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Research Paper

Interrelation of Phytoplankton and Water Quality at Bung Binh Thien Reservoir, An Giang Province, Vietnam

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Abstract
Seasonal changes in water quality and phytoplankton composition in Bung Binh Thien Lake, An Giang province were investigated in this study. Nine samples were collected in the dry and rainy season in 2019 for analyzing the composition of phytoplankton and identifying the principal water quality factors influencing the phytoplankton. Temperature, turbidity, pH, total suspended solid (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), ammonium (N-NH_4^+), orthophosphate (P-PO_4^{3-}) and coliforms were analyzed for water quality index (WQI) determination. The results indicated that five phyla of phytoplankton including Bacillariophyta, Chlorophyta, Cyanophyta, Euglenophyta and Dianophyta were identified at the lake. Species compositions of chlorophyta was the most abundant while Dinophyta were found in limited numbers in the two seasons. However, Bacillariophyta was the highest density thus dominating in the water through seasons. Season resulted in strong influence on the phytoplankton, for example, density and Shannon-Wiener diversity index (H') in the dry season were higher than those in the wet season. Both H' and WQI indexes revealed that water quality in the dry season was less polluted than that in the rainy season. Canonical Correspondence Analysis (CCA) showed that DO, turbidity, TSS and nutrients (P-PO_4^{3-} and N-N_O^{3-}) were the main factors affecting phytoplankton composition in the lake. This study provided important information on interrelation of phytoplankton composition and water quality parameters supporting water monitoring.

Keywords
Bung Binh Thien, CCA, Phytoplankton, water quality index, coliforms.

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1. INTRODUCTION

The decline in surface water quality in rivers, lakes and some other water bodies occurs easily due to the relatively easily access to waste disposal (Samarghandi et al., 2007). In recent years, the decline of water quality has stemmed from natural processes (flow characteristics, tidal regime, soil erosion, climate change, etc.) and human activities (use agricultural land, domestic activities and the discharge of wastewater from other activities) (Gantidis et al., 2006); (Arain et al., 2008). Phytoplankton is one of the basic biological components of rivers and ponds, providing energy for higher plants through the food chain (Li et al., 2019). Thus, phytoplankton is a biological indicator that is relatively sensitive to changes in the aquatic environment. Monitoring water environment could be implemented using physical, chemical characteristics of water or using diversity of phytoplankton. Water quality index (WQI) and Shannon-Wiener diversity index (H') are commonly used for water quality assessment and biodiversity measurement (Gao and Song, 2005). The application of multivariate techniques such as canonical correspondence analysis (CCA) in assessing water quality and biodiversity has been widely applied for interpretation of environmental data Feher et al. (2016); Luu (2017); Chounlamany et al. (2017). CCA analysis could provide useful information regarding significant changes in species distribution due to water quality. Several studies assessed the relationship between water quality and phytoplankton composition through CCA analysis on Dong Nai and Ba Lai rivers (Luu, 2017); (Luu et al., 2017); however, there has been no such study at Bung Binh Thien reservoir. This study was carried out to assess seasonal changes in water quality, phytoplankton diversity and examine the water quality parameters determine the diversity of phytoplankton. The findings from this study could be a useful information for water environment monitoring.

