytoplanktonic community of the highly eutroficated temple tank Bikaner. J Aquat. Biol. 2001;12(2):47-51.
7. Akindele EO, Adeniyi IF. A study of the physicochemical water quality, hydrology and zooplankton fauna of Opa Reservoir. Afr. J Environ. Sci. Technol. 2013;7(5):192-203.
8. Brettum P, Andersen T. The use of phytoplankton as indicators of water quality. In: NIVA report. Society for Neuro Oncology. 2005;12:4818-2004.
9. Egborje ABM. The seasonal variation and distribution of phytoplankton of the lake Asejire. A new impoundment in Nigeria: Preceeding of International conference on Kainji Lake, 1977, 136-145.
10. Ayode AA, Fagade SO, Adebisi AA. Dynamics of limnological features of two man-made lakes in relation to fish production. African Journal of Virology Research. 2018;12(6):001-009.
11. Egborje ABM. A preliminary checklist of the zooplankton organisms of the River Oshun in the Western State of Nigeria. Nig. J Sci. 1972;6(1):67-71.
12. Egborje ABM. The composition, seasonal variation and distribution of zooplankton in Lake Asejire, Nigeria. La Revue de zoologic Africaine. 1981;95:137-165.
13. Egborje ABM. Cyclomorphosis in *Keratella tropica* (Apstein) of Lake Asejire, Nigeria. Hydrobiologia. 1986;135:179-191.
14. Egborje ABM. The composition, seasonal variation and distribution of zooplankton in Lake Asejire, Nigeria. La Revue de Zooligic Africaine. FASC. 1990;(1-1981)95:137-165.
15. Asibor IG. The Macroinvertebrate fauna and sediment characteristics of Asejire Reservoir, Southwest Nigeria. Ph.D. Thesis, Dept. of Zoology, Obafemi Awolowo University, Ile-Ife, Nigeria, 2008, 1-192.

~ 15 ~
16. Asibor G, Adeniyi F. Benthic macro-invertebrates of Asejire reservoir, Southwest Nigeria. International Journal of Fauna and Biological Studies. 2017;4(3):119-124.

17. Ipinmoroti MO. Ichthyofauna diversity of Lake Asejire: Ecological implications. International Journal of Fisheries and Aquaculture. 2013;5(10):248-252.

18. Jenyo-Oni A, Oladele AH. Heavy Metals Assessment in Water, Sediments and Selected Aquatic Organisms in Lake Asejire, Nigeria. European Scientific Journal. 2016;12(24):339-351.

19. Odulate DO. Ichthyofauna diversity in Asejire Lake, Southwest, Nigeria. J Ecosys Ecograph. 2016;6:1-10.

20. Kareem K, Olanrewaju N, Igbaro B. Growth Pattern, Diet and Tropical Niche Breadth of the Nile Silver Catfish, Schilbe mystus (Linne 1758) in Asejire Lake, Southwestern, Nigeria. Egyptian Journal of Aquatic Biology & Fisheries Zoology. 2021;25(2):677-687.

21. Omoike A. The Trend in Fish Species Diversity and Abundance at Asejire Reservoir South Western Nigeria. Journal of Aquatic Fisheries. 2021:5:1-9.

22. Ojo O. The climates of West Africa. Heinemann Educational Books, Ltd, Nigeria, 1911, 198p.

23. Papadaki J. Crop ecology of West Africa. FAO, UN Publication MR/16439/1. 1961:2:188.

24. Agboola SA. An agricultural atlas of Nigeria. Oxford University Press, Oxford, 1979, 248p.

25. Prescott GW. How to Know the Freshwater Algae. WM.C Brown Co., Dubuque, Iowa, 1954, 211p.

26. Edmondson WT. Fresh water Biology. 2nd ed, London. 1951, 421-494.

27. Whitford LA, Schumacher GJ. A Manual of Freshwater Algae. Sparks Press, Raleigh, 1973, 324p.

28. Needham JG, Needham PR. A guide to the study of freshwater Biology. 5th Edn. Holden Day publishing, San Francisco, 1975, 267p.

29. Maosen H. Illustration of Freshwater Plankton. Agricultural Press, London, 1978, 171p.

30. Reynolds CS. The ecology of freshwater phytoplankton. Cambridge Univ. Press, Cambridge, New York, 1984, 384p.

31. Nwankwo DI. A practical guide to the study of algae in Nigeria. JAS publishers, Lagos, 2004, 190p.

32. Suthers IM, Rissik D. Plankton: A guide to their ecology and monitoring for water quality (p. 256). CSIRO Publishing. 2009, 54-177.

33. Opute FL, Kadiri MO, Phytoplankton algae of Nigeria: A practical and theoretical guide, The Desmids, Mindex Publishing Co. Ltd, Nigeria. 2013;1:304.

