Innovations

Phytoplankton Distribution, Abundance and Diversity in a Tropical Aquaculture Ponds in Calabar, Cross River State, Nigeria

Aniema Inyang-Etoh[1], Bassey Etim Job[2],Sunday Urom Eteng[3]& Samson Samuel Urom[4]

[1,3,4] Department of Fisheries and Aquaculture, Faculty of Agriculture, University of Calabar, Nigeria
[2]Department of Biological Oceanography, Faculty of Oceanography, University of Calabar, Nigeria

Correspondence Author: **Bassey Etim Job**

Abstract: *Phytoplankton are mainly unicellular plant-like organisms and usually known to drift on the surface layer of the euphotic zone of aquatic ecosystem. Their abundance, distribution and diversity was studied in Onesky Fish Ponds in Calabar, Nigeria. Three of the production ponds were randomly selected for the study. Surface water samples were collected by filtration method and microscopically analyzed in the laboratory. Results revealed that the ponds were inhabited by six major phytoplankton families namely: Bacillariophyceae, Chlorophyceae Chrysophyceae, Xanthrophyceae, Euglenophyceae and Charophyceae. In general, the Bacillariophyceae were the most abundant and diverse phytoplankton in the ponds.This was followed by Chlorophyceae, Euglonephyceae, Chrysophyceae, Xanthophyceae and Charophyceae with the following distribution pattern: Bacillariophyceae (466:38.0%) > Chlorophyceae (249:20.31%) > Euglenophyceae (172:14.03%) > Chrysophyceae (156:12.72%) > Charophyceae (87:7.10%). Margalef's index for the Bacillariophyceae was 1.690 in pond 1, with 2.006 in pond 2 and 2.060 in pond 3. Forthe Chlorophyceae, Margalef's index had a value of 1.70 (Pond 1), 1.78 (Pond 2) and 1.53 (Pond 3). Chrysophyceae had Margalef's index of 1.07 (Pond 1), 0.77 (Pond 2)and 0.954 (Pond 3). For the Xanthophyceae, Margalef's index was 1.16 (Pond 1), 0.093 (Pond 2) and 1.08 (Pond 3). Euglenophyceae had Margalelef's index of 1.50 (Pond 1), 1.28 (Pond 2) and 1.18 (Pond 3), Charophyceae was observed to have Margalef's index of 0.314 (Pond 1), 0.290 (Ponds 2 and 3), respectively. For the Bacillariophyceae, Shannon-Wiener index was 1.98 (Pond 1), 2.09 (Pond 2) and 2.22 (Pond 3), with 1.68 for Chlorophyceae (Pond 1), 1.68 (Pond 2) and 1.912 (Pond 3). For Chrysophyceae, Shannon-Wiener index was 0.53 (Pond 1), 1.64 (Pond 2) and 1.77 (Pond 3), with 1.68 for Xanthophyceae (Pond 1), 0.93 (Pond 2)* *and 1.08 (Pond 3). Euglenophyceae had Shannon-Wiener index of 1.63 (Pond 1), 1.59 (Pond 2) and 1.76 (Pond 3), while for Charophyceae, Shannon-Wiener index was 1.36 (Pond 1), 1.47 (Pond 2) and 1.79 (Pond 3). Simpson's index had a value of 0.0055 (Pond 1), 0.0051 (Pond 2) and 0.0031 (Pond 3) andfor Bacillariophyceae, it was 0.014 (Pond 1), 0.009 (Pond 2) and 0.006 (Pond 3). For Chlorophyceae, 0.012 (Pond 1), 0.0051 (Pond 2) and 0.0046 (Pond 3) for Chrysophyceae, 0.014 (Pond 1), 0.012 (Pond 2) and 0.007 (Pond 3) for Xanthophyceae, 0.014 (Pond 1), 0.012 (Pond 2) and 0.007 (Pond 3) for Euglenophyceae and 0.004 (Pond 1), 0.002 (Ponds 2 and 3, respectively) for Charophyceae. The results of the present study revealed generally that the ponds are ecologically stable for enhanced aquaculture production. Further studies are however recommended on the physico-chemical parameters, seasonal abundance, distribution and diversity of phytoplankton and chlorophyll-a concentration in the pond ecosystem, generally.*

***Keywords**: Phytoplankton, Tropical aquaculture ponds, Onesky, distribution, abundance, species, composition,diversity.*

Introduction

Phytoplankton are mainly unicellular (single-celled) plantlike organisms. Phytoplankton are predominantly aquatic and are found in both fresh and salt (marine) waters. Fresh water forms occur abundantly in ponds, lakes, slow flowing streams and water reservoirs. They may be free-swimming, free-floating or attached to the bottom of 2000 shallow waters and even mud and sandbars (Mann, 2000; Castro and Huber, 2005; Sverdrup *et al.,* 2006). Phytoplankton form the base of the primary productivity of the aquatic ecosystem. utilizing solar energy to photosynthesize and produce organic materials under the influence of nutrients or fertilizers, carbon (IV) oxide and water (Sverdrup *et al.,* 2006). The interplay of these materials enhance the production of new materials in the phytoplankton cells for enhanced cell multiplication. The main groups of phytoplankton include diatoms, dinoflagellates Cyanobacteria and Coccolithophore (Treasurer *et al.,* 1999:Prasad 2000, Castro Huber, 2005; Sverdrup *et al.,* 2006).