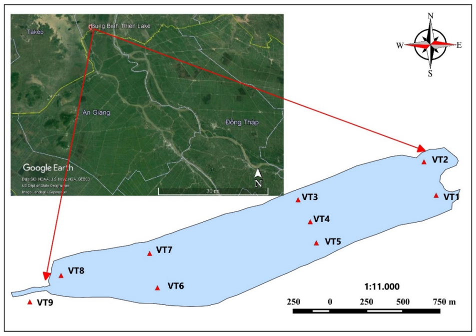

Figure 1. Map of sampling sites

2. Methodology

2.1 Study area

Binh Thien Bung is one of the largest freshwater reservoirs in the Vietnamese Mekong Delta with the water surface area in the dry season is 200 ha and 800 ha in dry and wet season, respectively. The average depth of the reservoir is approximately 3.5 m in the dry and the highest is 6 m in the flood season (for environment Monitoring and Giang, 2012). The reservoir receives freshwater from the Binh Di River on a regular basis. Agriculture (growing rice, vegetables, and fruits) and aquaculture (raising fish) are the two main activities of people around the reservoir. Water in the reservoir mainly serves for domestic activities, irrigation and recreation of the local people and visitors. However, the reservoir is also strongly affected by wastes generated by natural processes (water regime, erosion, weather conditions) and anthropogenic activities (domestic activities, agricultural production, aquaculture, and tourism activities). These activities could seriously influence on water quality and phytoplankton in the reservoir.

2.2 Water sampling and analysis

To evaluate quality of water, surface water and phytoplankton samples were simultaneously collected in the dry (March, 2019) and rainy seasons (September, 2019) at nine sites in the reservoir as indicated in figure 1 . Ten water quality parameters comprising temperature, turbidity, pH, total suspended solid (TSS, mg/L), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonium (N-NH_4^+), orthophosphate (P-PO_4^{3-}) and coliforms. Temperature, turbidity, pH and DO were immediately measured at the field using handheld meters. The other water variables were analysed using the methods in Standard Methods for the Examination of Water and Wastewater (APHA, 1998). The Water Quality Index (WQI) was calculated according to Decision 879/QĐ –TCMT of Vietnam Environment Administration using equation (1):

$$WQI = \frac{WQIpH}{100}\left[\frac{1}{5}\sum_{a=1}^{5} WQI_a.\frac{1}{2}\sum_{b=1}^{2} WQI_b.WQI_c\right]^{1/3} \quad (1)$$

Where WQIa is WQI calculated for DO, BOD, COD, N-NH_4^+, P-PO_4^3-; WQIb is WQI calculated for TSS, turbidity; WQIc is calculated for coliforms; WQIpH is WQI calculated for pH (pH ranged from 6 – 8.5).

According to the Decision 879/QD-TCMT, water qualitiy is divided into five levels based on the values of WQI. Level 1 ($91 < WQI < 100$) indicates clean water quality which is used well for domestic purposes. Level 2 ($76 < WQI < 90$), good water quality which is suitable for a living but appropriate treatment is needed. Level 3 ($51 < WQI < 75$) is used for irrigation and equivalent purposes, water quality is moderate pollution. Level 4 ($26 < WQI < 50$) indicates polluted water only suitable for navigation. Finally, level 5 ($0 < WQI < 25$) heavily polluted water requires future remedies.

2.3 Phytoplankton sampling and analysis

For phytoplankton, phytoplankton qualitative specimens were collected by net with a mesh size of 25 µm. Quantitative sampling was collected by filtering 100 litres of water through the phytoplankton net. After that, the samples were stored in 110 mL vials and fixed with formaldehyde (to the final concentration of 2-4%. Qualitative analysis samples were observed and classified according to Tien and Hanh (1997), Ho (1972), Reynolds (2006), Brierley et al. (2007), Suthers et al. (2019a). Quantitative analysis was performed by counting individuals of the phytoplankton followed the method of (Boyd and Tucker, 1992). The density of phytoplankton was calculated by equation 2:

$$Y = \frac{X * V_{cd} * 1000}{N * A * V_{tt}} \quad (2)$$

In which Y is the individual of phytoplankton per liter of sample (individuals/liter); X is the numbers of individuals counted; Vc is the volume of the concentrated sample (mL); N is the numbers of counting cells; A is the counting cell area (1 mm^2) and V_{tt} is volume of collected water (mL).

The Shannon - Wiener diversity index (H') was used to assess the diversity of phytoplankton in the study area and was calculated by the equation (3):

$$H' = -\sum P_i.ln(P_i) \quad (3)$$

Where pi=ni/N; ni is the number of individuals in the sample; N is total amount of individuals in the samples. The rating scale of water quality by H 'index (Henna & Rya

Sunoko, 1995) is mentioned in 5 different levels of pollution: very polluted (H' <1), polluted (1 <H' <2), mild pollution (2 <H' <3), good (3 <H' <4.5) and very good (H' >4.5).

