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Phytoplankton community dynamics and its impacts on the quality of water and sediments in the recirculated-water earthen pond system for hybrid red tilapia (*Oreochromis niloticus* x *mossambicus*) farming

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Abstract This study was conducted to determine the correlation between phytoplankton communities and the quality of water and sediments in the recirculated water earthen pond system for hybrid red tilapia farming. The water was recirculated from another earthen pond used for Pacific white shrimp (*Litopenaeus vannamei*) farming. The results showed that 35 phytoplankton taxa were identified in water at different growth phases of hybrid red tilapia. The key factors influencing the quantity of phytoplankton were salinity and temperature during water recirculation. The freshwater diatom, *Thalassiosira* sp. was the most abundant phytoplankton. The variety of phytoplankton was highly dependent upon the phosphorus and nitrogen contents in water and on all soil quality indicators.

Keywords: Phytoplankton, Water quality, Soil quality, Fish farming, Hybrid red tilapia

Introduction

Phytoplanktons are important microorganisms that serve as primary producers in aquatic ecosystems (Anetekhai *et al.*, 2018; Cunha *et al.*, 2019). Phytoplanktons can also be classified as microalgae and plant-like autotrophic organisms. The phytoplankton community composition in relation to water-body is mainly controlled by environmental conditions (George *et al.*, 2012). Phytoplanktons are being used as biological indicators because of their short generation time and phytoplanktons respond quickly to changes in their environment (Manickam *et al.*, 2020; Siddika *et al.*, 2012). It is known that phytoplanktons are indicators of water quality as they are used to determine the

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quality and the quantity of nutrition load in the water, which affects the growth of aquatic organisms and the productivity of the system (Ikpi *et al.*, 2013). In addition, phytoplankton can reduce carbon dioxide by binding carbon in their cells and produce dissolved oxygen which maintains the lives of aquatic animals within the aquaculture ponds thereby affecting the structure of the aquaculture systems (Rapatsa and Moyo, 2013).

The factors affecting water quality for aquatic animals consist mainly of environmental factors such as solubility of gases and solids, turbidity, temperature and density. Chemical factors such as salinity, pH, water hardness, phosphate and nitrate levels are very important to the growth and density of phytoplanktons (Roy, 2014; 2017). Stocking desity is a dependent variable of all these biotic and abiotic factors which is mainly driven by thermodynamics of water body.

The abiotic factors such as day light intensity, temperature and water chemistry must be well evaluated according to the required concentration and composition in the pond. These elements are among the many that have direct impact on nutrient concentration in the pond environment on initial production. These factors are required to be optimized to increase animal stock density where phytoplankton quality and quantitiy play a vital role. In order to achieve maximum cultivation efficiency and get the highest level of prduction, it is necessary to maintain the nutrients in the pond at appropriate levels throughout the culture (Bhakta *et al.*, 2015; Dauda *et al.*, 2019). Adequate quality and abundant quantity of phytoplankton are indicators of desired water status within that water source (Chowdhury *et al.*, 2008), therefore, a study and thorough knowledge of the growth and abundance of phytoplankton, the quality of water during the growth period and other related factors regarding the environment are essential for fish production. The relative quantities of phytoplankton populations can show the biological integrity of the water source as they are the main food source for zooplanktons and in turn to fish in ponds (El-Naggar *et al.*, 2019; Mo *et al.*, 2014).

The abundance of plankton in aquaculture ponds, both in quality and quantity, are very important for the successful management of aquaculture ponds because each pond in each area is different, although they have similar ecosystems (Boyd, 1982; Boyd, 1990). Phytoplankton communities fluctuate depending on the water and bottom soil conditions which are affected by seasonal changes. The water quality contributes to the most suitable type of environment for aquaculture (Espinal and Matulić, 2019; Sebastián-González *et al.*, 2012).

This study aimed to determine the effect of water and soil quality parameters for phytoplankton abundance and distribution, focusing on the measurement of physicochemical properties of water and sediment soil in hybrid red tilapia cage cultures in earthen ponds with circulated water with shrimp ponds.

Materials and Methods

Pond management

This research was carried out in a fish farm at Chachoengsao Province, Thailand (13°38'21.56"N and 101°6'40.26"E). The ponds studied were 3m deep with a surface area of 1600 m^2. Their sources of water are the recirculated water from shrimp ponds, other fish ponds, groundwater and run-off water during rainy periods. During the rainy season (March to September) the water exchange between upstream and downstream ponds is continuous, with a water renewal rate of 1% of the pond volume per day. The fishes, hybrid red tilapia (*Oreochromis niloticus* x *mossambicus*), used in this study were obtained from local suppliers. All fingerlings of hybrid red tilapia were cultured until they achieved a weight averaging 50.43 ± 3.12 g (mean ± SD). The fishes were fed with commercial aquafeed containing 25% protein, 3% lipid, 8% fiber with 12% moisture content.

Water quality

On-farm measurements of dissolved oxygen (DO), pH and temperature weredone in the afternoon (12.00 pm to 15.00 pm) at the water surface using a YSI oxygen meter (Multi-Probe PRO20, YSI Inc.). The water transparency was measured with a Secchi disk. Salinity was monitored at three points around the pond using a refractometer. Water was collected at around 15cm below the surface of the pond to be analyzed for total alkalinity, total hardness, nitrites, nitrates, ammonia, total nitrogen, total phosphorus, filterable phosphorus, orthophosphate, chlorophyll a and total suspended solids following standard methods (APHA *et al.*, 1995).

