*Original Research Article*

# Water Quality and Phytoplankton Appraisal of Agbarha River in Delta State of Nigeria, for Aquaculture Purposes

***Iloba, K.I. and Utuedor, H.A.**

Department of Animal and Environmental Biology
Faculty of Sciences, Delta State University
Abraka, Delta State, Nigeria

*Corresponding author: kisyiloba@gmail.com; iloba@delsu.edu.ng

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## Abstract

The use of any water body for aquaculture production is nexus to understanding its water quality and phytoplankton biomass, primary production surrogate. This study was undertaken to assess the Phytoplankton status and water quality of Agbarha River in Delta State of Nigeria; over a period of five weeks [March to May 2017] for its aquaculture potentials. The study revealed that fish farming is feasible in the River. Study found quality and quantity acceptable phytoplanktonic food (>3000 organisms/L) for fish farming. The plankton community was dominated by chlorophyta with ten species accounting for 49% of the overall assemblage, bacilariophyta had 9(nine) species constituting 41%, cyanophyta being five(5) species of 10% and dinophyta 2 species of 1% of the phytoplankton population. The mean results of the water quality parameters were air temperature, ranged from 29 – 39˚C, water temperature(25°C – 34˚C), pH (7.15 – 10.78), Total solids (0.23mg/l – 0.6mg/l), dissolved oxygen (2.2mg/l – 6.9mg/l), biochemical oxygen demand ranged from (0.1mg/l – 6.6mg/l), acidity ranged (14.0mg/l- 89.0mg/l), Alkalinity ranged from (10.0mg/l - 41.0mg/l), transparency ranged (0.02 – 1.2), phosphate (7.2mg/l – 10.8mg/l) and nitrate (0.005mg/l – 3.75mg/l). Most studied variables were aquaculture compliant and identified impairments were anthropogenically driven and controllable via withdrawal.

**Keywords**: Aquaculture, Phytoplankton assemblage, physicochemical parameters, Species diversity, Agbarha River

## Introduction

The aquatic world is complex and diverse in nature with amazing organisms arranged in an intricate sequence based on their food requirements (Striebel *et al*, 2012; Alhassan, 2015). This sequence is anchored on the energy obtained from nutrient fixation organisms primarily the phytoplankton, also known as producers (Murulidhar and Yogananda Murthy, 2015).

Phytoplankton productively in any aquatic ecosystem is a function of their composition, biomass and the prevailing water quality (Striebel *et al.*, 2012). For their trophic position, they can provide a good index for assessing aquatic productivity and its fish yield (Rynearson and Menden-Deuer, 2016). Thus they form an important component of aquatic ecosystems and provide information on its life-supporting capacity (Sharmin *et al.*, 2018). This basic information obtained from assessment of the composition, abundance or biomass of phytoplankton and water quality can be useful in traditional aquaculture practices in our water bodies, for youth's employment, and economic and societal development in a nation endowed with enormous natural water resources and undergoing recession (Pant *et al.*, 2014). This lucrative fast-growing agricultural sector is one of the primary gross revenue sources used by many developed countries to outwit food deficiency and recession (FAO, 2016; Joffre *et al*., 2017). The businesses of fish farming flourished yet in the developed countries such as the US with 16 % water withdrawals in aquaculture (Pradhan *et al*., 2008; Dieter *et al.,* 2018).

Unfortunately, Nigeria's enormous water resources distributed across the country have been under threat by our means of livelihood (anthropogenic activities) and industrialization, and yet without sign of economic improvement, even in the site area (Adesuyi, 2015; Idu, 2015). These activities have impacted directly or indirectly on the phytoplankton communities (due to their sensitivity) and their habitats, and adversely altered important environmental variables such as loss of river beds with associated increase in organic load among others, consequently impacting on the succeeding trophic levels (both the herbivorous and the omnivorous fish feeders and others) and making the water ecologically unfavourable for fish culture (Schabhutti *et al.*, 2013; Wang, *et al*., 2016).

The nationwide deterioration, eutrophication and pollution of water bodies in Nigeria have been noted and documented by several researchers (Erhunmwunse *et al*., 2013; Bukola *et al*., 2015; Idu, 2015; Oribhabor, 2016), and Agbarha River system is no exception. However, very little or no report exist on the Agbarha River system in Ughelli North, Delta State, Nigeria, except the records of Iloba *et al*. (2018) which examined the effects of various human activities on the system's macro invertebrates. This study is a supplementary plan into all biological components of the river system to verify the first hypothesis of anthropogenic impacts, probably on the abundance and composition (biomass) of the phytoplankton communities of this important water body with fisheries potentials. In this context the research was designed to assess its water quality and phytoplankton composition and abundance as well as evaluate their interactions.

## Materials and Methods

### *Study area*

Study was conducted in Agbarha River, located at Agbarha-Otor, Ughelli North Local Government Area of Delta State, Nigeria. Being one of the important rivers in the said town, River Agbarha is a freshwater river, and lies within longitude 5˚ 12'N of the equator and latitude 5˚ 45'E of the Greenwich meridian (Iloba *et al*., 2018) (Fig. 1).

