

Comparative Study-Analysis on Theof Phytoplankton Communities in Two Newly Inundated Ponds, Using Organic and Inorganic Fertilizers

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, and each replicated twice, using organic (chicken manure) and inorganic fertilizer (chicken manure and di-ammonium phosphate fertilizer, 20:10:10, 2.5kg for each) fertilizers. Out of 1114 individuals of phytoplankton identified, 611 were from belong to the organic fertilizer-treated tank, while 503 individuals were accounted for from the inorganic fertilizer-treated tank. The highest and the lowest phytoplankton species identified were *Dactylococloopsis irregularis* (79) > *Phormidium tenue* (53) > *Ankistrodesmus falcatus* (39) for 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 flosaquae* (7) > *Spirulina subtilissima* (4) > *Nitzschia linearis* (2). Physicochemical factors such as like Temperature, pH, pPotassium, and 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 physico-chemical parameters investigated. Potassium, phosphorus, nitrogen, and dissolved oxygen (DO) were significantly different across the two treatments, while temperature and pH were not significant, statistically significant (P<0.05). The result from the analysis of all community parameters (Shannon-Wiener diversity, Evenness, Simpson, and Margalef indices) showed that parameters varied slight variationsly. The highest in Shannon-Wiener diversity, Evenness, the Simpson, and Margalef indices were found in the inorganic fertilizer-treated tank with their respective values (3.216, 0.8901, 0.956, and 4.34, respectively), while the lowest in Shannon-Wiener diversity, Evenness, the Simpson and Margalef indices values were found in the organic fertilizer-treated tank with their respective values (3.141, 0.8256, 0.948, and 4.2109, respectively). This result indicates that the abundance and structure of phytoplankton communities were affected by the different fertilizer used and also the physicochemical condition of the tank the tank's physico-chemical conditions.

Keywords: Phytoplankton community, Organic Fertilizer, Inorganic Fertilizer, Inundated Ponds, Phytoplankton, Community Physico-chemical factors, Species diversity indices

1.0 Introduction

In the realm of aquatic ecosystems, phytoplankton serves as a fundamental component, playing a pivotal role in nutrient cycling and primary productivity (Ni *et al.*, 2018). It and the structure of phytoplankton community is a good indicator of water quality due to its sensitivity alertness to environmental stresses (George and Atakpa, 2015; George and Opeh, 2016; George *et al.*, 2021). The introduction of fertilizers, whether organic or inorganic, into aquatic ecosystems can significantly influence phytoplankton composition and abundance, thereby impacting overall ecosystem dynamics (Sipauba-Tavares *et al.*, 2011; Akpan, *et al.*, 2022; Asuquo, *et al.*, 2022).

The abundance and structure of phytoplankton the populations of phytoplankton are majorly primarily regulated by inorganic nutrients, which include, but are not limited to, nitrogen, phosphorus, and silica (Akunga *et al.*, 2018). The major forms of available nitrogen are occurs as nitrate, nitrite, and ammonia. Phosphorus occurs as soluble orthophosphate, while silicic acid exists in the form of silicates (USEPA, 2008). 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 (Chellappa *et al.*, 2009). Phytoplankton demonstrates water quality through changes in their community composition, and distribution, and proportion of sensitive species (Gharibet *et al.*, 2011). Phytoplankton are largely governed by light, nutrients, temperature, community structure, life-cycle history, stratification or vertical mixing, and tides (Yusuf, 2020).

Environmental conditions can directly or indirectly affect the community structure of phytoplankton (Whitton, 2012). Previous studies have proved shown that the change characteristics of phytoplankton structure changes are closely related to hydrological conditions, and nitrate concentration (Negro *et al.*, 2000). Additionally, these changes have a strong, and also have a good coupling relationship with chemical oxygen demand (COD) and particulate organic matter (POM) (Lee and Kang, 2010). When environmental factors change, they can still greatly control the

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56 | phytoplankton community structure, ~~to a great extent~~. It is becoming ~~more and more~~ increasingly essential to study the
57 | changes ~~in~~ phytoplankton community structure to improve water quality assessment (Huang *et al.*, 2022). Therefore,
58 | monitoring phytoplankton community structure and diversity has become ~~an~~ essential ~~for assessing~~ water ecosystem
59 | health and water quality ~~evaluation~~ (Nunes *et al.*, 2018). ~~Thus,~~ ~~u~~Understanding the changes ~~of~~ in phytoplankton
60 | communities in ponds contaminated by agriculture may contribute to determining the ~~best approaches for directions of~~
61 | protection ~~of~~ these ecosystems and provide reference cases for ~~broader~~ wider research (Huang *et al.*, 2022).

62 | Fertilization of ponds to enhance phytoplankton production and zooplankton suitable for larval fish is a
63 | common practice in Nigeria (Sipaúba-Tavares *et al.*, 2011). Fertilizer sources maybe inorganic or organic ~~(matter) as~~
64 | ~~the case may be~~, which include agricultural by-products and animal manures. Chemical fertilizers typically ~~is~~
65 | ~~composed~~ consist of nitrogen, phosphorus, and potassium compounds that dissolve readily to provide nutrients to
66 | phytoplankton (Green, 2015). Organic fertilizers includes agricultural by-products, for example, rice bran, cottonseed
67 | meal, and animal manures, ~~such as for example~~, poultry litter, cow manure, which first must undergo decomposition to
68 | release nutrients for phytoplankton growth. The combined use of organic and inorganic fertilizer is known to have
69 | direct impact on the plankton community structure (Sipaúba-Tavares *et al.*, 2011) by promoting both the autotrophic and
70 | heterotrophic organisms in the ponds. Organic fertilization is also known to promote the growth of smaller-sized
71 | zooplankton, especially the rotifers (Okojin and Obi, 1999), as well as other micro-zooplankton such as protozoans and
72 | copepod nauplii (Pinto-Coelho *et al.*, 2005) which usually dominate eutrophic waters.

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

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

86 | 2.0 Materials and Methods

87 | 2.1 Study Area

88 | The study was conducted from September 2023 to October 2023 at ~~the~~ hatchery research unit of the
89 | Department of Fisheries and Aquatic Environmental Management University of Uyo.

