



# Comparative Analysis of Phytoplankton Communities in Newly Inundated Ponds Using Organic and Inorganic Fertilizers

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

A comparative study on the communities of phytoplankton in two newly inundated ponds was carried out from September 2023 to October 2023. The study was conducted in a completely random design experimental setup with two treatments, each replicated twice using organic (chicken manure) and inorganic fertilizer (di-ammonium phosphate fertilizer, (20:10:10) (2.5kg for each) fertilizers. Out of 1114 individuals of phytoplankton identified, 611 were from the organic fertilizer- treated tank, while 503 individuals were from the inorganic fertilizer- treated tank. The highest and the lowest phytoplankton species identified were *Dactylococlopsis irregularis* (79) > *Phormidium tenue* (53) > *Ankistrodesmus falcatus* (39) for the organic fertilized tank while the dominant species for the inorganic tank were *Dactylococlopsis irregularis* (45) > *Ankistrodesmus*

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*falcatus* (36), > *Dinobryon bararicum* (31). The least dominant species found in this current study for organic fertilizer were *Closterium macilentum* (7) > *Amoeba polypodia* (7) > *Volvox aureus* (3) > *Raphidiopsis curvata* (2) while the trend for inorganic fertilizer were *Aphanizomenon flosaquae* (7) > *Spirulina subtilissima* (4) > *Nitzschia linearis* (2). Physicochemical factors like Temperature, pH, Potassium, Total nitrogen, were found to be the important factors influencing the growth and distribution of phytoplankton and they exhibited significant positive correlation with phytoplankton in the PCA and CCA biplot. This present study revealed inter-tank differences in some of the physicochemical parameters investigated. Potassium, phosphorus, nitrogen and dissolved oxygen (DO) were significantly different across the two treatments while temperature and pH were not statistically significant ( $P < 0.05$ ). The result from the analysis of all community parameters (Shannon-Wiener diversity, Evenness, Simpson and Margalef indices) showed slight variation. The highest in Shannon-Wiener diversity, Evenness, Simpson and Margalef indices were found in the inorganic fertilizer- treated tank (3.216, 0.8901, 0.956 and 4.34, respectively), while the lowest were found in the organic fertilizer treated tank (3.141, 0.825, 0.948 and 4.209, respectively). This result indicates that the abundance and structure of phytoplankton communities were affected by the different fertilizer used and the tanks physicochemical conditions.

**Keywords:** *Phytoplankton community; organic fertilizer; inorganic fertilizer; physico-chemical factors; species diversity indices.*

## 1. INTRODUCTION

In the realm of aquatic ecosystem, phytoplankton serves as a fundamental component, playing a pivotal role in nutrient cycling and primary productivity [1]. The structure of phytoplankton community is a good indicator of water quality due to its sensitivity to environmental stresses [2,3,4]. The introduction of fertilizers, whether organic or inorganic into aquatic ecosystem can significantly influence phytoplankton composition and abundance, thereby impacting overall ecosystem dynamics [5,6,7].

The abundance and structure of phytoplankton populations are primarily regulated by inorganic nutrients, which include, but are not limited to nitrogen, phosphorus, and silica [8]. The major forms of available nitrogen exist in the form of nitrate, nitrite and ammonia. Phosphorus occurs as soluble orthophosphate while silica exists in the form of silicates [9]. Phytoplankton communities are sensitive to alterations in their habitats, and therefore, phytoplankton total biomass and many phytoplankton species are utilized as indicators of aquatic habitat quality [10]. Phytoplankton demonstrate water quality through changes in their community composition, distribution, and proportion of sensitive species [11]. Phytoplankton are largely governed by light, nutrients, temperature, community structure, life-cycle history, stratification or vertical mixing, and tides [12].

Environmental conditions can directly or indirectly affect the community structure of

phytoplankton [13]. Previous studies have shown that the characteristics of phytoplankton structure changes are closely related to hydrological conditions, and nitrate concentration [14]. Additionally, these changes have a strong coupling relationship with chemical oxygen demand (COD) and particulate organic matter (POM) [15]. When environmental factors change, they can still greatly control the phytoplankton community structure. It is becoming increasingly essential to study the changes in phytoplankton community structure to improve water quality assessment [16]. Therefore, monitoring phytoplankton community structure and diversity has become essential for assessing water ecosystem health and water quality [17]. Understanding the changes of phytoplankton communities in ponds contaminated by agriculture may contribute to determining the best approaches for protecting these ecosystems and provide reference cases for broader research [16].