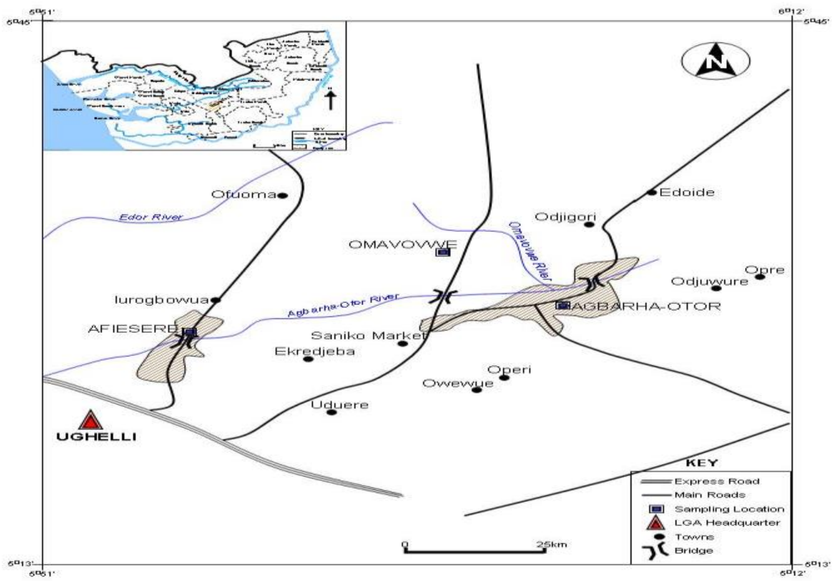


**Fig. 1:** Location of study

***Sample collection and analysis***

On monthly basis, water and phytoplankton samples were collected from March to May, 2017 at three stations of the Agbarha River (from about the hours of 9am to 2pm, Nigerian time) at Agbarha–Otor (station 1), Omavovwe (station 2) and Afiesere (station 3) (Fig 1). Stations 1 and 3 are renowned to have witnessed higher anthropogenic activities like farming, dredging, bathing and fishing relative to station 2. Temperature was estimated in-situ using a mercury-in-glass thermometer (0.0-110$^0$C). The rest of the parameters were analyzed in the laboratory. Conductivity and pH were determined using a Hanna conductivity meter and a pH meter (model H196107) respectively. Alkalinity was determined using the titrimetric method (APHA, 1998). Dissolved oxygen was determined using the Winkler's method, and biochemical oxygen demand (BOD) was determined after 5 days using the same method. Phosphate and nitrate were carried out spectrophotometrically following the procedure described in APHA (1998). Their values were expressed in mg/l.

Phytoplankton were collected by horizontal hauls of 25µm mesh size plankton net and preserved with 4% formalin. They were then viewed under an electron microscope, and identified using an identification key. Next, assemblages of Phytoplankton were studied by calculating the species diversity index (H) and species richness.

## Results

The observed mean values of the water variables at the three sampled stations are presented in Table 1. Of the twelve variables investigated, eight of them; air, water temperatures, conductivity, acidity, Biochemical oxygen demand (BOD), dissolved oxygen, phosphate and nitrate were maximal in station 3 while the minimal values were mostly in Station 1. Total dissolved solids (TDS) and pH were highest in Station 2 whereas turbidity and conductivity were highest in Station 1

The study noted significant changes and interactions in physical and chemical water quality variables. The study further showed similar trends in the weekly distribution of water and air temperature, Dissolved oxygen and BOD, total solids and conductivity , pH and Phosphate while transparency values were near equal during the entire study period (Figures 2, 3 and 4) These variables were found to be significantly associated ($P< 0.05$) (Tables 3, 4 and 5). Most importantly the parameters were comparable with the allowable levels for aquaculture (Table 1). This study noted ideal water quality for aquaculture.

**Table 1:** Comparisons of water quality variables means ± standard deviation (SD) in parenthesis among the three stations and suggested water-quality requirements for aquaculture

| **Water quality variables** | **Station 1** | **Station 1** | **Station 1** | **Acceptable range** | **Desirable range** |
|---|---|---|---|---|---|
| Air Temperature (°C) | 31.8(2.49) | 33(2.55) | 35(2.74) | | |
| Water Temperature (°C) | 28.4(1.82) | 29.2(2.59) | 31.2(2.17) | 15-35 | 20-30 |
| Total Solids (mg/L) | 0.03(0.04) | 0.43(3.88) | 0.34(0.21) | | |
| Transparency/Turbidity (cm) | 0.26(0.44) | 0.03(0.01) | 0.12(0.21) | < 30 | |
| pH | 8.24(1.15) | 8.5(1.47) | 8.34(1.62) | 7-9.5 | 6-5-9 |
| Conductivity | 26.2(2.50) | 39.2(3.88) | 42.9(11.8) | 30-5000 | 100-2000 |
| Alkalinity | 29.6(7.64) | 27.8(19.8) | 27.2(6.34) | 50-200 | 25-100 |
| Acidity | 37.4(24.5) | 28.8(0.01) | 45.8(26.6) | | |
| Dissolved Oxygen (mg/L) | 2.72(2.71) | 2.52(1.32) | 4.4(1.62) | 3-5 | |
| BOD (mg/L) | 2.72(2.21) | 2.52 | 4.38(2.50) | 3-6 | 1-2 |
| Phosphate (mg/L) | 9.58(0.66) | 9.1(1.10) | 9.6(0.51) | 0.03-2 | 0.01-3 |
| Nitrate (mg/L) | 0.68(0.16) | 0.7(0.21) | 2.16(1.66) | 0-100 | 0.1-4.5 |
| Plankton ($No.L^{-1}$) | $4.4\times10^{-1}$ | $6.5\times10^{-1}$ | $4.6\times10^{-1}$ | 2000-6000 | 3000-4500 |

Standards adopted from Bhatnagar and Devi (2013).