91 | 2.2 Pond Preparation and Experimental Design

92 | ~~A f~~ Few days prior to the trial, ponds were prepared ~~by~~ draining, washing, and checking water supply and
93 | draining systems ~~checked~~. ~~V~~vegetation was removed from the bottom and sides of the ponds. One week before the trial,
94 | ~~the~~ ponds were filled, and subsequently, water loss due to evaporation was compensated to maintain the same level
95 | throughout the study. The study lasted for ~~only~~ 31 days. ~~The study and~~ was conducted in a completely random design
96 | with two treatments and two replicates using organic and inorganic fertilizers (see Plate 1). Two types of fertilizers
97 | viz: chicken manure and di-ammonium phosphate fertilizer) were used in this experiment. Fresh manure from layers
98 | kept in the cages ~~was~~ collected from poultry unit belonging to ~~the~~ Department of Animal Science University of Uyo.
99 | ~~The nitrogen~~ (N (2.55%) and ~~phosphorus~~ (P (0.95%) ~~content~~ in chicken manure ~~were~~ determined using proximate
100 | analysis at ~~the~~ Animal Science laboratory according to ~~the~~ Association of Official Analytical Chemists (AOAC, 2002).
101 | Four concrete tanks, ~~each having with~~ an area of approximately 7.62m², ~~each~~ were used and ~~then~~ filled with water ~~to a~~
102 | depth of 2.5ft. Two treatments: 2.5kg of chicken manure, 2.5kg of di-ammonium phosphate fertilizer and ~~a no fertilizer~~
103 | ~~(control (no fertilizer))~~ were randomly assigned to the tanks, ~~with e~~ Each treatment was replicated once.

Comment [u3]: I would like to suggest that sections 2.1 and 2.2 be merged.



Plate 1: Experimental setup

Comment [u4]: In my opinion, Plate 1 and Plate 2 could be omitted from the paper.

2.3 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 collected and 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 (APHA, 2005). Identification of phytoplankton species was conducted by observing through the microscope and for enumeration under the light microscope (objective x 40), and by using standard keys for plankton identification according to Needham and Needham (1975); as well as guides provided by Newell and Newell (1975); APHA (1985), and Egborge (1973).



Plate 2: Plankton net

2.4 Species Indices

Species composition and abundance of phytoplankton were described using the method of Hoppenrath *et al.* (2009). The phytoplankton community structure was analyzed using the Shannon-Wiener Index (H'), species richness (d), and the Evenness index (J') using Partversion 3.25 (Hammer *et al.*, 2001). 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).

2.4.1. Phytoplankton species indices

The phytoplankton community structure was assessed using the Shannon diversity index (H') of biodiversity, the species equality index (E), and the Simpson dominance index (D). The diversity index was calculated with the using Krebs's equation (Krebs, 2014).

2.4.2 The species Evenness (or Equitability)

The calculation of the uniformity index is based on the equation of Krebs (2014):

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

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139 Where:
140 e - uniformity index;
141 H' - diversity index;
142 Hmax - ln S;
143 S - number of types.
144 The ratio of the observed diversity (H) to the maximum diversity (Hmax) was taken as a measure of the evenness (E).
145 According to Krebs (2014), it measures the distribution of individuals.
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2.4.3 Margalef's species richness index

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

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

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150 Where:
151 s = Total number of species in the sample
152 ln = natural or Napierian logarithm, and
153 N = total number of individuals in the sample
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2.4.4. Shannon – wiener diversity index (H)

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156 The index used to determine the level of species diversity in a community is the Shannon Wiener index (Krebs 2014):
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$$H = \sum_{i=1}^n P_i \ln P_i$$

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159 Where:
160 H - index of species diversity
161 Pi - probability function for each part as a whole (ni/N); ni - number of individuals of type-i;
162 N - total number of individuals.
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2.4.5 Simpson index

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165 The dominance index is used to determine the extent to which a species dominates another group. The
166 dominance index was obtained using the Simpson index (Krebs 2014):

167 Where:

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

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170 D - Simpson dominance index;
171 ni - number of individuals of type i;
172 N - total number of individuals;
173 S - number of types (species).
174

2.5 Collection of Water Sample

175 Three plastic bottles for water samples and dissolved oxygen (DO) bottles each measuring 50 cl, each were used to
176 collect water samples. The bottles were immersed to about 60 cm below the water surface and filled to capacity. After
177 removal from the water, each Then brought out of the water and properly closed. Each bottle was carefully sealed.
178 Flushed severally and confirmed that ensuring no air bubbles were exists present. They were then transported to the
179 fisheries laboratory in the Department of Fisheries and Aquatic Environmental Management for further analysis.
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2.6 Water quality

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182 Water temperature, dissolved oxygen (DO) DO, and pH were determined measured at in-situ in the morning by
183 8:00am using mercury – in – glass thermometer, portable pH meter model –(HI98107 Hanna instrument), and portable
184 dissolved oxygen DO meter (model HI98303 Hanna instrument) (APHA, 1998; APHA, 2005). Other water quality

185 parameters (phosphate, nitrates, and potassium) were determined in the laboratory based on following standard
186 laboratory procedure according to APHA (2005) and APHA (1998).
187

188 2.7 Statistical Analysis

189 Data on the physico-chemical parameters and phytoplankton composition were analyzed. Analysis of variance
190 (ANOVA) was used to test for statistical differences between the means of the physical and chemical parameters in of
191 the fish ponds. Descriptive statistics of data for water quality analyses and phytoplankton were done using Microsoft
192 Excel. Principal Components Analysis (PCA) was used to determine the relationship between physico-chemical
193 parameters and phytoplankton, utilizing the PAST software.
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195 3.0 Results

196 3.1 Mean Variations in Physicochemical parameters in the two Tanks

197 The Dissolved oxygen DO in this present study was 4.13 ± 0.16^b in for the inorganic tank and 4.71 ± 0.18^a in for
198 the organic tank. This parameter exhibited significant difference at $P < 0.05$ in the study. The highest mean DO value
199 (4.71 ± 0.18^a) was observed in the inorganic fertilized tank, while the lowest value (4.13 ± 0.16^b) was recorded in the
200 organic fertilized tank (Table 1).