Bottom soil quality

Bottom soils were sampled monthly during the crop in the early afternoon. Pond-bottom soil samples were taken at three sites near the cags and three sites far from the net cages. Samples were taken using an Ekman Grab. The analysis of soil texture was undertaken using a hydrometer (Weber, 1997). Redox (Eh) was monitored using a YSI Redox probe (model Multi Probe PRO20, YSI Inc.). Soil pH was determine using the method described by

Thunjai *et al.* (2004). Bulk density analysis was carried out using the procedure described by Blake and Hartge (1986). Organic carbon was analyzed using the Walkley-Black method (Nelson and Sommer, 1982). Total nitrogen was analyzed using the Kjeldahl method modified form Bremner and Mulvaney (1982) and Sáez-Plaza *et al.* (2013). Total phosphorus was calculated following sequential extraction with $HClO_4$ (Olsen and Sommers, 1982).

Phytoplankton

On-farm phytoplankton samples were taken at 15 cm below the water surface. Phytoplankton specimens were collected by filtration of 50 L water using a 20-micrometer plankton net. The phytoplankton samples were collected and fixed in 4% formalin for further analysis in the laboratory. Cell density calculation was performed according to the method used in Hoppenrath *et al.* (2009).

Data process

Environmental factors (water and bottom soil quality) were reported as mean ± standard division. 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 Part version 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).

Results

The physical and chemical parameters with regards to water quality and bottom soil were obtained from earthen ponds grown with hybrid red tilapia cultured in cages at two-month intervals (March, May, July and September). The resuts are shown in Table 1. The pond water which contained a relatively higher salinity was recorded in May.

A total of 35 phytoplankton species were obtained from different periods (every 2 months over the course of 7 months) of hybrid red tilapia growth in an earthen pond (Table 2). The population size of phytoplankton during the hybrid tilapia growth at different periods ranged from 0.01-59.44 $x10^3$ $cell.L^{-1}$. The phytoplankton with the largest population was *Thalassiosira* sp., which occured in July.

Table 1. Water and bottom soil qualities in hybrid red tilapia earthen pond

Parameter	**Code**	**Mean environment score at each point in 2016**			
		March	May	July	September
Water quality					
Temperature (^{o}C)	WT	33.13±0.06	30.23±0.64	32.30±0.10	32.27±0.06
Salinity (ng.L^{-1})	WS	0.00±0.00	5.00±0.00	3.00±0.00	2.00±0.00
Transparency (cm)	WTR	40.00±0.00	40.00±0.00	35.00±0.00	40.00±0.00
Total Suspended Solid (mg.L^{-1})	WTSS	107.67±4.51	110.00±4.00	75.00±5.57	39.00±5.57
Dissolved oxygen (mg.L^{-1})	WO	3.65±0.17	4.53±0.75	9.37±0.64	5.48±0.16
pH	WpH	7.07±0.06	6.53±0.15	6.7±0.03	6.12±0.05
Alkalinity (mg.L^{-1} of CaCO$_3$)	WA	56.00±6.08	121.00±2.00	25.33±0.58	80.00±10.00
Hardness (mg.L^{-1} of CaCO$_3$)	WH	322.67±7.77	1064.67±7.51	827.33±7.57	396.67±11.55
Orthophosphate (mg.L^{-1})	WOP	0.06±0.01	0.94±0.03	1.05±0.01	1.669±0.00
Filterable phosphate (mg.L^{-1})	WEP	0.09±0.00	0.89±0.01	1.26±0.02	2.62±0.10
Total phosphorus (mg.L^{-1})	WTP	0.16±0.00	1.73±0.28	2.26±0.02	4.72±0.00
Nitrate (mg.L^{-1})	WNO3	0.05±0.00	0.05±0.00	0.17±0.01	0.45±0.02
Nitrite (mg.L^{-1})	WNO2	0.01±0.00	0.03±0.00	0.17±0.00	0.27±0.00
Ammonia (mg.L^{-1})	WNH3	0.26±0.03	0.25±0.01	0.25±0.00	0.38±0.05
Total nitrogen (mg.L^{-1})	WTN	0.41±0.02	0.48±0.01	4.19±0.05	4.96±0.04
Chlorophyll a (mg.cubic m^{-1})	WCH	32.16±5.53	365.96±83.46	365.96±26.70	78.32±9.38
Soil quality					
pH	SpH	6.83±0.10	5.41±0.26	5.96±0.37	5.70±0.41
Organic matter (%)	SOM	4.07±0.33	4.10±0.39	5.91±0.52	6.28±0.57
Bulk density (g.cm^{-3})	SBD	0.55±0.10	0.37±0.05	0.37±0.03	0.34±0.03
High sediment (cm)	SHS	8.57±0.55	10.29±2.45	15.33±1.86	16.52±1.48
Total nitrogen (%)	STN	0.21±0.02	0.24±0.04	0.34±0.03	0.42±0.08
Total phosphorus (%)	STP	0.18±0.01	0.17±0.02	0.25±0.06	0.29±0.07