2.4 Data processing

Similarity Percentage Analysis (SIMPER) and Canonical Correspondence Analysis (CCA) were applied in this study. SIMPER analysis was performed to determine the dominance and contribution of each species to the diversity in the study area. SIMPER was performed using Primer 5.2 for Windows (PRIMER-E Ltd, Plymouth, UK). Phytoplankton composition data for analysis were the dominant species with a contribution level of over 5% through the simper multivariate analysis technique (Thai, 2018). Canonical Correspondence Analysis (CCA) was used to find the main water quality parameters affecting change of phytoplankton species. The direction of the arrow indicated positive and negative correlation and their length corresponds to the importance of the explanatory variable in the graph (Jasprica et al. (2012); Laskar and Gupta (2013)). The relationship between water quality variables and the abundance of phytoplankton in this study was determined by the PAST (Paleontological Statistics) version 3.06.

3. RESULTS AND DISCUSSION

3.1 Seasonal variations of phytoplankton

The results showed that 273 species belonging to five phyla including Chlorophyta (83 species), Euglenophyta (60 species), Bacillariophyta (59 species), Cyanophyta (42 species) and Dinophyta (29 species) were found in the dry season, (Figure 2). Meanwhile, 146 species comprising Chlorophyta (53 species), Bacillariophyta (30 species), Euglenophyta (28 species), Cyanophyata (27 species) and Dinophyta (8 species) were discovered in the wet season (Figure 2). There was a significant change in the species composition due to seasonal shift. This could be due to the difference in intensity of incident light and water temperature (Abrantes et al. (2006); Ke et al. (2008)). Previous studies only found 66 species belonging to seven phyla (Quyen, 2015) and 85 species belonging to six phyla Toan (2014) which were much lower in species composition compared to this study. However, the former and the current studies have found that Chlorophyta was the dominant phylum in the reservoir in dry and wet season. This phylum of algae is representative for the algal group occurred frequently in freshwater bodies and indicated for moderate water pollution (Wu, 1984).

The density of phytoplankton was found to be seasonally varied (Figure 2). The densities of algae inside the reservoir (VT1-VT8) in the dry season varied from 41,048 to 121,452 individuals/L and averaged at 81,250 individuals/L. The algal densities ranged from 1,275 to 38,389 individuals/L (averaged at 19,832 individuals/L) in the rainy season. As can be seen that less diversity of phytoplankton was found in the rainy season. The lower density of phytoplankton was also reported in the previous studies (Thai (2018); Hoang (2009);

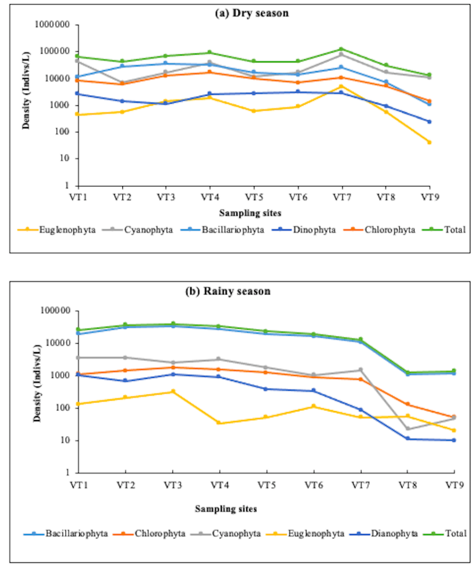

Figure 2. Seasonal variation of phytoplankton

Quyen (2015); Toan (2014); Li et al. (2019)). Phytoplankton density in the Bung Binh Thien reservoir (VT1-VT8) was higher than those in Binh Di river (VT9). It was also higher than the densities of phytoplankton in certain water segments in Hau River, for example, Hau river in An Giang section (7,868 - 47,155 individuals/L, in dry season) Dat (2014) and Hau river in Can Tho section (12,620 - 284,294 individuals/L in the dry season; 667 - 4,940 individuals/L in the rainy season) (Quy and Luu, 2011).