Fertilization of ponds to enhance phytoplankton production and zooplankton suitable for larval fish is a common practice in Nigeria [5]. Fertilizer sources maybe inorganic or organic which include agricultural by-products and animal manures. Chemical fertilizer typically consists of nitrogen, phosphorus, and potassium compounds that dissolve readily to provide nutrients to phytoplankton [18]. Organic fertilizer includes agricultural by-products, for example, rice bran, cottonseed meal, and animal manures, such as, poultry litter, cow manure, which first must undergo decomposition to release nutrients

for phytoplankton growth. The combined use of organic and inorganic fertilizer is known to have direct impact on the plankton community structure [5] by promoting both the autotrophic and heterotrophic organisms in the ponds. Organic fertilization is also known to promote the growth of smaller sized zooplankton especially the rotifers [19] as well as other micro-zooplankton such as protozoans and copepod nauplii [20] which usually dominate eutrophic water.

This comparative study aims to investigate the effects of organic and inorganic fertilizers on phytoplankton communities in two newly inundated ponds. The choice of fertilizers-organic and inorganic is motivated by their contrasting compositions and potential ecological implications. Organic fertilizers, derived from natural sources, typically contain complex organic compounds and micronutrients, while inorganic fertilizers are composed of synthetic compounds with readily available nutrients.

The inundation of ponds provides a unique opportunity to observe the establishment and development of phytoplankton communities in relatively undisturbed environments. By comparing the responses of phytoplankton to different types of fertilizers, this study seeks to elucidate how nutrient availability influences community structure, species diversity and biomass production. Furthermore, understanding the ecological implications of fertilizer type on phytoplankton communities can inform sustainable management practices for freshwater ecosystems. Insights gained from this study may contribute to the development of strategies aimed at mitigating eutrophication and maintaining the ecological integrity of aquatic habitats.

## 2. MATERIALS AND METHODS

### 2.1 Description of Study Area / Pond Preparation and Experimental Design

The study was conducted from September 2023 to October 2023 at the hatchery research unit of the Department of Fisheries and Aquatic Environmental Management University of Uyo. A Few days prior to the trial, ponds were prepared by draining, washing and checking water supply and draining systems. Vegetation was removed from the bottom and sides of the ponds. One week before the trial, the ponds were filled, and

subsequently, water loss due to evaporation was compensated to maintain the same level throughout the study. The study lasted for 31 days and was conducted in a completely random design with two treatments and two replicates using organic and inorganic fertilizers (see Plate 1). Two types of fertilizers viz: chicken manure and di-ammonium phosphate fertilizer) were used in this experiment. Fresh manure from layers kept in the cages was collected from poultry unit belonging to the Department of Animal Science University of Uyo. The nitrogen (N 2.55%) and phosphorous (P 0.95%) in chicken manure were determined using proximate analysis at the Animal Science laboratory according to the Association of Official Analytical Chemists [21]. Four concrete tanks, each with an area of approximately 7.62m<sup>2</sup> were used and filled with water to depth of 2.5ft. Two treatments: 2.5kg of chicken manure, 2.5kg of di-ammonium phosphate fertilizer and a control (no fertilizer) were randomly assigned to the tanks, with each treatment replicated once.

### 2.2 Phytoplankton Collection and Identification

One week after fertilization, water samples were collected. On-farm phytoplankton samples were taken at 15 cm below the water surface. Phytoplankton specimens were collected by filtration of 25 L of water using a 20-micrometer plankton net (Plate 2). The collected phytoplankton samples were fixed in 4% formalin for further analysis in the laboratory. Samples were taken at approximately 8 a.m. at 2 or 3-day intervals. Phytoplankton were concentrated by filtration through sand and counted in a counting chamber under a microscope fitted with an ocular micrometer [22]. Identification of phytoplankton species was conducted by observing through the microscope and enumerating under a light microscope (objective x 40) using standard keys for plankton identification according to Needham and Needham [23]; as well as guides provided by Newell and Newell [24]; APHA [25] and Egborge [26].

### 2.3 Species Indices

Species composition and abundance of phytoplankton were described using the method of Hoppenrath et al. [27]. The phytoplankton community structure was analyzed using the Shannon-Wiener Index ( $H'$ ), species richness ( $d$ ) and the Evenness index ( $J'$ ) using Partversion



**Plate 1. Experimental setup**



**Plate 2. Plankton net**

3.25 [28]. Correlation analysis and principal component analysis (PCA) were used to determine the relationships between the phytoplankton and environmental factors using the XLSTAT BASIC+ (Addinsoft, US).

### **2.3.1 Phytoplankton species indices**

The phytoplankton community structure was assessed using the Shannon diversity index ( $H'$ ), the species equality index, ( $E$ ) and Simpson dominance index ( $D$ ). The diversity index was calculated using the Krebs's equation [29].

### **2.3.2 The species evenness (or equitability)**

The calculation of the uniformity index is based on the equation of Krebs [29]:

$$E = H' / H_{maks}$$

Where:

- e - uniformity index;
- $H'$  - diversity index;
- $H_{max} = \ln S$ ;
- S - number of types.