In a typical aquatic ecosystem, each of these groups of phytoplankton is involved in the primary productivity of the system (Parsons*et al.,* 1984; Ekpenyong, 2006; Job, 2019). The rate of productivity is however controlled or influenced by the nutrient, temperature and sunlight, which are growth requirements of the phytoplankton themselves (Mann, 2000). Other factors such as hydrogen ion concentration, pH, and of course, the general pattern of the water quality in terms of the physical, chemical and biological settings of the water (Ekanem *et al.,*2018; Job *et al.,* 2011; Job, 2019).

Basically, two requirements are necessary for phytoplankton need two main things to perform photosynthesis. First, they need sunlight, the ultimate source of energy for the ecosystem. Second, they need a supply of essential nutrients

(Castro and Huber, 2005). Without sunlight and nutrients phytoplankton cannot grow and produce the food that fuels the classic food web of the ecosystem (Ekpenyong, 1996). Nutrients, especially nitrogen, iron and phosphorus, play a major part in controlling primary production. Even with plenty of light, phytoplankton cannot perform photosynthesis if there are not enough nutrients, that is, if primary production become nutrient-limited (Castro and Huber, 2005).

From available literature, studies on the influence of physico-chemical parameters on the abundance, distribution and diversity of phytoplankton in tropical, subtropical and temperate aquatic ecosystems include those of Offem *et al.* (2011), Dimowo (2013), Onyema and Ojo (2008), Akin-Oriola (2003) Davies *et al.* (2009), Rahaman *et al.* (2013) Ekanem *et al.* (2018), Ikpi *et al.* (2013), Rahman *et al.* (2018) Chukwu& Afolabi (2017), Adeogun *etal.,* (2005), Asha (2015), Chowdhury *et al.* (2008) Hossain *et al.* (2007), Roy (2014) and Siddika (2012). None of these studies however discusses the phytoplankton of Onesky Fish Farm, Calabar, Cross River State, Nigeria, which the current study is designed.

Materials and Methods

Study area

Onesky Fish Farm is located along Lemna Road in Calabar Municipality, approximately between latitude 5.00^0N and longitude 8.00^0E in Calabar, Cross River State, Nigeria. Calabar is one of the major tourism centers in Nigeria, boasting a rich history, beautiful scenery and great culture. Located in Southern Nigeria, Calabar City is capital of Cross River State. It is also known as Old Calabar, it is one of the most visited tourist cities in West Africa.The ponds which phytoplankton samples were collected are shown in Plates 1a-c.



Collection of phytoplankton samples

Phytoplankton samples were collected twice a month for three months (January, 2023 – March, 2023) and pooled into a single sample as recommended by Job (2019). About 20 litres of the surface water was filtered through a 64μm bolting plankton net into50mls plastic samples bottle and preserved with 10% formaldehyde solution. Samples were collected between 07.00-09.00hrs during

Plate 1a: Pond 1 **Plate 1b: Pond 2** **Plate 1c: Pond 3**

which time, solar radiation was less intense to cause photo-inhibition of the phytoplankton (Hulyal & Kalliwa, 2009; Job, 2019) and transported in a plastic box to the Biological Oceanography Laboratory, Faculty of Oceanography, University of Calabar, Calabar, Nigeria for analysis.

Laboratory analysis

In the Laboratory, the samples were concentrated to 10mls capacity and subjected to microscopical studies using an inverted microscope model of x10 objectives. 1ml of Lugol's iodine solution was added to aid in the identification of the phytoplankton species. On addition of the Lugol's iodine solution to phytoplankton samples, the stain became absorbed by the organelles of the phytoplankton cells, making them easily identifiable (Job *et al.,* 2011; Job, 2019).

Identification of phytoplankton species

Identification of the phytoplankton species was done using standard schemes and guides such as those of Whitford and Schumacher (1973), Needham and Needham (1974), Patrick and Reiner (1966) and Sverdrup *et al.* (2016).

Determination of numerical and relative abundance of the phytoplankton

The numerical abundance of each of the phytoplankton families was determined by enumeration method which involved counting the number of each species (n) in each of the families to know the total number of the species in the family. This was summed up to obtain the total abundance (N) and used for the calculation of the relative abundance, based on the formula:

$\%Ra = \frac{n(100)}{N}$(Job*et al.,* 2011; Udo*et al.,* 2015 and Ada &Job, 2018; Job, 2019)

where:

%Ra = relative percentage abundance

n = number of individual species

N = total number of all individuals in the family

Determination of ecological indices of the phytoplankton

In this study, the following ecological indices were used to determine the diversity of the phytoplankton: Margalef's species diversity (d), Shannon-wiener's index (H). Pielou's Evenness index (E), Simpson's Dominance index (D).

Margalef's index (d)

This index is dependent on sample size (Margalef, 1965; Ogbeigbu, 2005). It shows the pollution status of any ecological habitat. It is based on the relationship "S" and the total number of individuals observed (N) (Job, 2019) and is generally known to increase with increase in sample size (Ogbeigbu, 2005). The index is given by the formula:

$d = \frac{s-1}{lnN}$ (Margalef, 1965, Ogbeigbu, 2005, Job *et al.,* 2011 and Job, 2019)

where:

S = Total Number of species

N = total number of individuals samples and

lnN = the Niperian logarithm (Loge) of the total abundance of the phytoplankton

The values of Margalef's diversity index (d) obtained from any ecological survey usually windows the pollution status of the area (Job *et al.,* 2011 and Ali *et al.,* 2003).