**Table 2:** Phytoplankton counts (unit/ml) and diversity indices at the three stations

| | **Phytoplankton sp** | **Stations** | | | | | | **Diversity indices** | |
|---|---|---|---|---|---|---|---|---|---|
| S/N | **Bacillariophyta** | 1 | 2 | 3 | Total | Average | % | **I-D** | **H** |
| 1 | *Navicula Sp* | 28 | 12 | 28 | 68 | 22.7 | 10.66 | 0.6625 | 1.092 |
| 2 | *Cyclotella striata* | 19 | 28 | 0 | 47 | 23.5 | 7.37 | | |
| 3 | *Fragilaria javanica* | 39 | 7 | 32 | 78 | 26 | 12.23 | | |
| 4 | *Pinnularia nobilis* | 49 | 28 | 47 | 124 | 41.3 | 19.44 | | |
| 5 | *Thallssiosira subtilis* | 11 | 15 | 37 | 63 | 21 | 9.87 | | |
| 6 | *Bacillaria Paradoxa* | 4 | 6 | 10 | 20 | 6.7 | 3.13 | | |
| 7 | *Aulacoseira sp* | 47 | 57 | 37 | 141 | 47 | 22.10 | | |
| 8 | *Lauderia annulata* | 13 | 22 | 42 | 77 | 25.7 | 12.07 | | |
| 9 | *Thalassionema nitzchioides* | 2 | 9 | 9 | 20 | 6.7 | 3.13 | | |
| | *Total* | 212 | 184 | 242 | 638 | | 100% | | |
| | **Dinophyta/** | | | | | | | 0.6627 | 1.093 |
| 1 | *Peridinium africanum* | 4 | 3 | 4 | 11 | 3.7 | 84.62 | | |
| 2 | *Ceratium sp* | 0 | 2 | 0 | 2 | 0.7 | 15.38 | | |
| | **Total** | 4 | 5 | 4 | 13 | | 100% | | |
| | **Cyanophyta** | | | | | | | 0.6331 | 1.048 |
| 1 | *Aphanizomenon sp* | 23 | 10 | 12 | 45 | 15 | 32.14 | | |
| 2 | *Microcystis aeruginosa* | 5 | 17 | 6 | 28 | 9.3 | 20 | | |
| 3 | *Oscillatoria limnosa* | 32 | 5 | 4 | 41 | 13.7 | 29.29 | | |
| 4 | *Planktothrix rubescens* | 6 | 12 | 8 | 26 | 8.7 | 18.57 | | |
| | *Total* | 66 | 44 | 30 | 140 | | 100% | | |
| | **Chlorophyta** | | | | | | | 0.5882 | 0.988 |
| 1 | *Volvox rousseletti* | 3 | 17 | 17 | 37 | 12.3 | 4.89 | | |
| 2 | *Pandorina sp* | 3 | 234 | 57 | 294 | 98 | 38.84 | | |
| 3 | *Spirogyra porticalis* | 44 | 32 | 8 | 84 | 28 | 11.09 | | |
| 4 | *Chlorella vulgaris* | 9 | 2 | 1 | 12 | 4 | 1.59 | | |
| 5 | *Closterium enrenbergii* | 26 | 55 | 43 | 124 | 41.3 | 16.38 | | |
| 6 | *Mougeotia sp* | 19 | 19 | 9 | 47 | 15.7 | 6.21 | | |
| 7 | *Oedogonium suecicum* | 14 | 15 | 16 | 45 | 15 | 5.94 | | |
| 8 | *Pleurotaenium ovatum* | 3 | 10 | 3 | 16 | 5.3 | 2.11 | | |
| 9 | *Gonatozygon kinahanii* | 8 | 21 | 26 | 55 | 18.3 | 7.27 | | |
| 10 | *Tribonema bombycina* | 18 | 19 | 6 | 43 | 14.3 | 5.68 | | |
| | *Total* | | | | 757 | | 100% | | |