The ratio of the observed diversity (H) to the maximum diversity (Hmax) was taken as a measure of the evenness (E). According to Krebs [29], it measures the distribution of individuals.

### 2.3.3 Margalef's species richness index

According to Pielou (1966), this is presented as:

$$d = \frac{s - 1}{\ln(N)}$$

Where:

s = Total number of species in the sample  
ln = natural or Napierian logarithm, and  
N = total number of individuals in the sample

### 2.3.4 Shannon – wiener diversity index (H)

The index used to determine the level of species diversity in a community is the Shanon Wiener index [29]:

$$H = \sum_{i=1}^n P_i \ln P_i$$

Where:

H - index of species diversity  
Pi - probability function for each part as a whole (ni/N); ni - number of individuals of type-i;  
N - total number of individuals.

### 2.3.5 Simpson index

The dominance index is used to determine the extent to which a species dominates another group. The dominance index was obtained using the Simpson index [29]:

$$D = \sum_{i=1}^s \left( \frac{n_i}{N} \right)^2$$

Where:

D - Simpson dominance index;  
ni - number of individuals of type i;  
N - total number of individuals;  
S - number of types (species).

## 2.4 Collection of Water Sample

Three plastic bottles for water samples and DO each measuring 50 cl were used. The bottles were immersed to about 60 cm below the water surface and filled to capacity. After removal from

the water, each bottle was carefully sealed ensuring no air bubbles were present. They were then transported to the fisheries laboratory in the Department of Fisheries and Aquatic Environmental Management for further analysis.

## 2.5 Water Quality

Water temperature, DO and pH were measured in-situ in the morning by 8:00 am using mercury – in – glass thermometer, portable pH meter model – (HI98107 Hanna instrument), and portable DO meter model- (HI 98303 Hanna instrument) [30,22]. Other water quality parameters (phosphate, nitrates and potassium) were determined in the laboratory following standard procedures according to [22], and [30].

## 2.6 Statistical Analysis

Data on the physico-chemical parameters and phytoplankton composition were analyzed. Analysis of variance (ANOVA) was used to test for statistical differences between the means of the physical and chemical parameters of the fish ponds. Descriptive statistics of data for water quality analyses and phytoplankton were done using Microsoft Excel. Principal Components Analysis (PCA) was used to determine the relationship between physico-chemical parameters and phytoplankton utilizing the PAST software.

## 3. RESULTS

### 3.1 Mean Variations in Physicochemical parameters in the two Tanks

The DO in the present study was  $4.13 \pm 0.16^b$  in the inorganic tank and  $4.71 \pm 0.18^a$  in the organic tank. This parameter exhibited significant difference at  $P < 0.05$ . The highest mean DO value ( $4.71 \pm 0.18^a$ ) was observed in the inorganic fertilized tank while the lowest value ( $4.13 \pm 0.16^b$ ) was recorded in the organic fertilized tank (Table 1).

Temperature values for inorganic and organic treated tanks were  $6.20 \pm 0.19^a$  and  $5.96 \pm 0.23^a$  respectively. The highest mean temperature ( $6.20 \pm 0.19^a$ ) was observed in the organic treated tank while the least value ( $5.96 \pm 0.23^a$ ) was recorded in the inorganic treated pond. For the two treatments, there was no significant difference observed in temperature (Table 1).

The pH values were  $5.96 \pm 0.23^a$  and  $6.20 \pm 0.19^a$  for inorganic and organic fertilized tanks respectively. The highest value ( $6.20 \pm 0.19^a$ ) was recorded in the organic fertilized tank while the lowest value ( $5.96 \pm 0.23^a$ ) was obtained in the inorganic treated tank. Statistically, significant difference was not observed for this parameter at  $P < 0.05$  between the two treatment tanks (Table 1).

Potassium levels in the present study were  $51.29 \pm 2.88^a$  for the inorganic fertilized tank and  $16.52 \pm 1.19^b$  for the organic fertilized tank. The study revealed a significant difference across the two fertilizers used (Table 1).

Phosphorus levels were found to be  $27.97 \pm 1.08^a$  for the inorganic tank and  $12.30 \pm 0.43^b$  for the organic tank. This parameter was highly significant at  $P < 0.05$  in the study (Table 1).

Total nitrogen levels were found to be  $33.39 \pm 0.66^a$  for the inorganic tank and  $11.85 \pm 0.58^b$  for the organic tank. This parameter showed a marked significant difference ( $P < 0.05$ ) in the study (Table 1).