Table 2. Species composition and abundance of phytoplankton

Taxon	**Code**	**Abundance (x10^3 cell.L^{-1})**			
		March	May	July	September
Microcystis aeruginosa	Mae	0.07	0.05	nf	nf
Oscillatoria sp.	Ossp	0.37	0.48	0.42	0.16
Anabaena sp.	Ansp	nf	0.03	0.09	nf
Tetraedron gracile	Tgr	0.13	nf	nf	nf
Tetraedron trigonum	Ttr	0.11	nf	nf	nf
Monoraphidium sp.	Msp	0.09	nf	nf	nf
Oocystis parva	Opa	1.45	nf	nf	nf
Micratinium sp.	Misp	0.81	nf	nf	nf
Dictyosphaerium pulchellum	Dpu	1.95	nf	nf	nf
Actinastrum sp.	Acsp	0.27	0.35	nf	nf
Coelastrum sp.	Coesp	1.31	0.07	nf	nf
Crucigenia sp.	Crsp	1.1	0.23	nf	nf
Scenedesmus acuminatus	Sam	1.18	0.19	nf	nf
Scenedesmus acutus	Sac	0.03	0.03	nf	nf
Scenedesmus quadricauda	Squ	1.31	0.42	0.01	nf
Scenedesmus sp.	Scsp	0.92	0.09	nf	nf
Pediastrum duplex	Pdu	3.08	0.58	nf	nf
Pediastrum simplex	Psi	4.24	0.57	nf	nf
Cosmarium sp.	Cosp	0.02	nf	nf	nf
Staurastrum sp.	Stsp	1.63	nf	nf	nf
Euglena sp.	Eusp	nf	12.69	0.02	19.9
Lepocinclis salina	Lsa	nf	0.09	nf	nf
Phacus hamatus	Pha	0.18	0.08	nf	nf
Phacus tortus	Pto	nf	0.13	nf	nf
Trachelomonas crebea	Tcr	nf	nf	0.05	nf
Trachelomonas volvocina	Tvo	nf	0.19	0.14	0.11
Thalassiosira sp.	Thsp	nf	4.95	59.44	0.01
Aulacoseira granulata	Agr	6.79	nf	nf	nf
Synedra sp.	Sysp	1.33	nf	nf	nf
Gyrosigma sp.	Gysp	0.01	nf	0.01	nf
Navicula sp.	Nasp	2.4	0.02	0.05	0.01
Nitzschia sp.	Nisp	nf	nf	0.05	nf
Surirella sp.	Susp	0.09	nf	nf	nf
Peridinium sp.	Pesp	nf	nf	0.08	4.27

nf = not found

The phytoplankton communities within the hybrid red tilapia cage culture in the earthen pond were evaluated based on the species composition and abundance data. Phytoplankton of each hybrid red tilapia cage culture period was recorded and used for numerical analysis using the Shannon diversity index (H'), Evenness (J) and the Simpson index. These parameters varied depending on the period of culture (Table 3). The highest in the diversity index, evenness and Simpson index of phytoplankton community was found in March.

Table 3. Shannon diversity index, Evenness and Simpson index for phytoplankton communities in each period

Indices	**Score of indices in each period**			
	March	May	July	September
Shannon	2.584	1.364	0.108	0.33
Evenness	0.530	0.206	0.086	0.284
Simpson	0.900	0.586	0.031	0.307

Table 4. Pearson correlation coefficient between phytoplankton and environmental factors from cage culture in earthen pond

Parameter	**Pearson correlation coefficient with phytoplankton**	
	Kind	Quantity
Water quality		
Temperature (^{o}C)	-0.309	0.445*
Salinity (ng.L^{-1})	-0.030	-0.464*
Transparency (cm)	0.228	0.073
Total Suspended Solid (mg.L^{-1})	0.461*	-0.185
Dissolved oxygen (mg.L^{-1})	-0.452*	0.229
pH	0.471*	0.291
Alkalinity (mg.L^{-1} of CaCO$_3$)	0.361	-0.206
Hardness (mg.L^{-1} of CaCO$_3$)	0.064	-0.277
Orthophosphate (mg.L^{-1})	-0.753**	0.082
Filterable phosphate (mg.L^{-1})	-0.768**	0.047
Total phosphorus (mg.L^{-1})	-0.788**	0.080
Nitrate (mg.L^{-1})	-0.831**	0.344
Nitrite (mg.L^{-1})	-0.805**	0.154
Ammonia (mg.L^{-1})	-0.712**	0.061
Total nitrogen (mg.L^{-1})	-0.768**	0.125
Chlorophyll a (mg.cubic m^{-1})	-0.039	0.184
Bottom soil quality		
pH	0.622**	0.163
Organic matter (%)	-0.718**	0.143
Bulk density (g.cm^{-3}(	0.684**	0.051
High sediment (cm)	-0.666**	-0.082
Total nitrogen (%)	-0.706**	0.024
Total phosphorus (%)	-0.718**	0.035

* Correlation is significant at $p \leq 0.05$

** Correlation is significant at $p \leq 0.01$

Correlation analyses were performed on the basis of water and bottom soil qualities (Table 1), which allowed us to identify the main factors that determine the kind and quantity of phytoplankton in earthen ponds cultured with hybrid red tilapia. The Pearson correlation coefficient is shown in Table 4. The kind of phytoplankton is positively correlated with pH and total dissolved solid ($p \leq 0.05$). A positive correlation was marked for the kind of phytoplankton and soil pH and bottom soil bulk density ($p \leq 0.05$). The kinds of phytoplankton were significantly and negatively correlated with dissolved oxygen in water ($p \leq 0.05$), phosphorus and nitrogen in the water and bottom soil ($p \leq 0.01$). The organic matter in soil and high sediment was negatively correlated with the kind of phytoplankton ($p \leq 0.01$). The quantity of phytoplankton was positively correlated with water temperature ($P \leq 0.05$). The Pearson correlation coefficient shows that the quantity of phytoplankton was that negatively correlated with water salinity ($p \leq 0.05$).