Shannon-wiener index (H)

This is sensitive to the number of species present and how diverse the individuals are in the sample. It shows the abundance and richness of phytoplankton population in the habitat (Ogbeigbu, 2005 and Shannon-Wiener, 1949), and is given by the formula:

$H = \frac{logN - filogfi}{N}$

where:

N = total number of all individuals in the sample

fi = total number of individual species or group of species

Pielou's Evenness index (E)

Evenness of the phytoplankton was determined by dividing the observed diversity (H) by the maximum diversity (Hmax) of the phytoplankton at each sampling station. This is represented by the formula:

$E = \frac{H}{Hmax}$(Pielou, 1966, 1984; Ogbeigbu. 2005; Job, 2019).

Simpson's dominance index (D)

This index usually varies between 0 and 1, and measures the extent to which one group of organisms dominates the others and is mathematically represented as:

$D = \frac{ni(ni-1)}{Ni(Ni-1)}$(Ogbeigbu, 2005)

where:

ni = the number of individual species

Ni = the total number of all species from each group or family.

Results

Phytoplankton species composition

The phytoplankton species composition of Onesky fish ponds is presented in Table 1.

Table 1: Taxonomic list of the phytoplankton of Onesky fish ponds Calabar, Cross River State, Nigeria during the period of study

	Taxonomic List	Pond 1	Pond 2	Pond 3
A	**Bacillariophyceae**			
1.	*Melosira granulate*	23	21	25
2.	*Eunotiacaptitata*	-	24	12
3.	*Eunotiacarvata*	21	19	28
4.	*Stenopterobiaintermedia*	12	8	19
5.	*Epithemia zebra*	9	13	7
6.	*Epithemia* sp	6	-	19
7.	*Bidulphialaevis*	-	5	20
8.	*Cyclotellacomta*	11	19	22
9.	*Surirellaelegans*	9	8	15
10.	*Surirellaaugustata*	17	13	15
11.	*Cymbellaaffinis*	-	7	11
12.	*Synedra ulna*	6	9	13
	Total abundance (N)	**114**	**146**	**206**
	Number of species (S)	**9**	**11**	**12**
B	**Chlorophyceae**			
1.	*Nebriumoblingum*	11	9	16
2.	*Hematococcusleustris*	13	15	13
3.	*Sphaerocystisschroeteri*	9	7	11
4.	*Tetrasporalubrica*	-	13	13
5.	*Ptemonesangulosa*	7	11	-
6.	*Radiocucusnimbalus*	3	6	20
7.	*Volvoxteritus*	7	11	8
8.	*Phacotusangulosa*	3	5	5
9.	*Uothrixsp*	9	13	11
	Total abundance (N	**62**	**90**	**97**
	Number of Species (S)	**8**	**9**	**8**
C	**Chrysophyceae**			
1.	*Dinobryonelibergena*	9	11	18
2.	*Dinobryonacyminatum*	6	13	14
3.	*Phaeodermatiumregulere*	4	7	9
4.	*Phaeoflacuthellosa*	11	18	14
5.	*Syneryptavolvox*	13	-	11
	Total abundance (N)	**41**	**49**	**66**

	Number of species (S)	**5**	**4**	**5**
D	**Xanthophyceae**			
1.	*Ophiocytiumcochleare*	8	6	9
2.	*Arachnochlorisbrevispinosa*	7	5	5
3.	*Pseudoteraedionsp*	**4**	**3**	**9**
4.	*Glocopodiumsp*	**5**	**-**	**7**
5.	*Asterogloeagelatinesa*	**7**	**11**	**10**
	Total abundance (N)	**31**	**25**	**40**
	Number of species (S)	**5**	**4**	**5**
E.	**Euglenophyceae**			
1.	*Euglena acus*	10	16	13
2.	*Euglena vorax*	5	9	13
3.	*Euglena tripteris*	5	-	9
4.	*Euglena viridis*	11	8	14
5.	*Phacusbrevicanda*	6	4	-
6.	*Trachelomenonessuperbus*	11	4	13
7.	*Synuracaralinama*	7	8	6
	Total abundance (N)	**55**	**49**	**68**
	Number of species (S)	**7**	**6**	**6**
F	**Charophyceae**			
1	*Nitella acuminata*	14	5	12
2	*Nitella flexilis*	10	26	20
	Total abundance (N)	**12**	**31**	**32**
	Number of species (S)	**7**	**6**	**6**

This consisted of Bacillariophyceae(*Melosiragranulate*, *Melosira variance Eunotiacapitata*, *Eunotiacurvata*, *Cyclotella comta*, *surirellaelegans*, *surirellaangustate cymbella affirms* and *Synedra ulna*) Chlorophyceae(*Nebriumoblongum Hematococus leustris, Sphaerocystisschroeteri. Tetrasporalubrica, Ptemonesangulos Radiocucusnimbalus, volvoxtertius, Phasotusangulosa* and *Ullothrix*sp) Chrysophyceae(*Dinobryondivergena, Dinobryonactuminatum, Phacodermatiumreguler Phacoflacuthellosa* and *Syneryptavolvox*), Xanthophyceae(*OphiocytiumcochleearArachnochlorisbrevispinosa*,*Pseudoteraedio* nsp,*GloeopodiumrivulareAsteroglocagelatinosa*), Euglenophyceae(*Euglenaacus*, *Euglena vorax*, *Euglena tripterEuglenaviridis*, *Phacusbrevicauda*, *Trachelomonessuperbus* and *Synuracarolinana*) Charophyceae (*Nitellaacuminate* and *Nitellaflexilis*).