Composition and density of phytoplankton Bung Binh Thien reservoir in the dry season tended to be higher than those in the rainy season which could be explained that the high flow rate in the rainy season resulted in disturbing water quality due to suspended solids Egborge (1994), nutrient dilution and light penetration limit for phytoplankton production (Gosselain et al., 1994; Sowunmi (2001)).

3.2 Water quality assessment using H' and WQI

The variation of species composition and the number of phytoplankton species are proportional to the variation of Shannon-Wiener diversity index (H'). The calculation showed that H' ranged from 1.12 - 2.71 (Figure 3). The values of H' in the dry season indicated that water environment was slightly polluted (H' > 2). There was a significant shift in water quality from the dry to the wet season. The values of H' were in the range of 1< H' <2 indicated moderate water pollution.

The water quality index (WQI) in the Bung Binh Thien reservoir ranged from 57 - 88 (in the dry season) and 11 - 79 (in the rainy season) (Figure 4). Based on WQI, water quality in the dry season was suitable for domestic use but appropriate measures are required (level 2), except for the locations VT8 and VT9 only suitable only for irrigation or

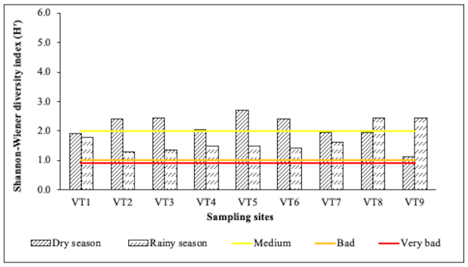

Figure 3. Seasonal change of Shannon-Wiener diversity index (H') at the sampling sites

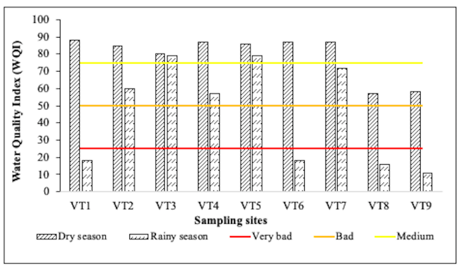

Figure 4. Seasonal change of Water Quality Index (WQI) at the sampling sites

equivalent purposes (level 3). However, the values of WQI in the rainy season indicated that the water was from slight (VT3, VT5) to moderate pollution (VT2, VT4, and VT7). The remaining locations (VT1, VT6, VT8) were classified as heavy pollution (WQI=13-72).

3.3 Environmental factors affecting phytoplankton

SIMPER analysis was performed to identify the dominance and representative species of phytoplankton for each season (Table 1). Among the occurred phytoplankton species, Nitzschia longissima, Melosira granulata and Oscillatoria muticola were the three dominant species in dry season, while Melosira granulata, Melosira granulata var. valida and Coscinodiscus rothii were identified as the species that frequently appeared in the samples during the rainy season. It was found that Melosira species occurred abundantly in both seasons and this observation was similar to the study of (Ogbuagu and Ayoade, 2012).

Simper analysis results indicated that only 20 species appeared regularly and dominated in both seasons out of 273 species in the dry season and 146 species in the rainy season (Table 1). CCA analysis was used to show the relationship of environmental parameters and composition of phytoplankton in the study area. The results of CCA analysis in the dry season were based on 10 water quality parameters and 6 dominant phytoplankton species. From Figure 5a, it can be seen that the value of eigenvalues constant and the percentage of difference were relatively large between axis 1 and axis 2, in which axis 1 explained

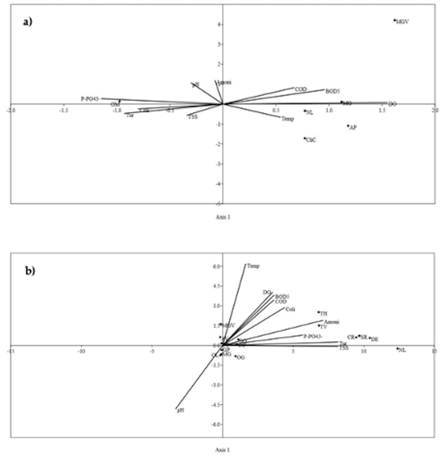

Figure 5. CCA analysis in dry season (a) and rainy season (b)