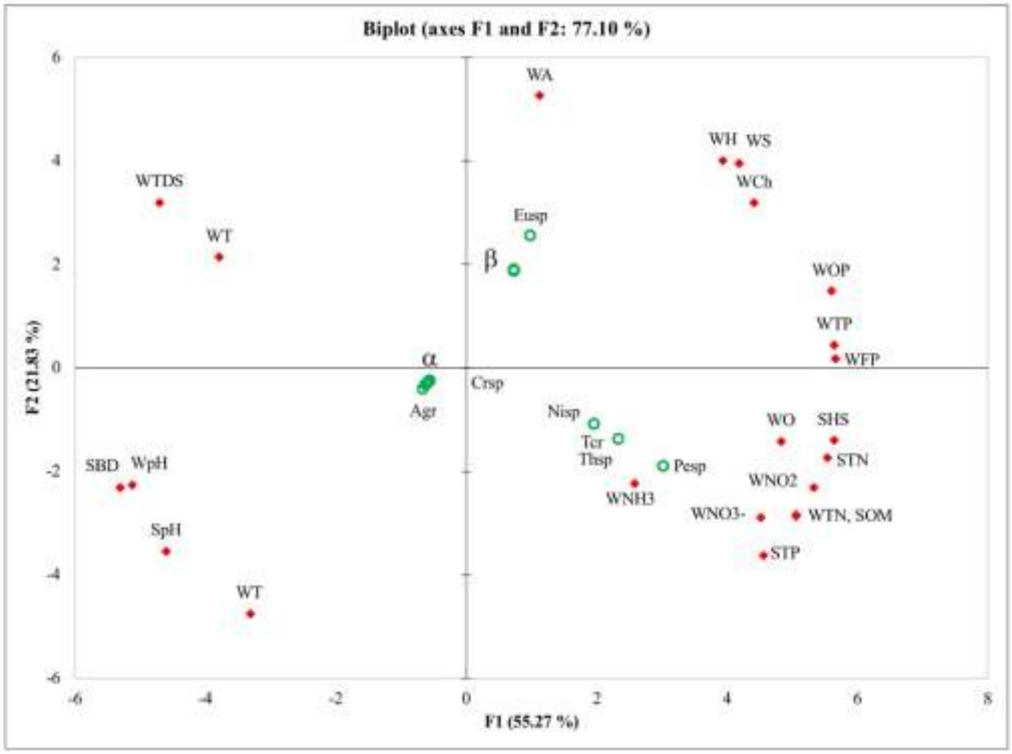

Figure 1. Principal component analysis of the phytoplankton, water and bottom soil quality obtained from hybrid red tilapia cage cultures in earthen pond. The alpha (α) consist of Ttr, Tgr, Sac, Sam, Dpu, Squ, Msp, Cosp, Coesp, Misp, Stsp, Susp, Gysp, Sysp, Nasp, Psi, Pdu, Pha, Scsp, Opa, Nasp and Mae. The beta (β) consist of Tvo, Ossp, Lsa, Pto and Acsp

The phytoplankton community structure from hybrid red tilapia cage cultures in the earthen pond was also viewed two-dimensionally using principal component analysis (Figure 1). The overall variance of data plots based on the abundance of phytoplankton community and influenced on the water and bottom soil quality factors were depicted in the percent variance of axes F1 and

F2. The percent variances ranged depending on the environmental factor, where F1 (55.27%) and F2 (21.83%) were found in the phytoplankton. *Nitzschia* sp., *Trachelomonas crebea, Thalassiosira* sp. and *Peridinium* sp. were closely related to water quality (consists of ammonia, nitrate, nitrite, total nitrogen and orthophosphate) and soil quality (consisting of total nitrogen, total phosphorus, high sediment and organic matter) in the surface of cage culture using a water circulation system between shrimp ponds and fish ponds in this farm.

Discussion

Water and soil quality play an important role in phytoplankton productivity as well as in the biology of the cultured organisms and final yields (Abou *et al*., 2012; Hossain *et al*., 2007; Singh *et al*., 2016). The phytoplankton community is comprised of the primary producers (Battish, 1992; Ni *et al*., 2018). Water quality determines the phytoplankton species under different environments (Hossain *et al*., 2007; Sipauba-Tavares *et al*., 2011). This study showed the difference that physicochemical factors make in determining the number and kind of phytoplankton in hybrid red tilapia cage culture in an earthen pond at Chachoengsao, Thailand. During the study, variations in water temperature exhibit differences in each observed time. The observed temperatures were within the ranges (30.23±0.64 to 33.13±0.06) in the ponds. Such temperatures are within the optimal ranges for plankton growth (18.3-37.8 ℃) (Bagchi and Jha, 2011) and are recommended for fish culture (26.06-31.97 ℃) (Boyd, 1982) in tropical ponds. Temperature is an important independent factor which can affect phytoplanktons. The temperature represents a key factor for the metabolic processes of aquatic organisms and can also be regarded as a biologically significant factor (Boyd and Tucker, 1998; Sun *et al*., 2011a) since it can alter the main thermodynamics of culture environment.