Numerical and relative abundance of the major phytoplankton families

As presented in Table 2, the six major phytoplankton families Bacillariophyceae, Chlorophyceae, Chrysophyceae, Xanthophyceae, Euglenophyceae and

Chlorophyceae, exhibited varied numerical and relative abundance in each of the ponds.

Table 2: Summary of the numerical and relative abundance of the major phytoplanktonfamilies in Onesky Fish Ponds during the period of study

		Pond 1		Pond 2		Pond 3			
	Major taxonomic families	n	%n	n	%n	n	%n	Marginal total	% marginal total
A.	Bacillariophyceae	114	34.86	146	37.44	206	40.47	466	28.00
B.	Chlorphyceae	62	18.96	90	23.08	97	19.06	249	20.31
C.	Chrysophyceae	41	12.54	49	12.56	66	12.97	156	12.72
D.	Xanthophyceae	31	9.48	25	6.41	40	7.86	96	7.83
E.	Euglenophyceae	55	16.82	49	12.56	68	13.35	172	14.03
F.	Charophyceae	24	7.34	31	7.95	32	6.29	87	7.10
	Overall Abundance (N)	**327**	**100.0**	**390**	**100.0**	**509**	**100.0**	**1226**	**99.99 ≈ 100**

In Pond 1, total of 114 individuals of Bacillariophyceae, which constituted 34.86% of the population of the phytoplankton were identified, with 146 (37.44%) in pond 2 and 206 (40.47%) in pond 3. Total of 62 Chlorophyceae which constituted 18.96% of the phytoplankton were identified in pond 1, with 90 (23.08%) in pond 2 and 97 (19.06%) in pond 3.Chrysophyceae had 41 individuals forming 12.54% of the total phytoplankton in pond 1 with a total of 49 individuals which constituted 12.56% of the phytoplankton in pond 2 and 66 individuals, which formed 12.97% of the phytoplankton population in pond 3. In pond 1, total of 31 (9.48%) of Xanthophyceae were collected, with 25 (6.41%) in pond 2 and 40 (7.86%) in pond 3.Euglenophyceae had 55(16.82%) in pond 1, with 49 (12.56%) in pond 2 and 68 (13.35%) pond 3. In pond 1, total of 24 (7.34%) of Charophyceae were collected. in pond 1, with 31 (7.93%) in pond 2 and 32 (6.29%) in pond 3. These variations in the numerical and relative abundance of the major phytoplankton families are depicted in Figure 1, while Figures 2a -c illustrate the relative abundance of each of the major phytoplankton families.

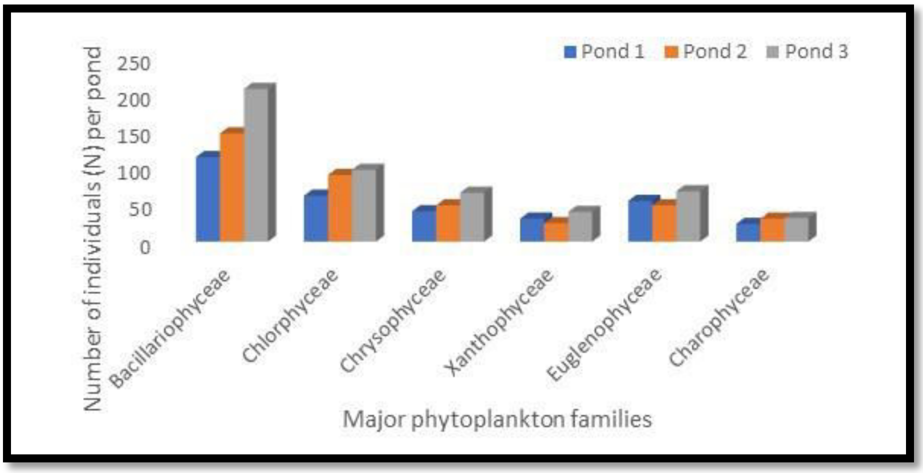

Fig. 1: Variations in the numerical abundance of the major phytoplankton families in the studied ponds in Onesky Fish Farm, Calabar, Nigeria.

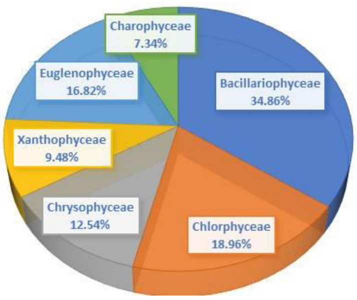

Fig. 2a: Relative abundance of the major phytoplankton families in pond 1 of Oneskey Fish Farm, Calabar, Nigeria, during the period of study.

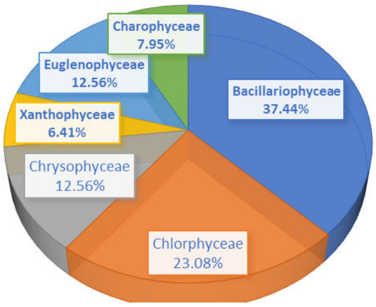

Fig. 2b: Relative abundance of the major phytoplankton families in pond 2 of Oneskey Fish Farm, Calabar, Nigeria, during the period of study.