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

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

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

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

213 Total nitrogen levels were found to be 33.39 ± 0.66^a for the inorganic tank and 11.85 ± 0.58^b for the organic tank.
214 This parameter showed a marked significant difference ($P < 0.05$) in the study (Table 1).
215

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

Variables	INORGANIC	ORGANIC
DO	4.71 ± 0.18^a	4.13 ± 0.16^b
TEMPERATURE	26.00 ± 0.14^a	25.97 ± 0.14^a
PH	5.96 ± 0.23^a	6.20 ± 0.19^a
POTASSIUM [MG/L]	51.29 ± 2.88^a	16.52 ± 1.19^b
PHOSPHORUS [MG/L]	27.97 ± 1.08^a	12.30 ± 0.43^b
TOTAL NITROGEN [MG/L]	33.39 ± 0.66^a	11.85 ± 0.58^b

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

218 3.2 Pearson Correlation Matrix for The Physio-Chemical Parameters

219 Pearson's correlation analysis was conducted to reveal the relationships between the environmental parameters
220 in the two tanks. Based on the Pearson analysis, potassium and total nitrogen have a significantly positive correlation
221 (0.90), potassium and phosphorus (0.90). A significant positive correlation was observed for phosphorus and total
222 nitrogen (0.85). DO has a relatively weak correlation with pH (0.34), and with phosphorus (0.23). pH has a weak
223 correlation with phosphorus (0.04). High negative correlations occur between pH and total nitrogen (-0.18), and
224 between pH and potassium (-0.14) (Table 2).
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232 **Table 2: Pearson correlation matrix for the physico-chemical parameters**

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Variables	DO	TEMP	PH	POTASSIUM	PHOSPHORUS	TOTAL NITROGEN
DO	1.00					
TEMPERATURE	0.09	1.00				
PH	0.34	0.10	1.00			
POTASSIUM	0.07	0.00	-0.14	1.00		
PHOSPHORUS	0.23	0.07	0.04	0.90	1.00	
TOTAL N	0.09	0.00	-0.18	0.90	0.85	1.00

234 *Values in bold are different from 0 with a significance level alpha=0.05*

235 **3.3Phytoplankton Abundance**

236 The phytoplankton species recorded during the study are presented in Table 3. A total of 1,114 individuals
 237 were recorded in both fertilized tanks. The phytoplankton composition was dominated by *Dactylococlopsis irregularis*
 238 (79)>*Phormidium tenue* (53)>*Ankistrodesmus falcatus* (39) in the organic fertilized tank, while the dominant specie for
 239 the inorganic tank were *Dactylococlopsis irregularis* (45)> *Ankistrodesmus falcatus* (36), >*Dinobryon bararicum*
 240 (31). The least dominant species found in this current study for organic fertilizer were *Closterium macilentum*
 241 (7)>*Amoeba polypodia* (7)>*Volvox aureus* (3)>*Raphidiopsis curvata* (2), while the trend for inorganic fertilizer were
 242 *Aphanizomenonflos-aquae* (7) >*Spirulina subtilissima* (4) >*Nitzschia linearis* (2).
 243
 244

Table 3: Phytoplankton Abundance in the two Fertilized Tanks

Phytoplankton Species	ORGANIC (INDIVIDUALS)	INORGANIC (INDIVIDUALS)
<i>Dactylococlopsis 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 chimulata</i>	15	11

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246 **3.4 Phytoplankton Diversity Indices**

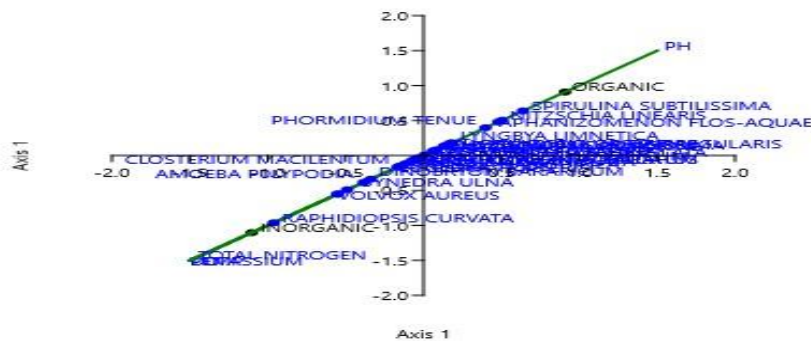
247 The existence of phytoplankton in each treatment investigated was recorded and used for numerical
 248 analysis in all community parameters (Shannon-Wiener diversity, Evenness, Simpson, and Margalef indices). These
 249 parameters varied slightly, as shown in (Table 4). The highest in Shannon-Wiener diversity, Evenness, the Simpson,
 250 and Margalef indices were found in the inorganic tank with their respective values thus of 3.216, 0.8901, 0.956, and
 251 4.34, while the lowest in Shannon-Wiener diversity, Evenness, the Simpson and Margalef indices were found in the
 252 organic fertilized tank with their respective values thus of 3.141, 0.8256, 0.948, and 4.2109.
 253

254 **Table 4: Phytoplankton Diversity Indices in the two Fertilized Tanks**

Indices	ORGANIC	INORGANIC
Taxa_S	28	28
Individuals	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	4.2109	4.34
Equitability_J	0.9425	0.9651

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 256 **3.5 Canonical Correspondence Analysis of Environmental Variables with Phytoplankton**