### 3.2 Pearson Correlation Matrix for the Physio-Chemical Parameters

Pearson's correlation analysis was conducted to reveal the relationships between the

environmental parameters in the two tanks. Based on the Pearson analysis, potassium and total nitrogen have a significantly positive correlation (0.90), potassium and phosphorus (0.90). A significant positive correlation was observed for phosphorous and total nitrogen (0.85). DO has a relatively weak correlation with pH (0.34), and with phosphorus (0.23). pH has a weak correlation with phosphorus (0.04). High negative correlations occur between pH and total nitrogen (-0.18), and between pH and potassium (-0.14) (Table 2).

### 3.3 Phytoplankton Abundance

The phytoplankton species recorded during the study are presented in Table 3. A total of 1,114 individuals were recorded in both fertilized tanks. The phytoplankton composition was dominated by *Dactylococloopsis irregularis* (79) > *Phormidium tenue* (53) > *Ankistrodesmus falcatus* (39) in the organic fertilized tank while the dominant species for the inorganic tank were *Dactylococloopsis irregularis* (45) > *Ankistrodesmus falcatus* (36), > *Dinobryon bararicum* (31). The least dominant species found in this current study for organic fertilizer were *Closterium macilentum* (7) > *Amoeba polypodia* (7) > *Volvox aureus* (3) > *Raphidiopsis curvata* (2) while the trend for inorganic fertilizer were *Aphanizomenon flos-aquae* (7) > *Spirulina subtilissima* (4) > *Nitzschia linearis* (2).

**Table 1. Mean ( $\pm$ SE) of Physico-chemical parameters in the two Fertilized Tanks**

Variables	INORGANIC	ORGANIC
Do (MG/L)	$4.71 \pm 0.18^a$	$4.13 \pm 0.16^b$
Temperature ( $^{\circ}$ C)	$26.00 \pm 0.14^a$	$25.97 \pm 0.14^a$
Ph	$5.96 \pm 0.23^a$	$6.20 \pm 0.19^a$
Potassium [MG/L]	$51.29 \pm 2.88^a$	$16.52 \pm 1.19^b$
Phosphorus [MG/L]	$27.97 \pm 1.08^a$	$12.30 \pm 0.43^b$
Total Nitrogen [MG/L]	$33.39 \pm 0.66^a$	$11.85 \pm 0.58^b$

Means with different superscripts along the same row are significantly different (Duncan's test)  $p < 0.05$

**Table 2. Pearson correlation matrix for the physico-chemical parameters**

Variables	DO	TEMP	PH	Potassium	Phosphorus	Total Nitrogen
Do	<b>1.00</b>					
Temperature	0.09	<b>1.00</b>				
Ph	<b>0.34</b>	0.10	<b>1.00</b>			
Potassium	0.07	0.00	-0.14	<b>1.00</b>		
Phosphorus	<b>0.23</b>	0.07	0.04	<b>0.90</b>	<b>1.00</b>	
Total N	0.09	0.00	<b>-0.18</b>	<b>0.90</b>	<b>0.85</b>	<b>1.00</b>

Values in bold are different from 0 with a significance level  $\alpha = 0.05$

**Table 3. Phytoplankton abundance in the two fertilized tanks**

<b>Phytoplankton Species</b>	<b>Organic (Individuals)</b>	<b>Inorganic (Individuals)</b>
<i>Dactylococloopsis irregularis</i>	79	45
<i>Dinobryon cylindricum</i>	27	22
<i>Dinobryon bararicum</i>	19	31
<i>Phormidium tenue</i>	53	18
<i>Euglena tripteris</i>	15	17
<i>Euglena sanguine</i>	23	24
<i>Closteriopsis longissima</i>	20	12
<i>Synedra ulna</i>	10	18
<i>Gonatozygon aculeatum</i>	19	17
<i>Nitzschia paradoxa</i>	19	12
<i>Aphanizomenon flos-aquae</i>	26	7
<i>Ankistrodesmus falcatus</i>	39	36
<i>Melosira granulata</i>	27	26
<i>Synedra acus</i>	17	19
<i>Closterium gracile</i>	27	19
<i>Spirulina subtilissima</i>	26	4
<i>Tabellaria floccusa</i>	17	12
<i>Tabellaria fenestrata</i>	23	21
<i>Phormidium valderiae</i>	33	19
<i>Lyngbya limnetica</i>	23	13
<i>Volvox aureus</i>	3	8
<i>Amoeba polypodia</i>	7	16
<i>Rivularia planctonica</i>	11	29
<i>Raphidiopsis curvata</i>	2	27
<i>Nitzschia linearis</i>	8	2
<i>Onychonema filiforme</i>	16	10
<i>Closterium macilentum</i>	7	8
<i>Glocotrichiae chinulata</i>	15	11

**Table 4. Phytoplankton diversity indices in the two fertilized tanks**

<b>Indices</b>	<b>Organic</b>	<b>Inorganic</b>
<b>Taxa_S</b>	28	28
<b>Individuals</b>	611	503
Dominance_D	0.05188	0.044
Simpson_1-D	0.948	0.956
Shannon_H	3.141	3.216
Evenness_e^H/S	0.8256	0.8901
Brillouin	3.018	3.07
Menhinick	1.133	1.248
Margalef	4.21	4.34
Equitability_J	0.9425	0.9651

### 3.4 Phytoplankton Diversity Indices

The existence of phytoplankton in each treatment investigated was recorded and used for numerical analysis in all community parameters (Shannon-Wiener diversity, Evenness, Simpson and Margalef indices).