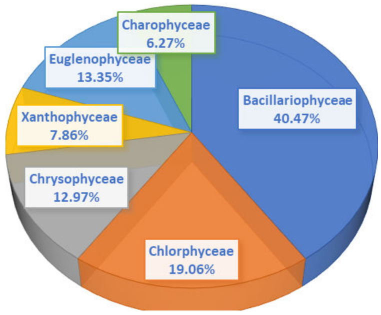

Fig. 2c: Relative abundance of the major phytoplankton families in pond 3 of Oneskey Fish Farm, Calabar, Nigeria, during the period of study.

Marginal total of the phytoplankton families

The marginal totals of the major phytoplankton families are presented in Table 2. Altogether, 1226 phytoplankton cells were collected from the study ponds, with 466(28.00%) of Bacillariophyceae, 249(20.31%) of Chlorophyceae, 156(12.72%) of Chrysophyceae, 96(7.83%) of Xanthophyceae, 172(14.03%) of Euglenophyceae and 87(7.10%) of Charophyceae. These variations are depicted in Figures 2a and b, respectively.

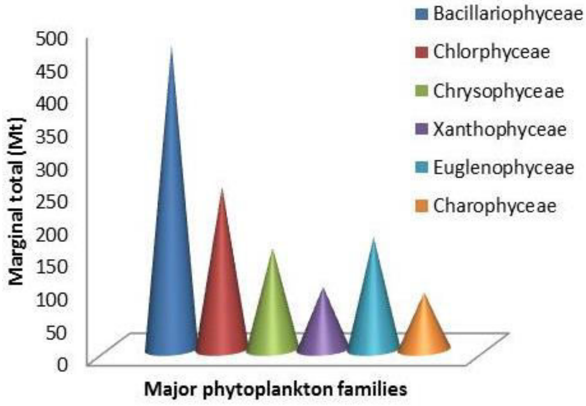

Fig. 3a: Variations in the marginal total of the major phytoplankton families in the studied ponds in Onesky Fish Farm, Calabar, Nigeria.

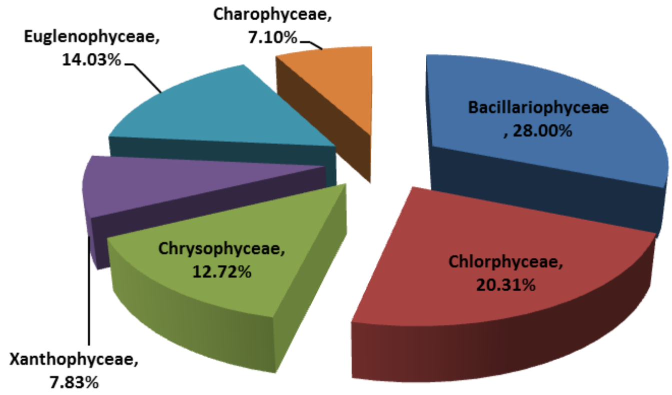

Fig.3b: Variations in the relative marginal total of the major phytoplankton families in the studied ponds in Onesky Fish Farm, Calabar, Nigeria.

Distribution pattern of the phytoplankton

The Bacillariophyceae were generally the most abundant phytoplankton in the ponds. This was followed by the Chlorophyceae, Euglenophyceae, Chrysophyceae, Xanthophyceae and the Charophyceae. with the following pattern of distribution: Bacilariophyceae>Chlorophyceae> Euglenophyceae>Chrysophyceae>Xanthophyceae>Charophyceae (Figures 4a and b).

Ecological indices of the phytoplankton

The ecological indices of the phytoplankton in each of the ponds studied are presented in Table 3.

Table 3: Summary of ecological indices of the phytoplankton in Onesky Fish Farm during the period of study

	Major phytoplankton families	Pond 1	Pond 2	Pond 3
A	**Bacillariophyceae**			
1	Total abundance (N)	144	146	206
2	Number of species (S)	9	11	12
3	Margalef's index (d)	1.69	2.006	2.06
4	Shannon-Wiener index (H)	1.98	2.09	2.2251
5	Simpson's dominance index (D)	0.0055	0.0051	0.0031
B	**Chlorophyceae**			
1	Total abundance (N)	62	90	97

2	Number of species (S)	8	9	8
3	Margalef's index (d)	1.70	1.78	1.53
4	Shannon-Wiener index (H)	1.68	1.86	1.912
5	Simpson's dominance index (D)	0.014	0.009	0.006
C	**Chrysophyceae**			
1	Total abundance (N)	41	49	66
2	Number of species (S)	5	4	5
3	Margalef's index (d)	1.07	0.77	0.954
4	Shannon-Wiener index (H)	0.53	1.64	1.767
5	Simpson's dominance index (D)	0.012	0.0051	0.0046
D	**Xanthophyceae**			
1	Total abundance (N)	31	25	40
2	Number of species (S)	55	4	5
3	Margalef's index (d)	1.16	0.93	1.08
4	Shannon-Wiener index (H)	1.68	1.59	1.76
5	Simpson's dominance index (D)	0.014	0.012	0.007
E	**Euglenophyceae**			
1	Total abundance (N)	55	49	68
2	Number of species (S)	7	6	6
3	Margalef's index (d)	1.50	1.28	1.18
4	Shannon-Wiener index (H)	1.63	1.59	1.76
5	Simpson's dominance index (D)	0.014	0.012	0.007
F	**Charophyceae**			
1	Total abundance (N)	24	31	32
2	Number of species (S)	2	2	2
3	Margalef's index (d)	0.314	0.290	0.290
4	Shannon-Wiener index (H)	1.36	1.47	1.49
5	Simpson's dominance index (D)	0.004	0.002	0.002