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



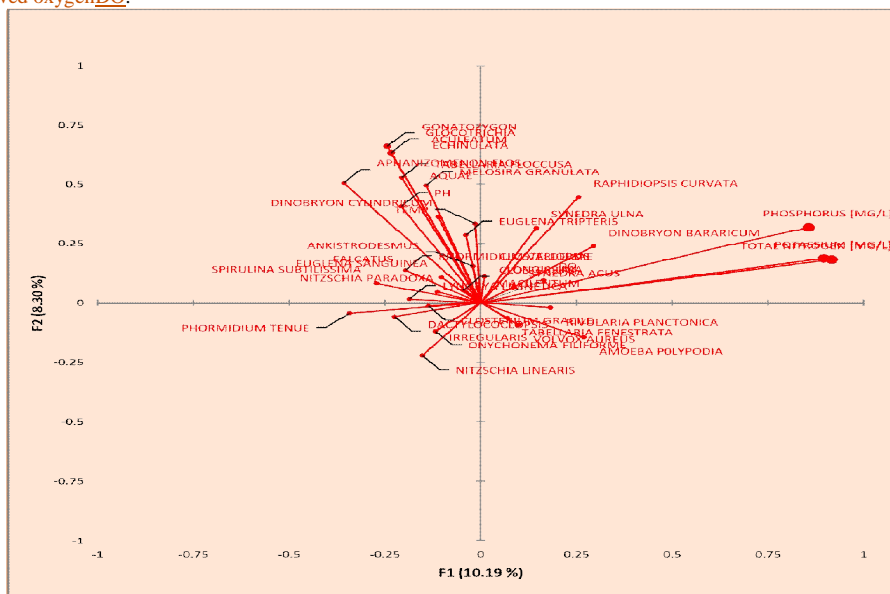
263
 264 **Figure 1: Canonical correspondence analysis of environmental variables with phytoplankton**

265 **3.6 Principal Component Analysis (PCA) Plot of The First Two Components of All Variables Measured During the Study Period**

266 The study revealed a total of 1114 individuals of 28 species of phytoplankton, consisting of 611 individuals in
 267 the tank fertilized with organic fertilizer and 503 individuals in the inorganic-treated tank. Six environmental
 268 factors (Temperature, DO, pH, Potassium, Phosphorus, and Total nitrogen) were screened for PCA analysis based
 269 on the abundance of phytoplankton. PCA biplot showed that the eigenvalues of the two axes were 18.49% (Fig. 3.). The
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271 PCA between the variance explained by the first environmental factors axis and species axis was 10.19%, while that for
 272 the second axes was 8.30%, indicating a close relationship between phytoplankton and the environmental variables
 273 analyzed. The most important environmental variables were pPhosphorus and total nitrogen (mg/l), potassium, and
 274 dissolved oxygen DO.



275 Figure 2: Principal component analysis (PCA) plot of the first two components of all variables measured.
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278 **4.0 Discussion, Conclusion and Recommendations**

279 **4.1 Discussion**

280 This present study revealed inter-tank differences in some of the physico-chemical parameters investigated.
 281 Potassium, phosphorus, nitrogen and dissolved oxygen DO were significantly different, but, temperature and pH was
 282 not statistically significant. Dissolved oxygen DO is the most significant ecological factor of the fish pond
 283 ecosystem (Prabhat, 2019). Mahboob (1992) recorded the maximum average dissolved oxygen DO when there was
 284 abundance of phytoplankton. A similar trend was observed in these present investigations
 285 as the values obtained were within the permissible level of 4mg/l for aquaculture. The water remained close to the
 286 saturation values with regard to oxygen, showing the presence of healthy environment during the study period.
 287 (4.13±0.16^b (4.71±0.18^b)).

288 A mean of 7.03±0.49 dissolved oxygen DO has been recorded in studies on physicochemical characteristics
 289 and phytoplankton diversity in fish ponds (El Nemaki *et al.*, 2008). A range of 7.69±0.0.15 to -7.74±0.0.20 DO was
 290 reported by Prabhat (2019) for two fertilized fish ponds. Akunga *et al.* (2018) reported the values of 7.0±0.2, 6.7±0.2,
 291 and 6.0±0.3 for concrete, earthen, and liner pond, respectively, which are all higher than the values recorded in this
 292 present study. The reason for this dissimilarity in DO with the present study could be due to high mean temperature
 293 observed in this study. This is because dissolved oxygen DO of in water declines with an increase in temperature of the
 294 water and vice versa. Yet other studies have shown a dissolved oxygen DO concentration of 2.53 mg/l⁻¹ for drainage
 295 water and 5.68 mg/l⁻¹ for irrigation water (Fafioye *et al.*, 2005), which are conformable-comparable to the values
 296 recorded in this present study.

297 Temperature is an important independent factor which can affect phytoplankton (Saeiamet *et al.*, 2020).
 298 Temperature affects-influences fish growth by influencing-affecting the physico-chemical conditions of water. It also
 299 affects-impacts the speed of chemical changes in soil, water, and the contents of dissolved gases (Prabhat, 2019).
 300 Studies on the effects of urea along with a constant supply of quality-of-poultry manure on phytoplankton production in
 301 earthen fish ponds-reveals that pond water temperature varied from 26.3°C to 33°C (Davies *et al.*, 2009) which is in
 302 line with the values obtained in this present study. The temperatures values recorded in this present study are within

303 the optimal ranges for plankton growth (18.3-37.8°C) (Bagchi and Jha, 2011) and are recommended for fish culture
304 (26.06-31.97°C) (Boyd, 1982) in tropical ponds. Inter-tank differences in water temperature in this current study
305 were non-significant, as the with values 26.00 ± 0.14^a for the inorganic fertilized tank and 25.97 ± 0.14^a were observed for
306 inorganic and organic fertilized tanks respectively. This result corroborates the submission findings of Prabhat (2019)
307 who also reported non-significant difference in the temperature of the fertilized ponds investigated. The
308 values of temperature values obtained in this present study is in line with the range 24.2 ± 0.4 - 24.1 ± 0.4 - 26.0 ± 0.4
309 reported by Akunga *et al.* (2018) for concrete pond, earthen, and liner pond, respectively.

310 Qiu *et al.*, (2018) stated that fertilizer application significantly affects the pH of a medium. However, no
311 significant difference was found in this current study. The pH values were 5.96 ± 0.23^a and 6.20 ± 0.19^a for inorganic and
312 organic fertilized tanks, respectively. This result corroborates the findings of Prabhat (2019) who also reported that
313 there was no significant difference in the pH values from their investigation. The authors reported pH values of both
314 fertilized ponds in the range between of 7.30 to 9.40 (T1) and 7.60 to 9.10 (T2) in their respective ponds. Hassan (1989)
315 observed that the production was more higher in experimental ponds whose with pH values ranged from 6.9 to 9.5,
316 which is also in tandem consistent with the values observed in this present study.