74.26% (0.21) and axis 2 explained 16.33% (0.05). In the dry season, DO and PO_4^{3-}-P were the two most pivotal factors affecting species composition in Bung Binh Thien lake. This was followed by organic matter (BOD and COD), turbidity and coliform, and the final was temperature, pH, TSS and NH_4^+-N. Some species were highly correlated with axis 1 such as Melosira granulata, Aphanocapsa pulchra and Oscillatoria muticola. Melosira granulata, Aphanocapsa pulchra were found to be positively correlated with DO and organic matter; however, Oscillatoria muticola was positively correlated with phosphate, turbidity and coliform.

Note: Anabaena variabilis – AV, Aphanocapsa pulchra – AP, Chodatella chodatii – ChC, Coscinodiscus rothii – CR, Cyclotella comta – CC, Diatoma elongatum – DE, Glenodinium penardiforme – GP, Melosira granulata – MG, Melosira granulata var. valida – MGV, Navicula lyra – NL, Nitzschia brebissonii – NB, Nitzschia longissima – NL, Oscillatoria guttulata – OG, Oscillatoria limosa – OL, Oscillatoria muticola – OM, Pediastrum simplex – PS, Scenedesmus quadricauda – SQ, Surirella robusta var. splendida - SR, Trachelomonas hispida – TH, Trachelomonas volvocina –TV.

In the rainy season, the first two axes explained 95.80% of the relationship between the two factors (axis 1 accounted for 89.53%, axis 2 accounted for 6.27) with eigenvalues of 0.43 and 0.03, respectively. Navicula lyra, Coscinodiscus rothii, Diatoma elongatum, Surirella robusta var. splendida, Trachelomonas volvocina and Trachelomonas hispida showed a positive correlation with axis 1 (Figure 5b). The distribution of these species was recorded as being affected and positively correlated with the factors of decreasing levels such as turbidity, TSS, NH_4^+-N and P-PO_4^{3-}. In addition, from the analysis of Simper and CCA, the presence of Anabaena variabilis, Cyclotella comta, Pediastrum simplex Glenodinium penardiforme, Scenedesmus quadricauda, Melosira granulata and Oscillatoria limosa were found to be affected by the season. Previous studies have also shown that the parameters such as TSS, temperature, pH and nutrients play a crucial role in forming the species composition of an area (Luu et al. (2017); Suthers et al. (2019b)). Similar to the previous studies, the rapid change in physicochemical factors between the two seasons (especially DO, TSS, turbidity and nutrients) in Bung Binh Thien reservoir could lead to major changes in the composition and quantity of phytoplankton.

4. CONCLUSIONS

Phytoplankton species in Bung Binh Thien reservoir was found to be 283 species (dry season) and 146 species (rainy season), belonging to five phyla Bacillariophyta, Chlorophyta, Cyanophyta, Euglenophyta and Dianophyta. In particular, Chlorophyta dominated species composition in both seasons. The average density of the individuals in dry season was around 81,250 individuals/L, while in the rainy season was only about 19,832 individuals/L. Diversity indexes H' and WQI fluctuated between 1.12 - 2.71 (dry season) and 1.35 - 2.44 (rainy season); 57 - 88 (in the dry season) and 11 - 79 (in the rainy season). The findings showed that the diversity of phytoplankton in the dry season was higher than that in the rainy season and the shift in phytoplankton diversity was closely related to water quality index. The results of CCA analysis showed that the composition of phytoplankton was affected by DO, TSS, turbidity, N-NH_4^+, and P-PO_4^{3-}. Melosira granulata and Oscillatoria muticola were found to be influenced by the environmental factors in the dry season while Coscinodiscus rothii, Diatoma elongatum, Surirella robusta var. splendida were environmentally affected in the rainy season.

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