Margalef's index

The Margalef's indices for the Bacillariophyceae was 1.69 in pond 1. with 2.006 in pond 2 and 2.06 in pond 3, while for the Chlorophyceae. Margalef's index had a value of 1.70 in pond 11 with a value of 1.78 in pond 2 and 1.53 in pond 3. For the Chrysophyceae, Margalef's index was 1.07 in pond 1, with a value of 0.77 in pond 2 and 0.954 in pond 3. For the Xanthophyceae, Margalef's index was 1.16 in pond, with a value of 0.93 in pond 2 and 1.08 in pond 3. Euglenophyceae had Margalef's index of 1.50 in pond, with 1.28 in pond 2 and 1.18 in pond 3.In pond 1, Margalef's index of 0.314 was obtained for the Charophyceae, with a value of 0.290 in ponds 2 and 3, respectively.

Shannon-Wiener index

For the Bacillariophyceae, Shannon-Wiener indexwas 1.98 in pond 1, with 2.09 in pond 2 and 2.25 in pond 3; for the Chlorophyceae, Shannon-Weiner index was 1.68 in pond 1, with 1.86 in pond 2 and 1.91 in pond 3, Xanthophyceae had Shannon-Wiener index of 1.66 in pond 1. with a value of 1.59 in pond 2 and 1.76 in pond 3.

Simpson's dominance index (D)

For the Bacillariophyceae, Simpson's dominance index was 0.0055 in pond 1, with a value of 0.0051 in pond 2 and 0.0031 in pond 3.For the Chlorophyceae, Simpson's dominance index was 0.014 in pond 1, 0.009 in pond 2 and 0.006 in pond 3 (Table 3), and for the ChrysophyceaeSimpson's dominance index 0.012 in pond 1, 0.0051 in pond 2 and 0.0046 in pond 3 and for Xanthophyceae, Simpson's dominance index had a value of 0.014 in pond 1, with a value of 0.012 in pond 2 and 0.07 in pond 3. Simpson's dominance of 0.014 was obtained for the Euglenophyceae in pond 1. with a value of 0.012 in pond 2 and 0.007 in pond 3, while for the Charophyceae, Simpson's dominance index of 0.004 was obtained in pond with a value of 0.002 each in pond 2 and 3.

Discussion

From the results of the study, six major phytoplankton families namely: Bacillariophyceae, Chlorophyceae, Chrysophyceae, Xanthophyceae, Euglenophycee and Charophyceaewere observed to inhabit the surface water of the ponds, with the Bacillariophyceae being the most abundant and diverse. According to Offem*et al.* (2011), the abundance of Bacillariophyceae(Diatoms) in fish ponds without forming blooms interplayed with the diversity of the diatomic species are an indication of ecological stability and productive nature of the pond in particular and aquatic systems in general. The results of the present study are also in line with those Dikel*et al.* (2005) who, when studying the potential of phytoplankton-based culture of Tilapia (*Oreochronusoreochromis* in floating cages in Seyham Dam Lake Turkey, reported that the diatoms were the most abundant and diverse phyto-groups in the lake without blooming. In any aquatic ecosystem, whether lentic or lotic, phytoplankton are the foundation of the classic food web (Ekwu and Sikoki, 2006, Ekeh and Sikoki, 2004; Job, 2019).

The phytoplankton population in a pond is usually comprised of numerous species of microscopic plants that live in a horizontal band near the water surface (Conte and Cubbage, 2001). Little wonder then for the premise for the diverse groups families and species of phytoplankton recorded in the ponds.The result of the present study are however in deviant with works of Treasurer and Grant (1999), who reported the occurrence of phytoplankton blooms in Mill Port University ponds and attribute it to nutrient inputs.

The ranges of the ecological indices (Margalef's indices, Shannon-Wiener index and Simpson's index) were additional supporting information on the ecological stability of the ponds. Margalef's index higher, than 1. signifies an unpolluted ecosystem. The high Margalef's indices recorded throughout the period of study in all ponds for every other phytoplankton families except for Charophyceae are in agreement with those of Ali *et al.* (2003) and Spitam*et al.* (2000) who respectively reported that Margalef's index greater than 1, interplayed higher Shannon-Wiener index and lower Simpson's index are all indicators of ecologically stable system especially in lentic systems like Onesky fish ponds.

Conclusion

A study was conducted on phytoplankton distribution, abundance and diversity in selected ponds in Onesky Fish Farm, Calabar, Nigeria. Samples were collected by filtering 20 litres of the surface water through a-64μm bolting plankton net and stored in 50mls plastic sample bottles preserved with 10% buffered formaldehyde solution prior to laboratory analysis.