317 Phytoplankton require nutrients such as nitrate and phosphate for growth. However, some phytoplankton can
318 fix nitrogen and can grow in areas where nitrate concentrations are low (Kumar *et al.* 2014). The potassium level in
319 this present study was 51.29 ± 2.88^a for the inorganic fertilized tank and 16.52 ± 1.19^b for the organic fertilized tank. The
320 tank with the inorganic fertilizer recorded a higher amount of potassium level as compared with to the tank fertilized
321 with organic fertilizer. This could be attributed to the high potassium released by the inorganic fertilizer.

322 The mean phosphorus level in this present study was higher in the inorganic tank than in the organic tank,
323 which was contrary to the submissions findings of Hossain *et al.* (2006) who suggested that the capacity of phosphorus
324 released from poultry manure might be more efficient than other organic fertilizers and inorganic fertilizers used in their
325 study. The mean phosphorus levels (27.97 ± 1.08^a) in the inorganic tank and (12.30 ± 0.43^b) in the organic tank in this
326 present study are lower than 610 - $1010 \mu\text{g l}^{-1}$ reported from in studies on phytoplankton diversity and its relationship to
327 physico-chemical parameters reported by Hossain *et al.* (2006). More so Additionally, it is also these levels are lower than
328 the mean total phosphorus levels (458.7 ± 50.8) reported in liner ponds by Akunga *et al.* (2018). The variations could be
329 attributed to the different water-holding facilities used in the previous findings studies and also could be attributed
330 influenced by the effects of pH in the pond since pH had a positive correlation with phosphorus levels in the earthen
331 pond. However, the mean phosphorus level in this current study is significantly higher than the values reported by
332 George and Atakpa (2015) in their investigations who recorded the range of 0.14 - 0.67 and 0.05 - 0.64 for phosphorus in
333 Pond A and Pond C, respectively.

334 The mean total nitrogen concentrations (33.39 ± 0.66^b) in the inorganic treated tank and (11.85 ± 0.58^b) in the
335 organic treated tank in this present study were higher in the inorganic treated tank than the organic. The tank treated
336 with inorganic fertilizer recorded a relatively high amount of total nitrogen due to the low number of nitrifying bacteria
337 and the absence of soil medium in at the bottom of the tank as compared to the one treated with organic fertilizer. Total
338 nitrogen concentration in this present study is far much lower when compared to the range of $272.81 \mu\text{g l}^{-1}$ in liner
339 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.* (2018) and the 200
340 - $300 \mu\text{g l}^{-1}$ reported by Saeed and Mohammed (2012). This variation can be ascribed attributed to the low number of
341 nitrifying bacteria present in their pond and the nature of the pond bottom in their study.

342 Based on the results from the Pearson correlation matrix of the physico-chemical parameters, the difference
343 in of phytoplankton composition is obtained influenced from by a combination of physical conditions and water
344 chemistry. The study revealed that some certain parameters say, potassium, phosphorus, and total nitrogen, have a
345 significantly positive correlation with phytoplankton abundance.

346 Phytoplankton has a play an important role in aquatic ecosystems due to their fast response to changes
347 (Soeprbowati *et al.*, 2021). In this present study, a total of 1,114 individuals of phytoplankton were identified of
348 which the trend of species dominated in composition were *Dactylococlopsis irregularis* (79) > *Phormidium tenue*
349 (53) > *Ankistrodesmus falcatus* (39) in the organic fertilized tank while the dominant species for the inorganic tank were
350 *Dactylococlopsis irregularis* (45) > *Ankistrodesmus falcatus* (36), > *Dinobryon bararicum* (31). The least dominant
351 species found in this current study for organic fertilizer were *Closterium macilentum* (7) > *Amoeba polypodia* (7) > *Volvox*
352 *aureus* (3) > *Raphidiopsis curvata* (2) while the trend for inorganic fertilizer were *Aphanizomenon flos-aquae* (7)
353 > *Spirulina subtilissima* (4) > *Nitzschia linearis*.

354 The species diversity, expressed with the Shannon index, was on a higher level within the ranged from 3.141 -
355 3.216 in this current study. The higher values of Shannon's index (H) in the inorganic fertilized tank of 3.216 indicated
356 greater species diversity as compared to 3.141 in the organic fertilized tank. This slight difference may be due to the
357 fact that the inorganic treated tank could not lose out retains fertility easily and due to the tank more effectively,
358 influenced by its physicochemical parameters. In addition Additionally, the higher Shannon index in inorganic tank over
359 the organic tank could be attributed to suitable more favorable atmospheric conditions of in the inorganic tank.

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360 Differences in phytoplankton diversity ~~could may~~ also be an ~~indication-indicate~~ that phytoplankton diversity is ~~affected~~
361 ~~influenced~~ by the tank type and physico-chemical parameters.

362 The combined range of ~~Shannon index (H')~~ from 3.141 ~~to-~~ 3.216 of ~~Shannon index~~ for organic and inorganic
363 treated tanks found in this ~~present~~ study is slightly higher than the reported range of 0.108 ~~to-~~ 2.584 by Saeiam *et al.*
364 (2020). Evenness Index (~~J'~~) of 0.8256 ~~to-~~ 0.8901 ~~showed-indicates that~~ all the species were ~~slightly equally~~ ~~relatively~~
365 ~~evenly~~ abundant ~~in-the~~ ~~across the~~ various treatments investigated. The combined range ~~0.8256-0.8901~~ of Evenness (~~J'~~)
366 for organic and inorganic treated tanks ~~found~~ in this ~~present~~ study ~~is in agreement~~ aligns with the reported range of 0.086
367 - 0.530 by Saeiam *et al.* (2020). ~~Similarly,~~ ~~(The~~ combined range of ~~Simpson index (1-D)~~ from 0.9481- 0.956 for
368 ~~Simpson in~~ organic and inorganic treated tanks found in this ~~present~~ study ~~agrees totally~~ also falls within the reported
369 range of 0.031 ~~to-~~ 0.900 by Saeiam *et al.* (2020).