34. Hammer O, Harper DAT, Ryan PD. Palaeontological Statistics version 1.15. Kluwer Academic Publishers, 2003, 24-98.

35. Ludwig JA, Reynolds JF. Statistical Ecology: A primer on methods and computing. John Wiley & Sons, New York, 1988, 53-121.

36. Yakubu AF, Sikoki FD, Abowei JFN, Hart SA. A Comparative Study of Phytoplankton Communities of Some Rivers, Creeks and Burrow Pits in the Niger Delta Area. Journal of Applied Science and Environmental Management. 2000;4:41-46.

37. Yakubu AS. Assessment of water quality and plankton of effluents receiving Awba stream and reservoir in Ibadan, Nigeria. Afr. J Appl. Zool. Environ. Biol. 2004;6:107-110.

38. Edward JB, Ugwumba AA. Physico-chemical parameters and plankton community of Egbe Reservoir, Ekiti State, Nigeria. Research Journal of Biological Sciences. 2010;5(5):356-367.

39. Anago IJ, Ensenowo IK, Ugwumba AA. The Physico-chemistry and Plankton Diversity of Awba Reservoir University of Ibadan, Ibadan Nigeria. Research Journal of Environmental and Earth Sciences. 2013;5(11):638-644.

40. Hameed IO, Adeniyi IF, Adesakin TA, Aduso AI. Phytoplankton Diversity and Abundance in Relation to Physico-chemical Parameters of Iewara Reservoir, Southwestern Nigeria. World News of Natural Sciences. 2019;24:251-268.

41. Adebayo ET, Ayoade AA. Ecological Assessment of Itapaji Reservoir Status in Itapaji Using Plankton Assemblage. Ethiopian Journal of Environmental Studies and Management. 2019;12(1):13-31.

42. Daoud H, Wakirwa BJ, Yusuf UM. Phytoplankton as Indicators of Water Quality in Gadan Jammel Dam Nangere, Yobe State, Nigeria. International Journal of Innovative Environmental Studies Research. 2020;8(3):10-19.

43. Adebayo AT, Adewole HA, Akindele EO, Olayeye VF. Planktonic fora and fauna of Opa Reservoir wetlands, Obafemi Awolowo University, Ile-Ife, Nigeria. The Journal of Basic and Applied Ecology. 2021;82(40):2-10.

44. Ugwumba AO, Ugwumba AAA. A study of the physico-chemical hydrology and plankton of Awba Lake in Ibadan, Nigeria. Fish Acadibiz. Comm. 1993;1(1-4):20-39.

45. Burgis MJ, Darlington JP, Dunn IG, Graf GG, Gwahaba JJ, McGomwan LM. The biomass and distribution of organisms in Lake George, Uganda. Proc. Royal Soc. London Series B. Biol. Sci. 1973;184:271-298.

46. Fish GR. The food of Tilapia in East Africa. Uganda J. 1955i;19:85-89.

47. Akpan AW. Limnology and net plankton periodicity of a tropical freshwater pond in Uyo (Nigeria). Tropical Fresh Biol. 1995;4:65-81.

48. Round FE, Crawford RM, Mann DG. The Diatoms: Morphology and biology of the genera. Cambridge University Press, Cambridge, 1990, 747p.

49. Aboul-El A, Khalil MT. Ecological studies on the plankton and Benthic of Wadi elrayan, a new lake in Egypt. Tropical Fresh Water Biol. 1989;2:101-111.

50. Ugwumba AAA. Food and feeding ecology of the Oreochromis niloticus (Pisces Osceichthytes) in Awba Reservoir Ibadan, Ph.D. Thesis, University of Ibadan, 1990, 188p.

51. Cole GA. A textbook of limnology. The C. V. Mosby Company, 1978, 245p.

52. Olaniyi RF. Physicochemical characteristics and Phytoplankton flora of Owena Reservoir, Southwest, Nigeria. Afr. J Med. Sci. 2010;3(1):6-10.

53. Nwankwo DI, Akinsoji A. Periphyton algae of a eutrophic creek and their possible use as indicator. Niger. J Bot. 1988;10:23-35.

54. Nkechinyere ON, Domrufus NA. Limnological studies on Nike Lake, Enugu State. The metaphyton and some physico-chemical aspects. Nig. J Bot. 2006;19:396-404.

55. Moss B. Ecology of freshwaters. 3rd edition, Blackwell Science, Oxford, 2001, 256p.
56. Lind OT, Terrell TT, Kimmel BG. Problems in reservoir trophic state classification and implications for reservoir management. In: M. Straskraba, J.G. Tundisi and A. Duncan (Ed.), Comparative Reservoir Limnology and Water Quality Management, Kluwer Ac. Publ., the Netherlands, 1993, 57-67.

57. Hutchinson GE. A treatise on limnology, vol: II, introduction to lake biology and the limnoplankton. John Wiley and Sons. Inc., New York, 1967, 115.