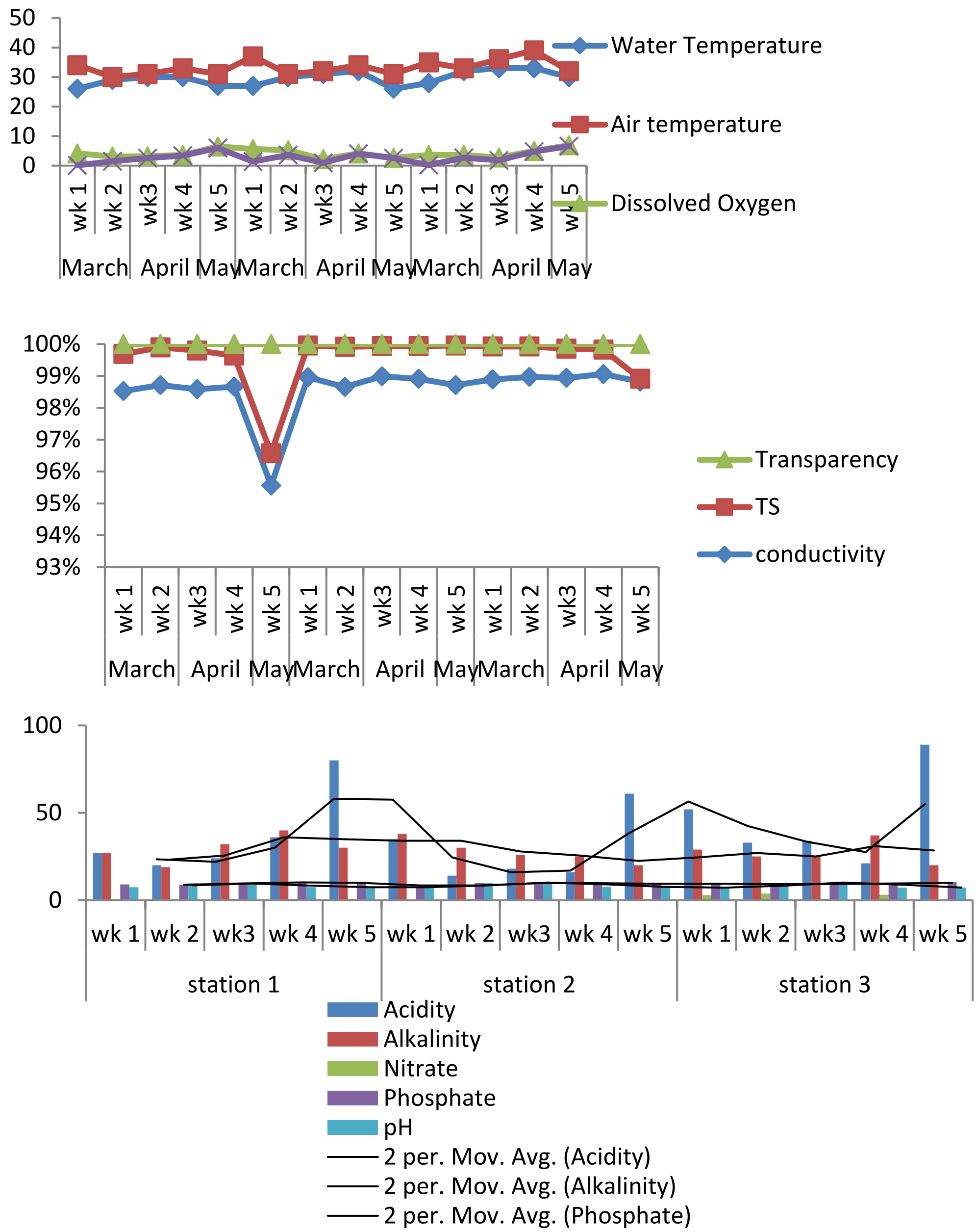


Fig.2: weekly changes in air and water temperature, dissolved oxygen and biochemical oxygen, transparency, total solids, conductivity, acidity and alkalinity, pH, nitrate and phosphate; the trend line pattern of fluctuations defines the distribution of these parameters during the study period at Agbarha River from March to May 2017.