These parameters varied slightly as shown in (Table 4). The highest in Shannon-Wiener diversity, Evenness, Simpson, and Margalef indices were found in the inorganic tank with respective values of 3.216, 0.8901, 0.956 and 4.34. The lowest in Shannon-Wiener diversity, Evenness, Simpson, and Margalef indices were

found in the organic fertilized tank with respective value of 3.141, 0.8256, 0.948 and 4.21.

### 3.5 Canonical Correspondence Analysis of Environmental Variables with Phytoplankton

Six environmental factors affected phytoplankton presence to varying degrees. Temperature, pH, DO, potassium, phosphorus and total nitrogen had a significant influence on phytoplankton, as indicated by their high correlation with the two significant canonical roots. The phytoplankton in the first quadrant of the biplot were strongly correlated with pH, temperature and DO, and negatively correlated with total nitrogen and potassium. Only one species of phytoplankton was found in the second quadrant. *Amoeba polyopdia*, *Closterium macilentum*, *Volvox aureus*, *Raphidiopsis curvata*, *Synedra ulna* were the dominant species distributed in the third quadrant (Fig. 1).

### 3.6 Principal Component Analysis (PCA) Plot of the First Two Components of All Variables Measured During the Study Period

The study revealed a total of 1114 individuals of 28 species of phytoplankton consisting of 611 individuals in the tank fertilized with organic fertilizer and 503 individuals in the inorganic treated tank. Six environmental factors (temperature, DO, pH, potassium, phosphorus and total nitrogen) were screened for PCA analysis based on the abundance of phytoplankton. PCA biplot showed that the eigenvalues of the two axes were 18.49% (Fig. 2). The variance explained by the first environmental factors axis and species axis was 10.19%, while that for the second axes was 8.30%, indicating a close relationship between phytoplankton and the environmental variables analyzed. The most important environmental variables were phosphorus, total nitrogen, potassium and DO.