In the present study, the salinity of the samples was higher in May (5.00 $ng.L^{-1}$) because the farmer channeled water from the shrimp ponds instead of using groundwater. Phytoplanktonic organisms instead experience a gradual increase in salinity, alkalinity and hardness during mixing of freshwater and effluent from the shrimp ponds. In this study, *Euglena* sp., *Trachelomonas volvocina* and *Thalassiosira* sp. increased in cell abundance after water from the shrimp pond was introduced into freshwater. Euglenoids can be found in aquaculture systems of freshwater fish rich in organic matter (Borowitzka, 2018; Zimba *et al*., 2017). Euglenophyceae bloom is one of the most common problems and phenomena in warmer shallow ponds (Rahman *et al*., 2007). Furthermore, Nwankwo (1995) reported that, euglenoid species bloom with high water temperature and more nutrients. When, the Euglenophyceae (*Euglena* sp., *T. volvocina* and *Thalassiosira* sp.) bloomed in the ponds in this study, the water temperature was over 30 ℃ which is quite similar to the findings of Rahman *et al.* (2007). In this study, heavy bloom was found to happen when the pH was between 6.12-6.70. This supports the findings by Olaveson and Nalewajko (2000) that *Euglena* spp. were growing optimally at pH 2.5 to 7.0. Furthermore, Rahman *et al*. (2007) reported that pH of around 6.0 is the most conducive condition which contributes to the heavy bloom of euglenophytes. In table 4, it can be seen that the phytoplankton was not significantly correlated with chlorophyll a in water because *Euglena* spp. and *Thalassiosira* spp. are found in large quantities. In *Euglena*, the apparent color of photosynthetic pigments can be changed from green (chlorophyll) to red (carotenoid). The euglenophyte *Euglena* chlorophyll synthesis depends on light utilization efficiency (Aitor *et al*., 2019; Johnson and Jahn, 1942). Meanwhile, yellow or xanthophyll (fucoxanthin*)* is a natural pigment found in *Thalassiosira* spp. (Kuczynska *et al*., 2015)

High salinity in ponds, especially with input water from the shrimp ponds during culture, delivered the increase in phytoplankton cell abundance for the family Eugleanaceae viz. *Euglena* sp., *Lepocinclis salina*, *Phacus tortus*, and *Trachelomonas* spp., while there was an abatement in the abundance of families of Chlorococaceae (*Trtraedron gracile*, *T. trigonum*), Oocystaceae (*Monoraphidium* sp., *Oocystis parva*), Micractiniaceae (*Micratinium* sp.), Dictyosphaeriaceae (*Dictyosphaerium pulchellum*) and decreased cell abundance for the Scenedesmaceae (Table 2) family. The quantity of phytoplankton was negatively correlated with salinity in water (Table 4). Changes in salinity may directly and indirectly influence plankton abundance, according to Perumal *et al.* (1999) who reported that salinity fluctuations may contribute to food shortage, thus affecting plankton abundance (Perumal *et al.*, 1999; Sun *et al.*, 2011b). Halophile species of plankton in freshwater such as *Diatoma vulgare*, *Cocconeis placentula*, *Navicula oblonga*, *N. placentula*, are salt-tolerant with a broad adaptation to salinity (Afonina and Tashlykova, 2018).

Thus, nitrogen and phosphorus compounds inspection affect the kind of autotrophic organism but do not affect the amount of phytoplankton (Table 4). Meanwhile, nitrogen and phosphorus compounds in water are the most important and most readily available for phytoplankton (Reed *et al.*, 2016; Rivera *et al.*, 2018). Principal component analysis showed that *Nitzschia* sp., *T. crebea, Thalassiosira* sp. and *Peridinium* sp. serve as monitoring variables to detect nitrogen and phosphors in water-quality assessment. The phytoplankton community composition and abundance of nitrogen can contribute to changes in phytoplankton community (Miranda *et al.*, 2016; Moschonas *et al.*, 2017). Chlorophyceae (Ansari *et al.*, 2015) and Cyanophyceae (Haque *et al.*, 2016; Hulyal and Kaliwal, 2009) members grow well in water that is rich in nutrients viz. nitrate and phosphate. Thus, the result of the present study revealed that Chlorophyceae (*T. gracile* and *T. trigonum*) and Cyanophyceae (*M. aeruginosa*, *Oscillatoria* sp., *S. platensis*, and *Anabaena* sp.) decreased in cell abundance while nitrogen and phosphorus compounds were increased in hybrid red tilapia culture in cages in earthen ponds.

The phytoplankton communities within the recirculated water earthen pond system for hybrid red tilapia farming were evaluated based on species composition and abundance. Existence of phytoplanktons in each hybrid red tilapia cage culture period were recorded and used for numerical analysis in all community parameters (Shannon-Wiener diversity, evenness, and the Simpson indices). These parameters varied depending on the period or time of the hybrid red tilapia culture (Table 3). The highest in Shannon-Wiener diversity, evenness, and the Simpson indices were found in the initial crop of hybrid red tilapia. All three diversity measures show decrease in values after growth period. It is recognized that changes in water and bottom soil qualities influence the environment in the water as well as the composition and abundance of phytoplankton produced in the earthen pond system (Reyes *et al*., 2019). The phytoplankton diversities decreases during the wet season (Yusuf, 2020). Decreased temperature, sunlight and environmental activities as a result of high-water level coupled with movement of water, decreased the abundance of phytoplankton during wet season (Khaliullina and Demina, 2015; Zhang *et al*., 2018).

Although this research results indicate that the relationship between phytoplankton community and water quality ponds are effected by seasonal changes, water recirculation has a significant effect on the water salinity and phytoplankton quality and quantity in turn. Basically phytoplankton absorb nutrients from water for use in growth and remove ammonia nitrogen from water, which is particularly important in lessening concentrations of this potentially toxic metabolite. However, this highly nitrogenous load stands in the form of phytoplanktons and their blooms should be managed carefully so as not tocause oxygen depletion as over excessive accumulation of organic matter in the ponds could affect water chemistry. The heavy or dense blooms use large amounts of dissolved oxygen at night and on very cloudy/overcast, windless days causing an oxygen depletion resulting to fish kill and brackish water.