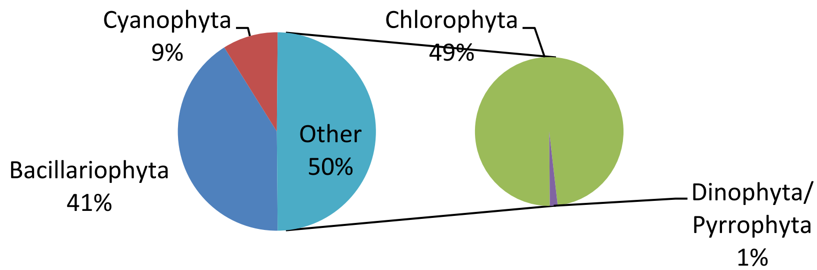


Fig. 3: Quality Composition of Phytoplankton Assemblage of Agbarha River

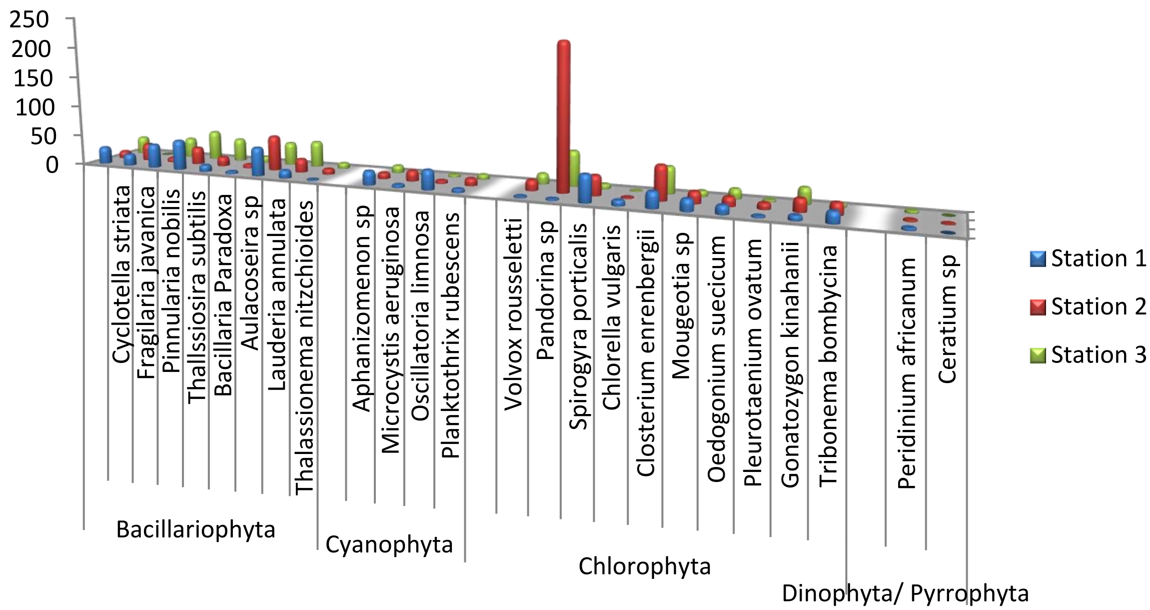


Fig. 4: Species composition, abundance and distribution of four phytoplankton taxa of Agbarha River from March to May 2017

## *Phytoplankton*

The study identified 25 phytoplankton species of four taxa (Table 2), dominated by Chlorophyta, with ten species accounting for 49% of the overall assemblage. Bacilariophyta had 9 (nine) species, constituting 41%, cyanophyta had five (5) species (10%) and dinophyta, two (2) species, equivalent to 1% of the phytoplankton population (Fig. 3). Station 2 had the highest counts of $6.5\times10^{-1}$/L, followed by station 3 ($4.6\times10^{-1}$/L), and closely by station 1($4.4\times10^{-1}$/L) (Table 1) while the abundance and distribution of four phytoplankton taxa at Agbarha River from March to May 2017 are presented in Fig 1.

The four phytoplankton taxonomic group species were positively associated with the water quality variables except the cyanophyta and phosphate (Tables 3, 4 and 5). Phytoplankton diversity indices were low. Shannon index (H) varied from 0.9878 to 1.093 while the Simpson's (1-D) varied between 0.5882 and 0.6627 (Table 2).

**Table 3:** Correlation results between means of environmental variables and Cyanophytes of Agbarha River system ($p<0.05$)

| 0 | conductivity | TS | Trans | Acid | Alkalinity | Nitrate | Phosphate | pH | Water T | Air T | DO | BOD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aphanizomenon sp | **0.62** | 0.17 | 0.36 | **0.47*** | **0.60** | **0.77*** | 0.28 | 0.22 | **0.76*** | **0.66*** | 0.37 | 0.14 |
| Microcystis aeruginosa | **0.80*** | **0.52** | 0.16 | 0.34 | **0.68*** | **0.84*** | 0.37 | **0.48*** | **0.86*** | **0.57** | 0.16 | 0.01 |
| Oscillatoria limnosa | **0.88*** | **0.62** | **0.69*** | **0.99*** | **0.56** | **0.46*** | 0.03 | 0.37 | **0.47*** | 0.39 | **0.63** | 0.30 |
| Planktothrix rubescens | **0.99*** | **0.99*** | **0.72*** | **0.94*** | 0.13 | 0.37 | 0.41 | 0.11 | **0.99*** | 0.07 | **0.55** | **0.69*** |
| conductivity | 0 | 0.07 | **0.51** | 0.39 | **0.99** | 0.10 | **0.73*** | **0.74*** | **0.73*** | **0.81*** | **0.95*** | **0.99*** |
| Total solids | **0.84*** | 0 | 0.17 | 0.18 | **0.94** | 0.12 | 0.37 | **0.46** | **0.78*** | **0.97*** | **0.59** | 0.38 |
| Transparency | -0.40 | **-0.71** | 0 | 0.01 | 0.31 | 0.20 | **0.62** | 0.49 | 0.27 | 0.38 | 0.16 | 0.15 |
| Acidity | **-0.50** | **-0.71** | **0.96*** | 0 | 0.38 | 0.20 | **0.92*** | 0.37 | 0.13 | **0.53** | 0.14 | 0.36 |
| Alkalinity | -0.01 | 0.05 | **-0.57** | **-0.51** | 0 | 0.33 | **0.93*** | **0.51** | 0.27 | 0.01 | **0.76*** | **0.63*** |
| Nitrate | **0.80*** | **0.77*** | -0.68 | **-0.68** | **0.56*** | 0 | **0.52** | **0.88*** | **0.50** | 0.43 | **0.93*** | **0.63*** |
| Phosphate | -0.22 | **-0.52** | 0.31 | 0.06 | -0.06 | -0.39 | 0 | **0.76*** | 0.36 | **0.74*** | **0.82*** | 0.18 |
| pH | 0.21 | 0.44 | -0.41 | **-0.52** | -0.40 | -0.09 | 0.19 | 0 | **0.61** | 0.41 | 0.11 | **0.64*** |
| Water Temperature | 0.21 | 0.17 | **-0.61** | **-0.77** | **0.61** | 0.40 | **0.53** | 0.31 | 0 | **0.47** | 0.27 | **0.99*** |
| Air Temperature | -0.15 | -0.03 | **-0.51** | -0.38 | **0.97*** | **0.46** | -0.21 | **-0.49** | 0.43 | 0 | **0.84*** | **0.51** |
| Dissolved Oxygen | 0.04 | -0.33 | **0.73*** | **0.76** | -0.19 | -0.06 | -0.14 | **-0.79** | **-0.62** | -0.13 | 0 | 0.31 |
| Biochemical oxygen demand | 0.01 | **-0.51** | **0.74*** | **0.53** | -0.29 | -0.29 | **0.70*** | -0.29 | -0.01 | -0.40 | **0.58** | 0 |