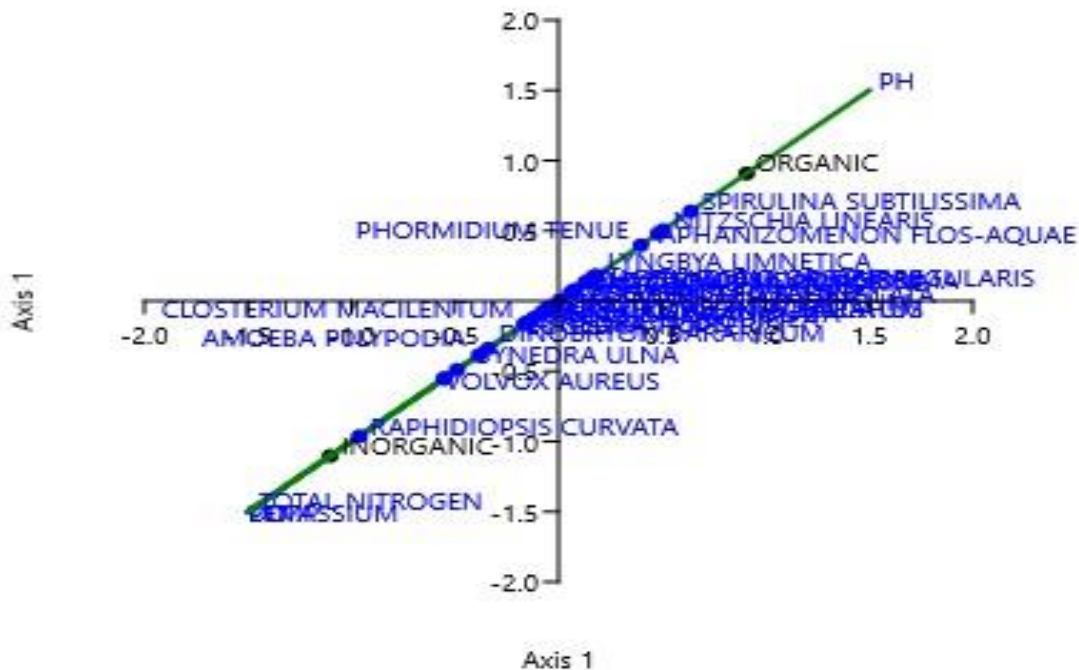
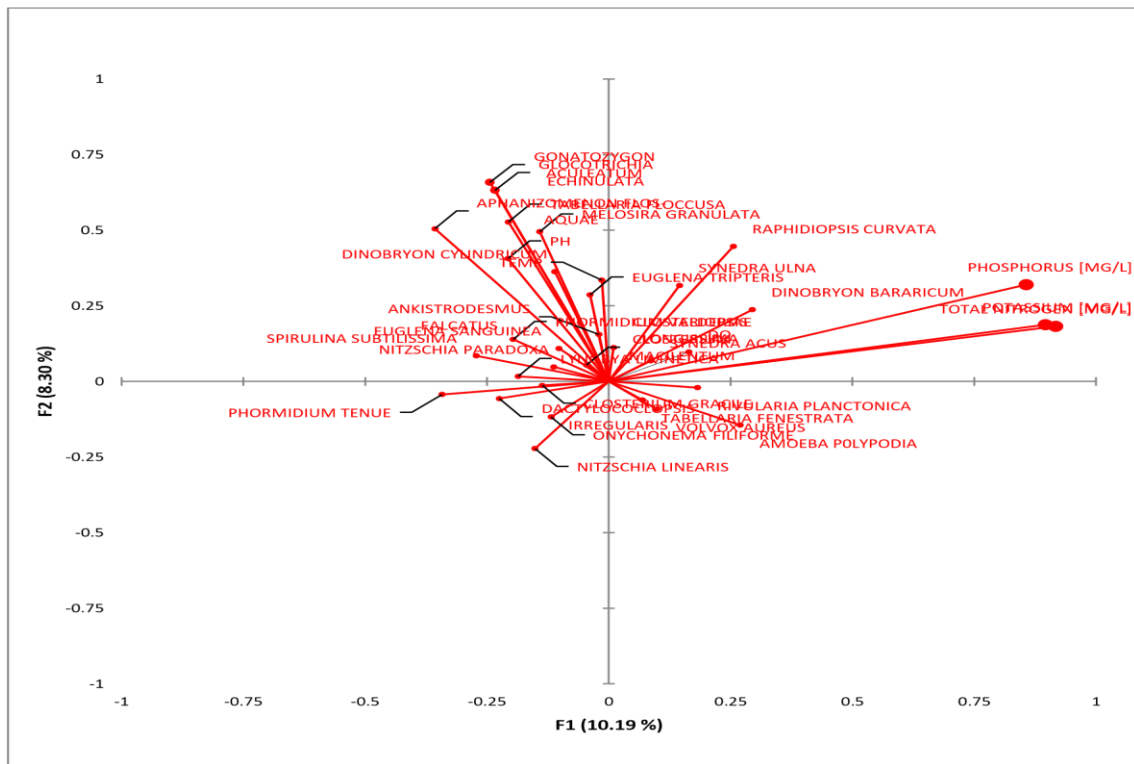


Fig. 1. Canonical correspondence analysis of environmental variables with phytoplankton





**Fig. 2. Principal component analysis (PCA) plot of the first two components of all variables measured**

#### 4. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

##### 4.1 Discussion

This present study revealed inter-tank differences in some of the physico-chemical parameters investigated. Potassium, phosphorus, nitrogen and DO were significantly different but temperature and pH was not statistically significant. DO is the most significant ecological factor of the fish pond ecosystem [31]. Mahboob [32] recorded the maximum average DO when phytoplankton was abundance. A similar trend was observed in these present investigations as the values obtained were within the permissible level of  $4\text{mg l}^{-1}$  for aquaculture. The water remained close to the saturation values with regard to oxygen showing the presence of healthy environment during the study period. ( $4.13 \pm 0.16^b$  ( $4.71 \pm 0.18^a$ ))

A mean of  $7.03 \pm 0.49$  DO has been recorded in studies on physicochemical characteristics and phytoplankton diversity in fish ponds [33]. A range of  $7.69 \pm 0.15$  to  $7.74 \pm 0.20$  DO was reported by Prabhat [31] for two fertilized fish pond, Akunga et al. [8] reported the values of

$7.0 \pm 0.2$ ,  $6.7 \pm 0.2$  and  $6.0 \pm 0.3$  for concrete, earthen and liner pond respectively which are all higher than the values recorded in this present study. The reason for this dissimilarity in DO with the present study could be due to high mean temperature observed in this study. DO in water declines with an increase in temperature and vice versa. Other studies have shown DO concentration of  $2.53\text{ mg l}^{-1}$  for drainage water and  $5.68\text{ mg l}^{-1}$  for irrigation water [34] which are comparable to the values recorded in this present study.