Water salinity levels should be monitored continuously all year around. It is also known that hybrid red tilapia cultured in 10% saline has significantly lower feed conversion ratios with high feed conversion efficiency, protein efficiency ratios, digestibility of crude protein, fat, ash and gross energy (Kang'ombe and Brown, 2008).

This advantageous practice is known to farmers. However, salinity alone is not sufficient to determine a well-balanced pond environment. Phytoplankton are at the very bottom of the food chain but their biomass and nitrogenous load are as important as their role in food chain. In this study salinity management is found to be more effective method to control phytoplankton community since temperature and other abiotic factors cannot be controlled in open pond aquaculture. Therefore, water salinity is a more manageable water parameter to assess pond sediment health. These results provide important information for understanding the mechanism of phytoplankton growth and in developing the technology to predict and assess of this important group of organisms in the pond system. The bacteria causing off-flavor problems in fish can also be effected by salinity and further studies can model this relationship. It is also recommended to measure the differences of phytoplankton grown in ponds and carried from water circulated shrimp ponds, since this difference maximized during May when the highest amount of water circulated is being circulated. Salinity is found to be the most significant independent variable on the distribution of phytoplankton families in pods. It is clear that either fish growth or water quality is positively correlated with increasing water salinity levels constantly but accumulation of nitrogenous load in the ponds can effect this beneficial practice since response of phytoplankton communities to nitrogenously overloaded pond sediment can come to a breaking point in time. In highly eutrophicated sediment structure, the phytoplankton biomass and diversity may appear relatively unpredictable and a vast majority of the species can show less or no clear relationship to the environmental conditions since fish feed borne compounds can unstabilize this balance. Therefore, farmers are advised to decrease excessive feed borne nitrogenous load in the pond sediments.

Fish stock density and feeding intensity are also important factors on phytoplankton but this study recommends a more in depth study to understand the effect of salinity and temperature relationship in the changing environment of tilapia ponds.

Our study revealed that the channeling of water from shrimp ponds could increase the salinity in the earthen ponds. This finding is important to understand the effluence from shrimp pond input to hybrid red tilapia culture in cages showing an increase in salinity, alkalinity, hardness, orthophosphate and filterable phosphate and their effect on communities of phytoplankton. The farmers should consider the accumulation of organic matter in the pond. This report found two groups of phytoplankton, Euglenophyceae and Cyanophyceae, in large numbers. This is a major problem to creating the compound of Geosmin and 2-methylisoborneol (MIB) that causes earthy off-flavor problems in fishes. The famers should pay attention to phytoplankton control, feeding the right amount and eliminating food residues in the culture system.

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References

Abou, Y., Darchambeau, F., Fiogbe, E. and Micha, J. C. (2012). Ecology of feeding nile tilapia under *Azolla* cover in earthen ponds: an assessment using structural equation modelling. International Journal of Biosciences, 2:105-111.

Afonina, E. Y. and Tashlykova, N. A. (2018). Plankton community and the relationship with the environment in saline lakes of Onon-Torey plain, Northeastern Mongolia. Saudi Journal of Biological Sciences, 25:399-408.

Aitor, L. M., Beatriz, F. M. and José I. G. P. (2019). Rapid colour changes in *Euglena sanguinea* (Euglenophyceae) caused by internal lipid globule migration. European Journal of Phycology, 54:91-101.

Anetekhai, M., Edwin, O., Osodein, O. and Morenikeji, T. (2018). Physical, chemical parameters and plankton in a tropical earthen pond catfish farm in Badagry, Nigeria. International Journal of Fisheries and Aquaculture, 10:71-76.

Ansari, E., Gadhia, M. and Ujjania, N. (2015). Phytoplankton diversity and water quality assessment of ONGC Pond, Hazira, 1:1-5.

APHA, AWWA and WPCF (1995). Standard methods for the examination of water and waste water 19th edition. Washington DC, American Public Health Association.

Bagchi, A. and Jha, P. (2011). Fish and fisheries in Indian heritage and development of pisciculture in India. Reviews in Fisheries Science, 19:85-118.

Battish, S. K. (1992). Freshwater zooplanktons of India, New Delhi, Oxford and IBH publishing co. Ltd.

Bhakta, J., Rana, S., Lahiri, S., Jana, B. and Ibrahim, S. (2015). Nutrients profile and fish growth of some fish culture ponds. International Journal of Environmental and Technological Sciences, 1:1-7.

Blake, G. R. and Hartge, K. H. (1986). Bulk density. In: Klute, A. ed. Methods of soil analysis, Part 1-Physical and mineralogical methods (second edition), Wisconsin, American Society of Agronomy and Soil Science Society of America, pp. 363-382.

Borowitzka, M. A. (2018). Chapter 3 - Biology of microalgae. In: Levine I.A and Fleurence J. eds. Microalgae in health and disease prevention. Massachusetts, Academic Press, pp. 23-72.

Boyd, C. and Tucker, S. C. (1998). Pond aquaculture water quality management, Massachusetts, Springer, pp. 576-600.

Boyd, C. E. (1982). Water quality management for pond fish culture, Amsterdam, Elsevier Scientific Publishing Co.

Boyd, C. E. (1990). Water quality in ponds for aquaculture, Department of Fisheries and Allied Aquaculture, Auburn University, Alabama, US.