**Table 4:** Correlation results between means of environmental variables and Bacillariophytes of Agbarha River system. p<0.05.

| 0 | Cond. | TS | Trans | Acidity | Alkalinity | Nitrate | Phosphate | pH | Water T | Air T | DO | BOD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Navicula | **0.97*** | **0.56** | **0.51** | **0.86*** | **0.54** | **0.50** | 0.02 | **0.56** | **0.56** | 0.35 | **0.90*** | 0.14 |
| Cyclotella | **0.54** | **0.61** | **0.58** | 0.46 | 0.41 | **0.82*** | 0.22 | **0.64*** | 0.09 | **0.52** | 0.23 | **1.00*** |
| Fragilaria | 0.16 | **0.62** | **0.60** | **0.80*** | **0.57** | **0.56*** | **0.91*** | **0.82*** | **0.80*** | 0.43 | 0.30 | 0.28 |
| Pinnularia | 0.34 | 0.07 | 0.40 | **0.55*** | **0.81*** | 0.39 | 0.07 | **0.65*** | **0.61*** | **0.88*** | **0.81*** | 0.20 |
| Thallssiosiras | 0.29 | **0.76*** | 0.45 | **0.54** | **0.58** | **0.63*** | **0.85*** | **0.53** | **0.51*** | **0.53** | 0.11 | 0.32 |
| Bacillaria | 0.36 | 0.48283 | **0.95*** | **0.68*** | 0.27 | **0.99*** | **0.56** | 0.12 | **0.78*** | 0.13 | **0.62** | **0.68*** |
| Aulacoseir | 0.28 | 0.16147 | **0.83*** | **0.92*** | 0.40 | **0.58*** | 0.18 | **0.69*** | 0.36 | **0.45** | **0.83*** | **0.58*** |
| Lauderia | **0.86*** | **0.67*** | **0.65*** | **0.50** | 0.17 | **0.76*** | 0.23 | **0.86*** | **0.05*** | 0.31 | **0.63*** | **0.70*** |
| Thalassiones | 0.40 | 0.14 | 0.37 | 0.32 | **0.51** | **0.743*** | **0.74*** | 0.04 | **0.85*** | 0.44 | 0.25 | 0.43 |
| conductivity | 0 | 0.07 | **0.51*** | 0.39 | **0.99*** | 0.10 | **0.73*** | **0.74*** | **0.73*** | **0.81*** | **0.96*** | **0.99*** |
| TS | **0.84** | 0 | 0.18 | 0.18 | **0.94*** | 0.12 | 0.37 | **0.46** | **0.78*** | **0.97*** | **0.59*** | 0.38 |
| Transparency | -0.40 | **-0.71*** | 0 | 0.01 | 0.31 | 0.20 | **0.61** | **0.49** | 0.27 | 0.38 | 0.16 | 0.15 |
| Acidity | **-0.51** | **-0.71*** | **0.96*** | 0 | 0.38 | 0.20 | **0.92*** | 0.37 | 0.13 | **0.53** | 0.14 | 0.36 |
| Alkalinity | -0.01 | 0.05 | **-0.57*** | **-0.51** | 0 | 0.33 | **0.93*** | **0.51** | 0.27 | 0.01 | **0.76*** | **0.63*** |
| Nitrate | **0.80** | **0.77*** | **-0.68*** | **-0.68*** | **0.56*** | 0 | **0.52*** | **0.88*** | **0.50*** | 0.43 | **0.93*** | **0.63*** |
| Phosphate | -0.22 | **-0.52** | 0.31 | 0.06 | -0.06 | -0.39 | 0 | **0.76*** | 0.36 | **0.74*** | **0.82*** | 0.19 |
| pH | 0.21 | 0.44 | -0.41 | **-0.52** | -0.40 | -0.09 | 0.19 | 0 | **0.61** | 0.41 | 0.11 | **0.64*** |
| Water Temperature | 0.21 | 0.17 | **-0.61** | **-0.77*** | **0.61** | 0.40 | **0.53** | 0.31 | 0 | **0.47** | 0.27 | **0.99*** |
| Air Temperature | -0.15 | -0.03 | **-0.51** | -0.38 | **0.97*** | **0.46** | -0.210 | **-0.49** | 0.43 | 0 | **0.84*** | **0.51** |
| Dissolved Oxygen | 0.04 | -0.33 | **0.73*** | **0.76*** | -0.19 | -0.06 | -0.14 | **-0.79*** | **-0.62** | -0.13 | 0 | 0.31 |
| Biochemical Oxygen Demand | 0.01 | **-0.51** | **0.74*** | **0.53** | -0.29 | -0.29 | **0.70*** | -0.29 | -0.01 | -0.40 | **0.58*** | 0 |