Results revealed that the ponds were inhabited by six major phytoplankton families namely: Bacillariophyceae. Chlorophyceae. Chrysophyceae, Xanthophyceae, Euglenophyceae and Charophyceae. The Margalef's index for the Bacilariophyceae was 1.69 in pond 1. with 2.006 in pond 2 and 2.06 in pond 3. while for the Chlorophyceae. Margalef's index was 1.70 in pod 11 with a value of 1.78 in pond 2 and 1.53 in pond 3. For the Chrysophyceae, Margalef's index was 1.07 in pond 1, with a value of 0.77 in pond 2 and 0.954 in pond 3. For the Xanthophyceae, Margalef's index was 1.16 in pond 1. with a value of 0.93 in pond 2 and 1.08 in pond 3. Euglenophyceae had Margalef's index of 1.50 in pond 1. with 1.28 in pond 2 and 1.18 in ponds while in pond 1. Margalef's index of 0.314 pond 3 while in pond 1. Margalef's index of 0.314 was obtained in pond 1 with 0.290 in pond 2 and 3, respectively.

For the Bacillariophyceae, Shannon-Wiener indices stood at 1.98 in pond 1, with a value of 2.09 in pond 2 and 2.25 in pond 3.For the Chlorophyceae, Shannon-Wiener index was 1.68 in pond 1, with 1.86 in pond 2 and 1.912 in pond 3. Xanthophyceae had Shannon-Wiener index was 1.68 in pond 1, with a value of 1.59 in pond 2 and 1.76 in pond 3.

For the Bacillariophyceae, Simpson's dominance index was 0.055 in pond 1, with a value of 0.0051 in pond 2 and 0.0031 in pond 3; for the Chrysophyceae,Simpson's dominance index was 0.012 in pond 1, 0.0051 in pond 2 and 0.0046 in pond 3 (Table 4), and for the Xanthophyceae, Simpson's dominance index was 0.014 in pond 1, with a value of 0.012 in pond 2 and 0.007 in pond 3. Simpson's dominance of 0.014 was obtained for the Euglenophyceae in pond 1, with a value of 0.012 in pond 2 and 0.007 in pond 3, while for the Charophyceae, Simpson's dominance index of 0.004 was obtained in pond 1, with a value of 0.002 in ponds 2 and 3, respectively. The pond understudied were observed to be ecologically stable for enhance aquaculture practices.

Recommendation

This study recommends further studies on phytoplankton abundance, distribution and diversity on a seasonal basis to enable the discernment of the primary productivity in the pond ecosystem since the period of this study was very short and wouldn't provide the necessary spectra of phytoplankton in the pond ecosystem generally.

References

1. *Ada. F. B. & Job, B.E. (2018). Impact of human activities on the distribution, abundance and diversity of Phytoplankton in the Calabar River System, Cross River State Nigeria. Journal of Marine Science Research and Oceanography, 1(1): 1-7.*
2. *Adeogun, O. A., Fafioye, O. O., Olaleye, B. A. and Ngobili, G. O. (2005). The relationship between some physicochemical parameters and plankton in ponds. In: The 19th Annual Conference of the Fisheries Society of Nigeria (FISON), Ilorin, Nigeria.*
3. *Akin-Oriola, G.A. (2003). On the phytoplankton of Awba Reservor Ibadan, Nigeria. Reviewof Tropical Biology, 1(1):231-241.*
4. *Alan, A. M., Khan. B.A &Rizri. S. (2000), Seasonal changes in physic- chemical parameters of River Chenab, Muzaffar GARTH, Purjab. Pakistan Journal of Biological Sciences 4:299-301.*
5. *Ali, M., Salam, A. Jamshaid, S. & Zahra, T. (2003) Studies on the biodiversity in relation to seasonal vitiations in water of River Indus at GhasiGhatt, Punjab, Pakistan. Pakistan Journal of Biological Sciences, 6(2): 1840-1844.*
6. *Asha, M. S. (2015). Effect of water quality on phytoplankton abundance in selected ponds of Nedumangad Block, Panchayat, Kerala. Emer Life Science Research, 1(2): 35-44.*
7. *Castro, P. & Huber, M.E. (2005) Marine Biology (5 edition), McGraw-Hill Higher Education, 452p.*
8. *Chowdhury, M. M. R., Shahjahan, M., Rahman, M. S. and Sadiqul, I. M. (2008). Duckweed (Lemna minor) as supplementary feed in monoculture of Nile tilapia, Oreochromis niloticus.Journal of Fisheries and Aquatic Sciences, 3, 54-59.*
9. *Chukwu, M. N. and Afolabi, E. S. (2017). Phytoplankton abundance and distribution of fish Earthen pond in Lagos, Nigeria. Journal of Applied Science and Environmental Management, 21(7): 1245-1249.*
10. *Conte. F. S. &Cubbage. J. S. (2001). Phytoplankton and recreation ponds. Western Regional Aquaculture Center Alaska WRAC. 105-1-5.*
11. *Davies, O. A., Abowei, L.F.N. &Otere. B.B. (2009) Seasonal abundance and distribution of plankton of Minichinda stream, Niger Delta, Nigeria. American Journal of Scientific Research, 2:20-30.*