Bremner, J. M. and Mulvaney, C. S. (1982). Total nitrogen. In: Page, A. L., Miller, R. H. and Keeny D. R. eds. Methods of soil analysis. Wisconsin, American Society of Agronomy and Soil Science Society of America, pp. 1119-1123.

Chowdhury, M. M. R., Shahjahan, M., Rahman, M. S. and Islam, M. (2008). Duckweed (*Lemna minor*) as supplementary feed in monoculture of nile tilapia, *Oreochromis niloticus*. Journal of Fisheries and Aquatic Science, 3:54-59.

Cunha, M. E., Quental-Ferreira, H., Parejo, A., Gamito, S., Ribeiro, L., Moreira, M., Monteiro, I., Soares, F. and Pousão-Ferreira, P. (2019). Understanding the individual role of fish, oyster, phytoplankton and macroalgae in the ecology of integrated production in earthen ponds. Aquaculture, 512:734297.

Dauda, A. B., Ajadi, A., Tola-Fabunmi, A. S. and Akinwole, A. O. (2019). Waste production in aquaculture: Sources, components and managements in different culture systems. Aquaculture and Fisheries, 4:81-88.

El-Naggar, H. A., Khalaf Allah, H. M. M., Masood, M. F., Shaban, W. M. and Bashar, M. A. E. (2019). Food and feeding habits of some Nile River fish and their relationship to the availability of natural food resources. The Egyptian Journal of Aquatic Research, 45:273-280.

Espinal, C. A. and Matulić, D. (2019). Recirculating aquaculture technologies. In Goddek, S., Joyce, A., Kotzen, B., and Burnell, G. M. eds. Aquaponics food production systems: Combined aquaculture and hydroponic production technologies for the Future. Cham, Springer International Publishing, pp. 35-76.

George, B., Nirmal Kumar, J. I. and Kumar, N. K. (2012). Study on the influence of hydrochemical parameters on phytoplankton distribution along Tapi estuarine area of Gulf of Khambhat, India. Egyptian Journal of Aquatic research, 38:157-170.

Hammer, O., Harper, D. A. T. and Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica, 4:9.

Haque, M. R., Islam, M. A., Wahab, M. A., Hoq, M. E., Rahman, M. M. and Azim, M. E. (2016). Evaluation of production performance and profitability of hybrid red tilapia and genetically improved farmed tilapia (GIFT) strains in the carbon/nitrogen controlled periphyton-based (C/N- CP) on-farm prawn culture system in Bangladesh. Aquaculture Reports, 4:101-111.

Hoppenrath, M., Elbrachter M. and Drebes, G. (2009). Marine phytoplankton, Stuttgart, E Schweizerbart'sche Verlagsbuchhandlung, 9:240-241.

Hossain, M. Y., Jasmine, S., Ibrahim, A., Ahmed, Z., Ohtomi, J., Fulanda, B., Begum, M., Mamun, A., El-kady, M. and Wahab, M. (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.

Hulyal, S. B. and Kaliwal, B. B. (2009). Dynamics of phytoplankton in relation to physico-chemical factors of Almatti reservoir of Bijapur District, Karnataka State. Environmental Monitoring and Assessment, 153:45-59.

Ikpi, G. U., Offem, B. O. and Okey, I. B. (2013). Plankton distribution and diversity in tropical earthen fish ponds. Environment and Natural Resources Research, 3:45-51.

Johnson, L. P. and Jahn, T. L. (1942). Cause of the green-red color change in *Euglena rubra*. Physiological Zoology, 15:89-94.

Kang'ombe, J. and Brown, J. A. (2008). Effect of salinity on growth, feed utilization, and survival of *Tilapia rendalli* under laboratory conditions. Journal of Applied Aquaculture, 20:256-271.

Khaliullina, L. Y. and Demina, G. V. (2015). Seasonal dynamics of phytoplankton communities residing in different types of shallow waters in the Kuibyshev Reservoir (Russia). International Aquatic Research, 7:315-328.

Kuczynska, P., Jemiola-Rzeminska, M. and Strzalka, K. (2015). Photosynthetic pigments in diatoms. Marine drugs, 13:5847-5881.

Manickam, N., Saravana Bhavan, P., Santhanam, P., Muralisankar, T., Dinesh Kumar, S., Balakrishnan, S., Ananth, S. and Shenbaga Devi, A. (2020). Phytoplankton biodiversity in the two perennial lakes of Coimbatore, Tamil Nadu, India. Acta Ecologica Sinica, 40:81-89.

Miranda, T., Lima, H., Galon, B., Veronez, A., Moretti, M., Roper, J. and Gomes, L. (2016). Changes in water quality and the phytoplankton community associated with tilapia cage farming in tropical lakes. Aquatic Living Resources, 29:1-8.

Mo, W. Y., Cheng, Z., Choi, W. M., Man, Y. B., Liu, Y. and Wong, M. H. (2014). Application of food waste based diets in polyculture of low trophic level fish: Effects on fish growth, water quality and plankton density. Marine Pollution Bulletin, 85:803-809.

Moschonas, G., Gowen, R. J., Paterson, R. F., Mitchell, E., Stewart, B. M., McNeill, S., Glibert, P. M. and Davidson, K. (2017). Nitrogen dynamics and phytoplankton community structure: the role of organic nutrients. Biogeochemistry, 134:125-145.

Nelson, D. W. and Sommer, L. E. (1982). Total carbon, organic carbon, and organic matter. In: Page, A. L., Miller, R. H. and Keeney, D. R. eds. Methods of soil analysis Part 2 Chemical and microbiological properties, Wisconsin, American Society of Agronomy. pp. 539-579.