**Table 5:** Correlation results between means of environmental variables and Chlorophytes of Agbarha River system (p<0.0)

| 0 | Conductivity | TS | Trans | Acidity | Alkalinity | Nitrate | Phosphate | pH | Water T | Air T | DO | BOD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Volvox | 0.36 | 0.06 | 0.07 | 0.08 | **0.95*** | 0.40 | **0.57*** | 0.14 | **0.57*** | **0.97*** | 0.15 | 0.20 |
| Pandorina | **0.76*** | **0.83*** | **0.47** | **0.79*** | 0.26 | **0.57*** | 0.16 | **0.45** | **0.84*** | 0.12 | **0.98*** | 0.17 |
| Spirogyra | 0.34 | 0.31 | 0.26 | 0.35 | 0.15 | 0.02 | 0.37 | **0.54*** | **0.63*** | 0.18 | **0.93*** | **0.52*** |
| Chlor | 0.02 | 0.23 | **0.83*** | **0.70*** | **0.97*** | 0.15 | **0.77*** | **0.89*** | **0.93*** | **0.81*** | **0.55*** | **0.70**** |
| Closter | 0.33 | **0.48** | 0.27 | 0.18 | 0.12 | 0.08 | **0.86*** | **0.83*** | 0.12 | 0.27 | **0.79*** | **0.97*** |
| Mougeo | **0.98*** | 0.38 | 0.29 | **0.45** | **0.85*** | **0.96*** | 0.34 | 0.26 | **0.89*** | **0.96*** | 0.20 | 0.04 |
| Oedogo | **0.49** | **0.51** | **0.63** | **0.57*** | 0.14 | **0.99** | 0.37 | **0.86*** | 0.13 | 0.20 | **0.50** | **0.99*** |
| Pleuro | **0.75*** | **0.76*** | 0.23 | 0.22 | 0.01 | 0.22 | **0.89*** | **0.73*** | 0.11 | 0.06 | **0.64*** | **0.75*** |
| Gonato | **0.60*** | **0.96*** | **0.80*** | **0.63*** | 0.20 | 0.34 | **0.50*** | 0.47 | 0.23 | 0.35 | **0.78*** | **0.48*** |
| Tribon | **0.99*** | **0.66*** | 0.49 | **0.80*** | 0.33 | 0.41 | 0.08 | 0.41 | **0.73*** | 0.19 | **0.86*** | 0.20 |
| conductivity | 0 | 0.072 | **0.50*** | 0.39 | **0.99*** | 0.10 | **0.73*** | **0.74*** | **0.73*** | **0.81*** | **0.96*** | **0.99*** |
| Total solids | **0.84*** | 0 | 0.17 | 0.18 | **0.93*** | 0.12 | 0.37 | 0.46 | **0.78*** | **0.97*** | **0.59*** | 0.38 |
| Transparency | -0.40 | **-0.71*** | 0 | 0.01 | 0.31 | 0.20 | **0.62*** | 0.49 | 0.27 | 0.38 | 0.16 | 0.15 |
| Acidity | **-0.50*** | **-0.71*** | **0.96*** | 0 | 0.38 | 0.20 | **0.92*** | 0.37 | 0.13 | **0.53** | 0.14 | 0.36 |
| Alkalinity | -0.01 | 0.05 | **-0.57*** | **-0.51** | 0 | 0.33 | **0.93*** | **0.51*** | 0.27 | 0.01 | **0.76*** | **0.63*** |
| Nitrate | **0.80*** | **0.77*** | **-0.68*** | **-0.68*** | **0.56*** | 0 | **0.52*** | **0.88*** | **0.50*** | 0.43 | **0.93*** | **0.63*** |
| Phosphate | -0.22 | **-0.52*** | 0.31 | 0.06 | -0.06 | -0.39 | 0 | **0.76*** | 0.36 | **0.74*** | **0.82*** | 0.19 |
| pH | 0.21 | 0.44 | -0.41 | **-0.52** | -0.40 | -0.09 | 0.19 | 0 | 0.61* | 0.41 | 0.11 | **0.64*** |
| Water Temperature | 0.21 | 0.17 | **-0.61** | **-0.77*** | **0.61*** | 0.40 | **0.53*** | 0.31 | 0 | 0.47 | 0.27 | **0.99*** |
| Air Temperature | -0.15 | -0.03 | **-0.51*** | -0.38 | **0.97*** | 0.46 | -0.21 | -0.49 | 0.43 | 0 | **0.84*** | **0.51*** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dissolved Oxygen | 0.036 | -0.33 | **0.73*** | **0.76*** | -0.19 | -0.056 | -0.14 | **-0.79*** | **-0.62*** | -0.13 | 0 | 0.31 |
| BOD | 0.01 | **-0.51*** | **0.74*** | **0.53** | -0.29 | -0.29 | **0.70*** | -0.29 | -0.01 | -0.40 | **0.60*** | 0 |

# Discussion

Nature's provision is one of the natural means of survival for mankind when fully harnessed. Fish farming is one the ways to put our natural water resources into use to provide finance, and food for man particularly in this present dispensation (Boyd and McNevin, 2015). The present study has identified Agbarha River as a potential site for aquaculture development notwithstanding the current human activities which are controllable through proper management (Dickson *et al* 2016; Oribhabor, 2016; Fore *et al*., 2018).