Temperature is an important independent factor that can affect phytoplankton [35]. Temperature influences fish growth by affecting the physicochemical conditions of water. It also impacts the speed of chemical changes in soil, water and the contents of dissolved gases [31]. Studies on the effects of urea along with a constant supply of poultry manure on phytoplankton production in earthen fish ponds, revealed that pond water temperature varied from  $26.3\text{ }^\circ\text{C}$  to  $33\text{ }^\circ\text{C}$  [36] which is in line with the values obtained in this present study. The temperatures values recorded in this study are within the optimal ranges for plankton growth ( $18.3\text{-}37.8\text{ }^\circ\text{C}$ ) [37] and are recommended for fish

culture (26.06-31.97°C) (Boyd, 1982) in tropical ponds. Inter-tank differences in water temperature in this study were non-significant with values  $26.00 \pm 0.14^a$  for the inorganic fertilized tank and  $25.97 \pm 0.14^a$  for organic fertilized tanks. This result corroborates the findings of Prabhat [31] who also reported no significant difference in the temperature of the fertilized ponds investigated. The temperature values obtained in this study are in line with the range  $24.2 \pm 0.4$  -  $24.1 \pm 0.4$  -  $26.0 \pm 0.4$  reported by Akunga et al. [8] for concrete, earthen and liner pond, respectively.

Qiu et al. [38] stated that fertilizer application significantly affects the pH of a medium. However, no significant difference was found in this current study. The pH values were  $5.96 \pm 0.23^a$  and  $6.20 \pm 0.19^a$  for inorganic and organic fertilized tanks respectively. This result corroborates the findings of Prabhat [31] who also reported no significant difference in the pH values from their investigation. The authors reported pH values of both fertilized ponds in the range of 7.30 to 9.40 (T1) and 7.60 to 9.10 (T2) in their respective ponds. Hassan [39] observed that the production was higher in experimental ponds with pH values ranged from 6.9 to 9.5 which is also consistent with the values observed in this study.

Phytoplankton require nutrients such as nitrate and phosphate for growth. However, some phytoplankton can fix nitrogen and grow in areas where nitrate concentrations are low [40]. The potassium level in this study was  $51.29 \pm 2.88^a$  for the inorganic fertilized tank and  $16.52 \pm 1.19^b$  for the organic fertilized tank. The tank with the inorganic fertilizer recorded a higher amount of potassium compared to the tank fertilized with organic fertilizer. This could be attributed to the high potassium released by the inorganic fertilizer.

The mean phosphorus level in this study was higher in the inorganic tank than in the organic tank, which was contrary to the findings of Hossain et al. [41] who suggested that the capacity of phosphorus released from poultry manure might be more efficient than other organic and inorganic fertilizers used in their study. The mean phosphorus levels ( $27.97 \pm 1.08^a$ ) in the inorganic tank and ( $12.30 \pm 0.43^b$ ) in the organic tank in this study are lower than  $610-1010 \mu\text{g l}^{-1}$  reported in studies on phytoplankton diversity and its relationship to physicochemical parameters by

Hossain et al. [41]. Additionally, these levels are lower than the mean total phosphorous levels ( $458.7 \pm 50.8$ ) reported in liner ponds by Akunga et al. [8]. The variations could be attributed to the different water-holding facilities used in previous studies and could be influence by the effects of pH in the pond since pH had a positive correlation with phosphorus levels in the earthen pond. However, the mean phosphorus level in this current study is significantly higher than the values reported by George and Atakpa (2015) who recorded the range of 0.14-0.67 and 0.05-0.64 for phosphorus in Pond A and Pond C respectively

The mean total nitrogen concentrations ( $33.39 \pm 0.66^a$ ) in the inorganic treated tank and ( $11.85 \pm 0.58^b$ ) in the organic treated tank in this study were higher in the inorganic treated tank. The tank treated with inorganic fertilizer recorded a relatively high amount of total nitrogen due to the low number of nitrifying bacteria and the absence of soil medium at the bottom of the tank compared to the one treated with organic fertilizer. Total nitrogen concentration in this study is much lower when compared to the ranged of  $272.81 \mu\text{g l}^{-1}$  in liner ponds to  $2887.6 \mu\text{g l}^{-1}$  in concrete ponds with a mean of  $728.2 \pm 68.1 \mu\text{g l}^{-1}$  as reported by Akunga et al. [8] and the 200 - 300  $\mu\text{g l}^{-1}$  reported by Saeed and Mohammed [42]. This variation can be attributed to the low number of nitrifying bacteria present in their pond and the nature of the pond bottom in their study.

Based on the results from the Pearson correlation matrix of the physico-chemical parameters, the difference in phytoplankton composition is influence by a combination of physical conditions and water chemistry. The study revealed that certain parameters, potassium, phosphorous and total nitrogen, have a significantly positive correlation with phytoplankton abundance.