370 The Index of individual abundance was highest in ~~the~~ tank treated with organic fertilizer, with (611)
371 individuals, followed by ~~the~~ inorganic fertilized tank with (503) individuals. The highest individual phytoplankton
372 abundance observed in the organic fertilized tank in this ~~present~~ study might be due to the fact that the tank was ~~not~~
373 ~~less~~ severely ~~impacted by~~ ~~polluted~~ ~~pollution~~ and ~~so~~ ~~thereby~~ ~~favoured~~ ~~-favoring~~ ~~the~~ ~~species~~ ~~abundance~~ ~~of~~ ~~species~~. The
374 Margalef Index (~~a~~ measure of species ~~richness~~ ~~r~~Richness or ~~(Taxa~~ ~~richness~~ 'd') was highest (4.34) in tank treated with
375 inorganic fertilizer, reflecting that ~~this~~ fertilizer-treated tank ~~was still rich in~~ maintained a high level of biodiversity.

376 In ~~the~~ CCA biplot ~~of the study~~, it was ~~noticed-observed~~ ~~in the study~~ that most of the dominant species were
377 distributed in the first and fourth quadrants, ~~which might be related to the heavy~~ ~~possibly~~ ~~indicating~~ ~~higher~~ ~~pollution~~
378 ~~levels~~ ~~of~~ ~~in~~ ~~the~~ ~~fertilized~~ ~~treated~~ ~~tanks~~. ~~There were many~~ ~~Various~~ environmental factors ~~were found to significantly~~
379 ~~impact~~ ~~affecting~~ the growth and distribution of phytoplankton. However, the ~~main~~ ~~impacted~~ ~~specific~~ factors varied
380 ~~among the~~ ~~across~~ different CCA biplots. The ~~main~~ ~~key~~ ~~factors~~ ~~impacting~~ ~~influencing~~ ~~the~~ ~~phytoplankton~~ ~~community~~ ~~in~~
381 ~~this current study~~ were ~~identified as:~~ pH, DO, ~~and~~ total nitrogen, and potassium. ~~Thus~~ ~~Therefore~~, it ~~can be~~ ~~is~~ inferred that
382 ~~the condition of~~ ~~water quality~~ ~~condition~~ in the two treated tanks had ~~great a significant~~ impact on phytoplankton
383 community.

384 The ~~projections of the entire sets of variables in~~ PCA plots ~~show-illustrate~~ the role of pH, total nitrogen, and
385 potassium in structuring of the phytoplankton system, ~~with~~ ~~high~~ ~~amounts~~ ~~concentrations~~ of the phytoplankton ~~species~~
386 ~~such as~~ *Dinobryon bararicum*, *Euglena tripteris*, *Synedra ulna*, *Raphidiopsis curvata*, ~~and~~ *Spirulina subtilissima* ~~were~~
387 strongly correlated ~~to~~ ~~with~~ ~~DO~~, total nitrogen ~~and~~ potassium, ~~and~~ phosphorus in the first quadrant ~~and~~ ~~Species~~
388 ~~like~~ *Ankistrodesmus falcatus*, *Spirulina subtilissima*, *Dinobryon cylindricum*, *Euglena sanguine*, ~~and~~ *Nitzschia paradoxa*
389 ~~had~~ ~~showed~~ a strong affinity for temperature, and pH, as shown in ~~Figure (2)~~.

391 4.2 Conclusion

392 ~~From~~ ~~The~~ ~~results~~ ~~obtained~~ ~~in~~ ~~of~~ ~~this~~ ~~study~~ ~~it~~ ~~can~~ ~~be~~ ~~concluded~~ ~~indicate~~ that the abundance and composition of
393 phytoplankton ~~was~~ ~~were~~ ~~affected~~ ~~significantly~~ ~~influenced~~ by the ~~type~~ of ~~fertilizer~~ ~~tank~~ ~~treatment~~ ~~type~~ and ~~the~~ physico-
394 chemical condition of the tanks. ~~The~~ ~~tank~~ ~~treated~~ ~~with~~ ~~organic~~ ~~fertilizer~~ ~~exhibited~~ ~~A~~ ~~higher~~ ~~abundance~~ ~~and~~ ~~species~~
395 ~~composition~~ ~~of~~ ~~phytoplankton~~ ~~was~~ ~~found~~ ~~in~~ ~~tank~~ ~~treated~~ ~~with~~ ~~organic~~ ~~fertilizer~~ ~~as~~ ~~compared~~ ~~to~~ ~~the~~ ~~tank~~ ~~one~~ ~~treated~~ ~~with~~
396 ~~inorganic~~ ~~fertilizer~~. ~~Furthermore~~, ~~The~~ ~~current~~ ~~study~~ ~~found~~ ~~that~~ ~~higher~~ ~~phytoplankton~~ ~~diversity~~ ~~observed~~ ~~in~~ ~~organic~~
397 ~~fertilizer-treated~~ ~~tank~~ ~~of~~ ~~phytoplankton~~ ~~might~~ ~~may~~ ~~reflect~~ ~~the~~ ~~better~~ ~~water~~ ~~quality~~ ~~and~~ ~~the~~ ~~environmental~~
398 ~~condition~~ ~~compared~~ ~~to~~ ~~the~~ ~~inorganic~~ ~~fertilizer-treated~~ ~~tank~~ ~~in~~ ~~the~~ ~~different~~ ~~tank's~~ ~~treatment~~. ~~The~~ ~~results~~ ~~study~~ ~~also~~
399 ~~found~~ ~~in~~ ~~this~~ ~~study~~ ~~revealed~~ that the addition of fertilizers ~~to~~ ~~the~~ ~~tank~~ ~~influenced~~ ~~some~~ ~~of~~ ~~the~~ ~~altered~~ ~~several~~ physico-
400 chemical properties of the water. ~~It~~ ~~is~~ ~~assumed~~ ~~that~~ ~~Water~~ ~~bodies~~ ~~with~~ ~~a~~ ~~higher~~ ~~diversity~~ ~~of~~ ~~phytoplankton~~ ~~generally~~
401 ~~affect~~ ~~indicate~~ ~~better~~ ~~water~~ ~~quality~~, ~~which~~ ~~could~~ ~~be~~ ~~observed~~ ~~through~~ ~~the~~ ~~as~~ ~~evidenced~~ ~~by~~ ~~fluctuation~~ ~~in~~ ~~its~~ ~~both~~ ~~biotic~~ ~~and~~
402 ~~abiotic~~ ~~variables~~. ~~The~~ ~~results~~ ~~of~~ ~~this~~ ~~present~~ ~~study~~ ~~indicated~~ ~~suggest~~ that the addition of fertilizers ~~increased~~ ~~to~~ ~~the~~ ~~fish~~
403 ~~tanks~~ ~~also~~ ~~increased~~ ~~the~~ ~~level~~ ~~of~~ ~~nitrogenous~~ ~~compounds~~, ~~which~~ ~~is~~ ~~considered~~ ~~as~~ ~~a~~ ~~good~~ ~~source~~ ~~are~~ ~~beneficial~~ ~~for~~
404 ~~phytoplankton~~ ~~growth~~. Canonical Correspondence Analysis (CCA) and Principal Component Analysis (PCA) ~~showed~~
405 ~~highlighted~~ ~~that~~ ~~DO~~, ~~pH~~, ~~(T~~ ~~total~~ ~~nitrogen~~, ~~p~~ ~~Potassium~~, and ~~p~~ ~~Phosphorus~~ ~~were~~ ~~important~~ ~~as~~ ~~critical~~ ~~environmental~~
406 ~~factors~~ ~~influencing~~ ~~the~~ ~~distribution~~ ~~of~~ ~~phytoplankton~~ ~~communities~~. The study ~~also~~ ~~further~~ ~~revealed~~ that different
407 ~~phytoplankton~~ ~~species~~ ~~demand~~ ~~different~~ ~~exhibit~~ ~~preferences~~ ~~for~~ ~~specific~~ ~~environmental~~ ~~conditions~~. ~~The~~ CCA biplot
408 ~~results~~ ~~indicate~~ ~~underscored~~ ~~that~~ the relationship between phytoplankton community ~~structure~~ and water quality ~~are~~
409 ~~strongly~~ ~~affected~~ ~~by~~ ~~the~~ ~~treatment~~ ~~of~~ ~~the~~ ~~influenced~~ ~~fertilizer~~ ~~treatments~~ ~~used~~.