The study identified 28 acceptable species of algae which were excellent fish food in aquaculture (Halima, 2017), partitioned into four taxonomic groups. Phytoplankton biomass/ml was quantitatively and qualitatively sufficient to grow or culture herbivorous fish like *Tilapia*, silver and grass carp, and was of good quality (Bhatnagar and Devi, 2013; Napiorkowskwa-Krzebietke, 2017). The phytoplankton number/ L observed in the present study was more than the super margin of the desirable plankton limit, and is suggestive of high grazing and yield of zooplankton and fish (Halima, 2017). Similar phytoplankton species; *Bacillariophytes* such as *Navicula, Cyclotella, Pinnularia, Fragillaria, Thallssiosira, Aulacoseira, Dinophyta, Peridium, Ceratium, Chlorophyta, Volvox , Pandorina, Spirogyra, Chlorella, Closterium, Mougeotia, Oedogonium, Gonatozygon, Cyanophyta, Aphanizomenon, Microcystis* and *Oscillatoria*, have been identified in the diet of herbivorous fishes (Pradhan *et al*., 2008; Sipauba-Tavares *et al* ., 2010; Dalal *et al* ., 2012; Atindana *et al* ., 2016; Halima, 2017).

The study revealed that the phytoplankton abundance/biomass were positively associated with the physical and chemical variables, thus depicting a favourable environment for their enhanced growth, and qualifying the system for aquaculture. The low transparency, turbidity and total solids in the present study are major and important factors to ensure continuous manufacture of food through photosynthesis (Murulidhar and Yogananda, 2015). This could probably be the factor underlying the strong association between turbidity and total dissolved solids. The low turbidity and total solids in this study is suggestive of reduced or no impact of anthropogenic activities such as dredging on the phytoplankton population in the system due to self-purification.

The buffering capacity of the river is high, as is evident from the low alkalinity range (19-40 mg$CaCO_3$/l) across the stations when compared with the lower preferred range (50 -100mg $CaCO_3$/ml) for fish cultures (Pradhan *et al*., 2008). The nutrient status was relatively high compared with water bodies around this region (Iloba, 2012). The study noted the sufficiency of the basic nutrients: nitrate and phosphate. The phosphate values were in excess of the acceptable limits. The phosphate level in the present study could be responsible for the high number of species /ml of sample (Kuang, *et al* 2004). Phosphate is not a limiting factor for phytoplankton growth in this system.

The pH reported in the present study is within the recommended pH for freshwater fish culture. The upper limit dissolved oxygen range is within the acceptable range and in agreement with the dissolved oxygen range in successful fish farms (Pradhan *et al* .2008; Bhatnagar and Devi, 2013). The levels of most water variables in this study (Table 1) were within fish tolerable limits. The outliers observed outside the permissible limits are not far from the already-mentioned effects of anthropogenic imparts which could be curtailed by withdrawals from the site. The air temperature of the study area is typical of its location around the equator. Strong interdependence exists between the air and water temperatures, a natural phenomenon in tropical waters, and directly or indirectly governs diverse activities in the system (Iloba *et al*., 2018). This is further confirmed by the strong correlation between these variables.

The study also demonstrated sufficient phytoplankton diversity in Agbara River which is an indicator of enough food for fish culture. Vallina *et al*. (2014) noted that phytoplankton diversity greater than 1% is of great significance in accounting for ecosystem productivity. High phytoplankton count has been implicated severally by researchers as a major reason for high fish production (Pradhan *et al*., 2008). The phytoplankton count at the different stations is more than the super marginal limit of the acceptable plankton (zooplankton and phytoplankton) range. This is suggestive of high primary productivity and possibly high zooplankton grazing, although not quantified in the present study. Hence the possibility of polyculture is not farfetched in this system. Primary production and the high nutrient variables show weekly variations and were highly correlated (Vallina *et al*., 2014). The bio-remediatory role of microorganisms in our study is revealed by the association between alkalinity and BOD ($r = 0.63$), although the diversity indices pointed an impaired water body (Fulazzaky, 2009). However, the positive influence of physico-chemical parameters on phytoplankton abundance offers these system good aquaculture potentials.

## Conclusion

The phytoplankton abundance revealed species which were abundant in quality and quantity and can support fisheries and other aquatic life. However the diversity indices revealed a moderately disturbed water body. The undesirable limits of some physico-chemical parameters noted in the present study are anthropogenically driven, and could be controlled by withdrawal. Proper monitoring of the water body should be done in order to sustain the biological structure of the river.

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