Phytoplankton play an important role in aquatic ecosystems due to their fast response to changes [43]. In this study a total of 1114 individuals of phytoplankton were identified of which the trend of species dominated in composition were *Dactylococlopsis irregularis* (79) > *Phormidium tenue* (53) > *Ankistrodesmus falcatus* (39) in the organic fertilized tank while the dominant species for the inorganic tank were *Dactylococlopsis irregularis* (45) > *Ankistrodesmus falcatus* (36), > *Dinobryon bararicum* (31). The least dominant species

found in this current study for organic fertilizer were *Closterium macilentum* (7) > *Amoeba polypodia* (7) > *Volvox aureus* (3) > *Raphidiopsis curvata* (2) while the trend for inorganic fertilizer were *Aphanizomenonflos-aquae* (7) > *Spirulina subtilissima* (4) > *Nitzschia linearis*.

The species diversity, expressed with the Shannon index ranged from 3.141 -3.216 in this current study. The higher values of Shannon's index (H) in the inorganic fertilized tank of 3.216 indicated greater species diversity compared to 3.141 in the organic fertilized tank. This slight difference may be due to the fact that the inorganic treated tank retains fertility more effectively, influence by its physicochemical parameters. Additionally, the higher Shannon index in inorganic tank over the organic tank could be attributed to more favorable atmospheric conditions in the inorganic tank. Differences in phytoplankton diversity may also be an indicator that phytoplankton diversity is influence by the tank type and physicochemical parameters.

The combined range of Shannon index (H') from 3.141 to 3.216 for organic and inorganic treated tanks found in this study is slightly higher than the reported range of 0.108 to 2.584 by Saeiam et al. [35]. Evenness Index (J) of 0.8256 to 0.8901 indicate that all the species were relatively evenly abundant across the various treatments investigated. The combined range of Evenness for organic and inorganic treated tanks in this study aligns with the reported range of 0.086 to 0.530 by Saeiam et al. [35]. Similarly, the combined range of Simpson index (1-D) from 0.9481 to 0.956 for organic and inorganic treated tanks in this study also fall within the reported range of 0.031 to 0.900 by Saeiam et al. [35].

The Index of individual abundance was highest in the tank treated with organic fertilizer, with 611 individuals, followed by the inorganic fertilized tank with 503 individuals. The high individual phytoplankton abundance observed in the organic fertilized tank in this study might be due to the fact that the tank was less severely impacted by pollution, thereby favoring species abundance. The Margalef Index (a measure of species richness or taxa richness 'd') was higher (4.34) in tank treated with inorganic fertilizer, reflecting that this fertilizer-treated tank maintained a high level of biodiversity.

In the CCA biplot of the study, it was observed that most of the dominant species were

distributed in the first and fourth quadrants, possibly indicating higher pollution levels in the fertilized treated tanks. Various environmental factors were found to significantly impact the growth and distribution of phytoplankton. However, the specific factors varied across different CCA biplots. The key factors influencing the phytoplankton community were identified as pH, DO, total nitrogen, and potassium. Therefore, it can be inferred that water quality condition in the two treated tanks had a significant impact on phytoplankton community.

The PCA plots illustrate the role of pH, total nitrogen, and potassium in structuring the phytoplankton system. High concentrations of phytoplankton species such as *Dinobryon bararicum*, *Euglena tripteris*, *Synedra ulna*, *Raphidiopsis curvata*, and *Spirulina subtilissima* were strongly correlated with DO, total nitrogen, potassium, and phosphorus in the first quadrant. Species like *Ankistrodesmus falcatus*, *Spirulina subtilissima*, *Dinobryon cylindricum*, *Euglena sanguine*, and *Nitzschia paradoxa* showed a strong affinity for temperature and pH, as shown in Fig. 2.

## 4.2 Conclusion

The results of this study indicate that the abundance and composition of phytoplankton were significantly influenced by the type of fertilizer treatment and the physico-chemical condition of the tanks. The tank treated with organic fertilizer exhibited higher abundance and species composition of phytoplankton compared to the tank treated with inorganic fertilizer. Furthermore, higher phytoplankton diversity observed in organic fertilizer-treated tank may reflect better water quality and the environmental conditions compared to the inorganic fertilizer-treated tank. The study also found that the addition of fertilizers altered several physico-chemical properties of the water. Water bodies with a higher diversity of phytoplankton generally indicate better water quality, as evidenced by fluctuation in both biotic and abiotic variables. The results suggest that the addition of fertilizers increased nitrogenous compounds, which are beneficial for phytoplankton growth. Canonical Correspondence Analysis (CCA) and Principal Component Analysis (PCA) highlighted DO, pH, total nitrogen, potassium, and phosphorus as critical environmental factors influencing the distribution of phytoplankton communities. The study further revealed that different phytoplankton species exhibit preferences for

specific environmental conditions. The CCA biplot results underscored the relationship between phytoplankton community structure and water quality influenced fertilizer treatments.

### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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