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

Nwankwo, D. I. (1995). Euglenoids of some polluted storm-water channels in Lagos, Nigeria. Tropical Freshwater Biology, 4:29-39.

Olaveson, M. M. and Nalewajko, C. (2000). Effects of acidity on the growth of two Euglena species. Hydrobiologia, 433: 39-56.

Olsen, S. R. and Sommers, L. E. (1982). Phosphorus. In: Page, A.L., Miller R. H., and Keeney, D. R. eds. Methods of soil analysis part 2 chemical and microbiological properties. Wisconsin, American Society of Agronomy, Soil Science Society of America, pp. 403-430.

Perumal, P., Sampathkumar, P. and Karuppasamy, P. K. (1999). Studies on the bloom-forming species of phytoplankton in the Vellar estuary, southeast coast of India. Indian Journal of Marine Sciences, 28:400-403.

Rahman, M. M., Jewe, M. A. S., Khan, S. and Haque, M. M. (2007). Study of Euglenophytes bloom and it's impact on fish growth in Bangladesh. Algae, 22:185-192.

Rapatsa, M. M. and Moyo, N. A. G. (2013). Performance evaluation of chicken, cow and pig manure in the production of natural fish food in aquadams stocked with *Oreochromis mossambicus*. Physics and Chemistry of the Earth, Parts A/B/C, 66:68-74.

Reed, M. L., Pinckney, J. L., Keppler, C. J., Brock, L. M., Hogan, S. B. and Greenfield, D. I. (2016). The influence of nitrogen and phosphorus on phytoplankton growth and assemblage composition in four coastal, southeastern USA systems. Estuarine, Coastal and Shelf Science, 177:71-82.

Reyes, A., Ramos, A. and Saturno, J. (2019). Phytoplankton abundance, diversity, evenness and composition in tilapia ponds fertilized with chicken manure and organic fertilizer. International Journal of Botany Studies, 4:72-76.

Rivera, V. F., Menezes, R. F. and Attayde, J. L. (2018). Effects of the Nile tilapia (*Oreochromis niloticus* L.) on the plankton community of a tropical reservoir during and after an algal bloom. Hydrobiologia, 817:393-401.

Roy, K. (2014). Sediment fertility based management of aquaculture in urban and rural ponds of Chhattisgarh. Journal of Inland Fisheries Society of India, 46:69-75.

Roy, K. (2017). Fertilization and stocking of unmanaged ponds through temporal plankton community structure map (PCSM): A nascent concept in aquaculture planning. PeerJ Preprints, 5:e2856v1.

Sáez-Plaza, P., Navas, M. J., Wybraniec, S., Michałowski, T. and Asuero, A. G. (2013). An overview of the Kjeldahl method of nitrogen determination. Part II. Sample preparation, working scale, instrumental finish, and quality control. Critical Reviews in Analytical Chemistry, 43:224-272.

Sebastian-Gonzalez, E., Navarro, J., Sánchez-Zapata, J., Botella, F. and Delgado Huertas, A. (2012). Water quality and avian inputs as sources of isotopic variability in aquatic macrophytes and macroinvertebrates. Journal of limnology, 71:191-199.

Siddika, F., Shahjahan, M. and Rahman, M. S. (2012). Abundance of plankton population densities in relation to bottom soil textural types in aquaculture ponds. International Journal of Agricultural Research Innovation and Technology, 2:56-61.

Singh, G., Bhatnagar, A., Kalla, A. and Singh, A. (2016). Fish yields in relation to water quality and plankton production in managed and unmanaged fresh water ponds. Journal of Experimental Agriculture International, 14:1-10.

Sipauba-Tavares, L. H., Donadon, A. R. V. and Milan, R. N. (2011). Water quality and plankton populations in an earthen polyculture pond. Brazilian Journal of Biology, 71:845-855.

Sun, C. -C., Wang, Y. -S., Wu, M. -L., Dong, J. -D., Wang, Y. -T., Sun, F. -L. and Zhang, Y. -Y. (2011a). Seasonal variation of water quality and phytoplankton response patterns in Daya Bay, China. International Journal of Environmental Research and Public Health, 8:2951-2966.

Sun, W., Dong, S., Jie, Z., Zhao, X., Zhang, H. and Li, J. (2011b). The impact of net-isolated polyculture of tilapia (*Oreochromis niloticus*) on plankton community in saline–alkaline pond of shrimp (*Penaeus vannamei*). Aquaculture International, 19:779-788.

Thunjai, T., Boyd, C. E. and Boonyaratpalin, M. (2004). Bottom soil quality in tilapia ponds of different age in Thailand. Aquaculture Research, 35:698-705.

Weber, J. B. (1997). Soil properties, herbicide sorption and model soil systems. In: Truelove, B. ed. Research methods in weed science (Second Edition), Alabama, Southern Weed Science Society, pp. 59-62.

Yusuf, Z. (2020). Phytoplankton as bioindicators of water quality in Nasarawa reservoir, Katsina State Nigeria. Acta Limnologica Brasiliensia, 32: e4.

Zhang, M., Shi, X., Yang, Z., Yu, Y., Shi, L. and Qin, B. (2018). Long-term dynamics and drivers of phytoplankton biomass in eutrophic Lake Taihu. Science of The Total Environment, 645:876-886.

Zimba, P. V., Huang, I. S., Gutierrez, D., Shin, W., Bennett, M. S. and Triemer, R. E. (2017). Euglenophycin is produced in at least six species of euglenoid algae and six of seven strains of *Euglena sanguinea*. Harmful Algae, 63:79-84.

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