12. *Dhaman, S.A. Sathya. A. & Elayara J. (2016) Study of physico-chemical parameters and phytoplankton diversity of Ouster Lake in Puducherry, World Scientific News, 13, 15-21 pp.*
13. *Dikel, S., Kiris, G.A &Alev.M. V. (2005). The potential of phytoplankton based culture of Tilapia (Oreochromisniloticus) in floating cages in Operational Research, BACOR. 05 Constanta, 1-7.*
14. *Dimowo, B. O. (2013). Monthly spatial occurrence of phytoplankton and zooplankton in River Ogun, Abeokuta, Ogun State, South West Nigeria. International Journal of Fisheries and Aquaculture, 5(8):193-203.*
15. *Ekanem, A.P. Job, B.E. &Essien, A.E. (2018). Influence of some physic-chemical parameters on the spatio-temporal abundance and diversity of phytoplankton in the Great Kwa River, South-East Nigeria. European Academic Research, 6(4):1774- 1795.*
16. *Ekeh. 1. B. &Sikoki, F.D. (2004). Diversity and spatial distribution of phytpoplankton in New Calabar River, Nigeria. Living systems and Sustainable Development, 1(3): 25-31.*
17. *Ekpenyong. E. (2006). Effect of limiting and fertization on phytoplankton distribution and primary production of tropical earthen ponds. International Journal of Natural and Applied Sciences.*
18. *Ekwu, A.O. &Sikoki, F.D. (2006) Phytoplankton diversity in the Cross River Estuary of Nigeria. Journal of applied science and Environmental Management, 10 (1): 89-95.*
19. *G.M., Sallam. A., Jamshaid, S. &Zahara, T. (2003) Studies on the Biodiversity in relation to seasonal variations in water of River Indus at GhasiGhatt. Punjab, Pakistan. Pakistan Journal of Biological Science, 6 (2): 1840-1844.*
20. *Hassain, M. Y., Jasmine, S., Ibrahim, A. H., Ahmed, Z. F., Obtomi, J. and Fulanda, B. (2007). A preliminary observation on water quality and plankton of an earthen fish pond in Bangladesh: Recommendations for Future Studies. Pakistan journal of Biological Sciences, 10: 868-873.*
21. *Hulyal, S.B. &Kaliwal, B.B (2009). Dynamics of phytoplankton in relation to physical chemical factors of Almatti Reservoir of District. Kamataka State. EnvironmentalMonitoringAssessment, 153:45-49.*
22. *Ikpi, G. U., Offem, B. O. and Okey, I. B. (2013). Plankton distribution and diversity in tropical earthen fish pond. Environment and Natural Resources Research, 3(3): 45-51.*
23. *Job, B. E., Ekenyong. E. & Bassey, N.U. (2011). Occurrence distribution and diversity of microflora in the intertidal mindificats and sambars of the Cross River Estuary. Nigeria. Global Journal of Pure and Applied Science, 17(3):255-260.*
24. *Job. B. E. (2019). Assessment of phytoplankton species composition, abndance and diversity within the Itu bridge-end area of the lower Cross River State, Nigeria. International Journal of Fisheries and Aquatic Studies, 7(4):398-405.*

25. *Mann. K. H. (2000). Ecology of coastal waters with implication for management (2nd edition) Blackwell science incorporated. Massachusetts, USA. 406p.*
26. *Needham. J.G. & Needham. P.R. (1974). A guide to the study of freshwater biology 2 edition. San Francisco, Holden Day Incorporated, 468p.*
27. *Odum, E.P. (1971). Fundamental of Ecology, W.B. Saunders, Philadelphia 202p.*
28. *Offem, B.D, Ayotunde. E.O., Ikpi. G. U. Ocange, SN & Ada, F.B. (2011). Influence of seasons on water quality, abundance of fish and plankton species of Ikwori Lake. South Eastern Nigeria. Fisheries and Aquaculture Journal, PAJ-13.*
29. *Ogbeibu, A.E. (2005). Biostatistics A practical Approach to Research and Data handling. Mine publishing company Limited Benin City, Nigeria, 264p.*
30. *Onyema, 1.C &Ojo A.A. (2008). The zooplankton and phytoplankton biomass in a tropical Greek, in relation to water quality indices. Life Science Journal, 5(4):75-82.*
31. *Owens, N.J. P., Hosie, G. W., Batten, S. D., Edwads, M. Johns, D.H. & Gregory. B. (2013). All plankton sampling systems underestimate abundance: Response to "continuous plankton recorder underestimates zooplankton abundance. Journal of Marine Systems, 128, 240-242.*
32. *Parsons. T.R., Takahashi, M. &Hargrave, B. (1984). Biological Oceanographic Processes.Third edition, Perganum Press. Toronto, 330p.*
33. *Patrick. R. & Reiner, C. (1966). The diatoms of the United States, Alaska and Hawaii. Fragillariaceae, Achanthaceae and Naviculaceae.*
34. *Pielou, E. C. (1966). The measurement of diversity in different types of biological collection. Journal of Theoretical Science, 13:131-144.*
35. *Pielou, E. C. (1984). The interpretation of ecological data u premier on classification and coordination. John Wiley and Sons. New York, 263p.*
36. *Rahman, M. M., Parvez, Md. S., Bhuiyan, K. A. and Rahman, M. (2018). Phytoplankton community structure of commercial earthen aquaculture ponds. International Journal of Fisheries and Aquatic Research, 3(4): 31-34.*
37. *Roy, K. (2014). Ecological dynamics and hydrobiological correlations in freshwater ponds. Recent researches and application. International Journal of Environmental and Biological and Universal Research Publications, 4(2): 112-118.*
38. *Siddiku, F. (2012). Abundance of plankton population densities in relation to bottom soil textural types in agriculture, pondsint. Journal of Agricultural Research and Innovations and Technology, 291): 56-61.*