411 5.0 References

412 Akpan, I. I., Ukekpe, U. S., George, U. U. and Okon, J. E. (2022). The Relationship of Plankton Abundance to
413 Physicochemical Parameters in a Segment of Lower Imo River Estuary. *International Journal of Fauna and*
414 *Biological Studies*; 9(2): 30 – 37.

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- 415 Akunga, G., Getabu, A. and Njiru, J. (2018). Effect of pond type on physicochemical parameters, phytoplankton
416 diversity and primary production in, Kisii, Kenya *International Journal of Fisheries and Aquatic Studies*; 6(6):
417 125-130
- 418 American Public Health Association (APHA) (1985). Standard Methods for Examination of Water and Wastewater.
419 16th Edition APHA, AWWA, WPCF, Washington D.C.;1268Pp.
- 420 American Public Health Association (APHA), (2005): Standard methods for examination of water and wastewater. 21st
421 Edn. APHA, AWWA, WPCF, Washington DC, USA (2005).
- 422 American Public Health Association (APHA). (1998). Standard methods for the examination of water and wastewater.
423 20th edition. Washington, D.C.: American Public Health Association Inc.
- 424 Association of Official Analytical Chemists, (2002). *Official Methods of Analysis*, Association of Official Analytical
425 Chemists (AOAC). JRC-European Commission, Washington D.C. USA
- 426 | Asuquo, G. I., Akpan, I. I., George, U. U., Asuquo, I. E. Ukpatu, J. E., and. Ejiogun, I. N. (2022). Phytoplankton
427 Composition and Abundance in Mbiakong River, Cross River Estuary, Niger Delta, Nigeria. *Asian Journal of*
428 *Environment & Ecology*, 19(4):135-141.
- 429 Bagchi, A. and Jha, P. (2011). Fish and fisheries in Indian heritage and development of pisciculture in India. *Reviews*
430 *in Fisheries Science*, 19:85-118.
- 431 Chellappa, N.T., Câmara, F.R.A. and Rocha, O. (2009). Phytoplankton community: indicator of water quality in the
432 Armando Ribeiro Gonçalves Reservoir and Pataxó Channel, Rio Grande do Norte, Brazil. *Brazilian*
433 *Journal of Biology*; 69(2), 241-251.
- 434 Davies, O. A., Abowei, J. F. N. Otene, B.B. (2009). Seasonal abundance and distribution of plankton of Minichinda
435 stream. Niger Delta, Nigeria *Americal of Journal Science Research*; 2(2):20-30.
- 436 Egborge, A. B. M. (1973). A Preliminary Checklist of the Phytoplankton of River Oshun. *Freshwater Biology*. 3:569-
437 572.
- 438 El Nemaki, F., Ali, N., Zeinhom, M. and Radwan, O. (2008). Impacts of different water resources on the ecological
439 parameters and the quality of Tilapia production at El Abbassa, Fish farm in Egypt. 8th International
440 symposium on tilapia in Aquaculture, 191 – 512
- 441 Fafioye, O. O., Olurin, K. B. Sowunmi A. A. (2005). Studies on the physicochemical parameter of Omi water body of
442 Ago-Iwoye, Nigeria. *African Journal of Biotechnology*; 4(9): 1022-1024.
- 443 | George, U. U. and Atakpa, E. O. (2015). Diversity and Species Composition of Periphyton in a Tropical Earthen Pond
444 in South Eastern Nigeria. *World Rural Observations*, 7(4): 65-70.
- 445 | George, U. U. and Opeh, P. B. (2016). Spatial distribution and abundance of bacteria and phytoplankton in Calabar River,
446 Cross River State, Nigeria. *International Journal of Fauna and Biological Studies*, 3(3): 45-51.
- 447 | George, U. U., Mbong, E. O., Ita, R. E. (2021). Spatio-Temporal variation in Phytoplankton Distribution and
448 Abundance in a Tropical Freshwater Body in Niger Delta, Nigeria. *Nature and Science*; 19(4):18-26.
- 449 Gharib, S.M., EL-Sherif, A.Z.M., Abdel-Halim, M. and Radwan, A.A. (2011). Phytoplankton and environmental
450 variables as a water quality indicator for the beaches at Matrouh, south-eastern Mediterranean Sea, Egypt: an
451 assessment. *Oceanologia*, 53(3), 819-836.
- 452 Green, B (2015) "Fertilizers in aquaculture" (2015). Publications from USDA-ARS / UNL Faculty. 2422.
- 453 Hammer, O., Harper, D. A. T. and Ryan, P. D. (2001). PAST: Paleontological statistics software package for education
454 and data analysis. *Palaeontologia Electronica*, 4(1):1-9.
- 455 Hassan M. (1989). Effect of cowdung lurea-fedi manure fertilization of fish pond on the growth performance of three
456 maior carps. viz., *Caffa catla*, *Labeo rohita* and *Cirrfina mrigafa*. M.Phil. Thesis. Univ. Agric. Faisalabad.
457 Pakistan, 91.
- 458 Hoppenrath, M., Elbrachter M. and Drebes, M. (2009). Marine phytoplankton, Stuttgart, E Schweizerbart'sche
459 Verlagsbuchhandlung, 49:1-264.
- 460 Hossain, M. Y., Jasmine, S., Ibrahim, A., Ahmed, Z., Ohtomi, J., Fulanda, B., Begum, M., Mamun, A., El-kady, M. and
461 Wahab, M. (2007). A Preliminary observation on water quality and plankton of an earthen fish pond in
462 Bangladesh: Recommendations for future studies. *Pakistan Journal of Biological Sciences*, 10:868-873.
- 463 Huang Y, Shen Y, Zhang S, Li Y, Sun Z, Feng M, Li R, Zhang J, Tian X and Zhang W (2022). Characteristics of
464 Phyttoplankton Community Structure and Indication to Water Quality in the Lake in Agricultural Areas.
465 *Frontiers in Environmental Science*; 10:833409
- 466 Krebs C. J. (2014). Ecological methodology. 3rd edition. Harper Collins Publisher, New York, 680 p.
- 467 Kumar, S. D., Kumar, S. P., Kumar, V. U. and Anbuganapathi, G. (2014). Efficacy of Biofertilizer Enriched Flower
468 Waste Vermicompost on Production and Growth of Primary Producers and Freshwater Aquarium Fishes.
469 *Global Veterinaria*, 56 (2): 215-220.

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470 Mahboob S. (1992). Influence of fertilizer and artificial feed on the growth performance in composite culture of major,
471 common and some Chinese carps. Ph.D. Thesis, Deptt. Zool. Fisheries, Univ. Agric., Faisalabad, Pakistan,
472 261.

473 Needham, J. G., Needham, P. R. (1975). A guide to the study of fresh water biology. San Francisco: Holding-Day Inc. 1-
474 108.

475 Negro, A. I., De Hoyos, C., and Vega, J. C. (2000). Phytoplankton Structure and Dynamics in Lake Sanabria and
476 Valparaíso Reservoir (NW Spain). *Hydrobiologia*, 424 (1-3), 25–37.

477 Newell, G. B., Newell, R. C. (1977). Marine plankton: A practical Guide. Hutchinson and Company Publishers Ltd.
478 London; 229 Pp.

479 Ni, M., Yuan, J. L., Liu, M. and Gu, Z. M. (2018). Assessment of water quality and phytoplankton community of
480 *Limpnaeusvannamei* pond in intertidal zone of Hangzhou Bay, China. *Aquaculture Reports*, 11:53-58.

481 Nunes, M., Adams, J. B., and Rishworth, G. M. (2018). Shifts in Phytoplankton Community Structure in Response to
482 Hydrological Changes in the Shallow St Lucia Estuary. *Mar. Pollut. Bull.*; 128:275–286.

483 Okojin, V.A. Obi, A.W. (1999). Effects of three fertilizer treatments on zooplankton productivity in plastic tanks. *Indian*
484 *Journal of Animal Science*, 69(5): 360-363.

485 Pielou, E. C., (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical*
486 *Biology*, 131-144.

487 Pinto-coelho RM, Giani A, Morais Junior CA, Carvalho Junior ER, Bezerra-neto, JF. (2005). The nutritional status of
488 zooplankton in a tropical reservoir: effects of food quality and community structure. *Brazilian Journal of*
489 *Biology*, 65(2): 313-324.

490 Prabhat, R. (2019). Study of fish pond fertilization: Comparison of ecological conditions. *International Journal of*
491 *Fisheries and Aquatic Studies*; 7(4):310-313

492 Qiu, Y.; Lin, Y.; Tang, L.; Guan, T.; Chen, Q.; Chen, K. and Wang, L. (2018). The biodiversity assessment of
493 phytoplankton community in summer within main stream and tributary of Huaihe River. *J. Environ. Sci.-*
494 *China*, 38: 1665–1672.

495 Saeed, M.S. and Mohammed, M.A. (2012). Influence of physicochemical characteristics of water on metals
496 accumulation in water and *Tilapia Zillii* inhabiting different habitats in Egypt. *Journal of the Arabia*
497 *Aquaculture Society*; 7(1):29-50.

498 Saeiam, Y., Pichitkul, P., Nedtharn, U. and Wudtisn, I. (2020). Phytoplankton community dynamics and its impacts
499 on the quality of water and sediments in the recirculated-water earthen pond system for hybrid red tilapia
500 (*Oreochromis niloticus x mossambicus*) farming. *International Journal of Agricultural Technology*; 16(3): 695-
501 710.

502 Sipauba-Tavare, L. H., Donadon, A. R. V. and Millan, R. N. (2011). Water Quality and Plankton Populations in an
503 Earthen Polyculture Pond. *Brazilian Journal of Biology*, 71(4): 1-11.

504 Soeprbowati, T. R., Addadiyah, N. L., Hariyati, R., and Jumari, J. (2021). Physico-chemical and biological water
505 quality of Warna and Pengilon Lakes, Dieng, Central Java. *Journal of Water and Land Management* 51(10-
506 12):38-49

507 Whitton, B. A. (2012). Changing Approaches to Monitoring during the Period of the 'Use of Algae for Monitoring
508 Rivers' Symposia. *Hydrobiologia* 695 (1): 7–16

509 Yusuf, Z. H. (2020). Phytoplankton as bioindicators of water quality in Nasarawa Reservoir, Katsina State Nigeria.
510 *Acta Limnologica Brasiliensia*, 32(4):1-11.