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Characteristics of Phytoplankton Production in Wet and Dry Seasons in Hyper-Eutrophic Lake Taihu, China

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Abstract: Primary productivity plays a key role in aquatic lake ecosystems. This study addresses the characteristics of primary phytoplankton productivity and its relationship with environmental factors in a large, shallow, and eutrophic lake (Lake Taihu, China). Surface water samples were collected in wet and dry seasons from eight lake areas to investigate physicochemical factors and primary productivity. The results show obvious seasonal differences in phytoplankton primary productivity and physicochemical factors in Lake Taihu. The primary productivity in the wet season is about five times larger than that in the dry season, and the spatial distribution of primary productivity is obviously inhomogeneous in the wet season, while in the dry season, there are no significant differences in different lake areas. Most of the lake areas are in the middle eutrophic state regardless of the season; the northwest region has the heaviest degree of eutrophication, while the southeast region has the lightest degree of eutrophication. Pearson correlation indicated that nutrients are the main factors affecting primary productivity in the wet season, while temperature is the most important factor affecting primary productivity in the dry season. Multiple stepwise regression suggested that chlorophyll-a (Chl-a), temperature (T), and water transparency (SD) can be used to estimate the phytoplankton primary productivity in Lake Taihu in different seasons, and the main influencing factors for primary productivity are Chl-a, nutrients, and SD/total suspended solids (TSS) in the wet season and T, Chl-a, and SD/TSS in the dry season.

Keywords: phytoplankton primary productivity; environmental factors; eutrophication; vertically generalized production model (VGPM); trophic level index (TLI)

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1. Introduction

Lakes have various functions, such as water supply, shipping, atmospheric regulation, water purification, soil conservation, and the maintenance of biodiversity, which are of great significance to human production and life [1]. However, rapid economic development and human activities have caused varying degrees of damage to the lake ecosystem, and a variety of environmental problems have been triggered [2,3]. Eutrophication has become a major ecological problem in lake and reservoir ecosystems [4]. Lake eutrophication can stimulate the growth of phytoplankton and cause a series of environmental problems, such as harmful algal blooms, hypoxic and anoxic conditions, noxious odors, adverse water-quality problems, and the mortality of aquatic plants and animals [4–8]. There may also be other potential problems, such as damage to biodiversity, degradation in the lake's ecological functions, damage to fishery resources, etc. Therefore, the protection of lakes is urgent.

The causes of eutrophication in China's major watersheds include external and internal factors [1,5,7,8]. External factors refer to the suitability of light intensity and water temperature, domestic waste, industrial and agricultural pollutants, etc.; internal factors include the deficiency of microorganisms and the increase in and accumulation of nitrogen and phosphorus content in the water body. The enrichment of nitrogen and phosphorus will cause a rapid reduction in dissolved oxygen and an increase in plankton in the water, which will eventually lead to the death of fish or other aquatic organisms [4,7,8]. Eutrophication will bring huge losses to aquaculture, especially fish and shellfish farming [9]. If people eat these aquatic products by mistake, they will cause chronic poisoning.

Primary productivity, as one of the basic links in aquatic ecosystem functions, refers to the ability of phytoplankton, epiphytic algae, higher aquatic plants, and autotrophic bacteria to convert inorganic matter into organic matter through photosynthesis or chemical energy synthesis [10–12]. About 50% of the biosphere's primary productivity is contributed by phytoplankton; thus, phytoplankton have been considered the most important primary producers [10]. Aquatic plants and benthic algae are negligible, and phytoplankton are almost the only producers in deep waters [12]. Primary productivity is of great significance for the study of aquatic ecosystems and their environmental characteristics. A quantitative assessment of the primary productivity of phytoplankton in lake ecosystems not only helps us to understand the process of nitrogen and phosphorus circulation and energy flow but also helps us to estimate the production potential of fisheries and provides theoretical support for the rational utilization and management of aquatic biological resources in lakes [13–16]. In addition, phytoplankton primary productivity also increases with the deepening of eutrophication; it is, therefore, an important indicator of lake eutrophication [15,16].

Lake Taihu is China's third largest (2338 km^2) freshwater lake with a mean depth of only 1.9 m. It serves flood detention, irrigation, fishery, drinking water, waterway carriage, and tourism functions. Taihu is well known as a hyper-eutrophic lake and has been plagued by algal blooms in recent years [1,17,18]. Cyanobacterial blooms even caused a drinking water crisis in Wuxi city in 2007 [19]. With a series of treatment and protection measures, the water quality of Lake Taihu has gradually improved in recent years, but there is still a big gap between the improvements and the governance goal [20]. The present study analyzed the characteristics of primary productivity in Lake Taihu in wet and dry seasons and its relationship with environmental factors, aiming to provide a data basis and theoretical support to increase the understanding of nutritional status, water environment protection, and fishery proliferation management.

2. Materials and Methods

2.1. Field Sampling and Laboratory Analysis

Lake Taihu (30°55′40′′–31°32′58′′ N, 119°52′32′′–120°36′10′′ E) is located between the middle subtropical zone and the north subtropical zone. It has a monsoon climate with abundant rainfall. Summer rainfall can account for more than 35% of annual rainfall, and its water depth can reach more than 3.8 m in the wet season [21]. The annual average wind speed is generally below 10 m/s (4.3 m/s in the wet season; 0.9 m/s in the dry season) [21]. Sunny days with light wind were selected to conduct our field work.

Lake Taihu contains eight areas, and each lake area was set a sampling point (Figure 1), namely Zhushan Bay (S1), Meiliang Bay (S2), Gonghu Bay (S3), East Epigeal Zone (S4), East Taihu Bay (S5), Southwest Zone (S6), Northwest Zone (S7), and Central Zone (S8). The field sampling was conducted in December 2017 (dry season) and August 2018 (wet season). After GPS positioning was completed on-site, a Hach HQ40d water quality analyzer was used to measure water temperature (T), pH, and dissolved oxygen (DO). The transparency (SD), total suspended solids (TSS), and water depth (D) were determined by a Secchi disc, Hach 2100Q portable turbidimeter (Loveland, CO, USA), and SM-5 depth sounder (Unionville, VA, USA), respectively. After that, the surface (0.5 m) water sample was placed in the bucket with a 5 L water collector, and a 1 L water sample was collected into the sampling bottle and marked. A total of 500 mL was used for the filtration and determination of chlorophyll-a (Chl-a), and the other 500 mL was used for the determination of total nitrogen (TN) and total phosphorus (TP). The sampling bottles were stored in a portable refrigerator at 4 °C and transported back to the laboratory for testing.

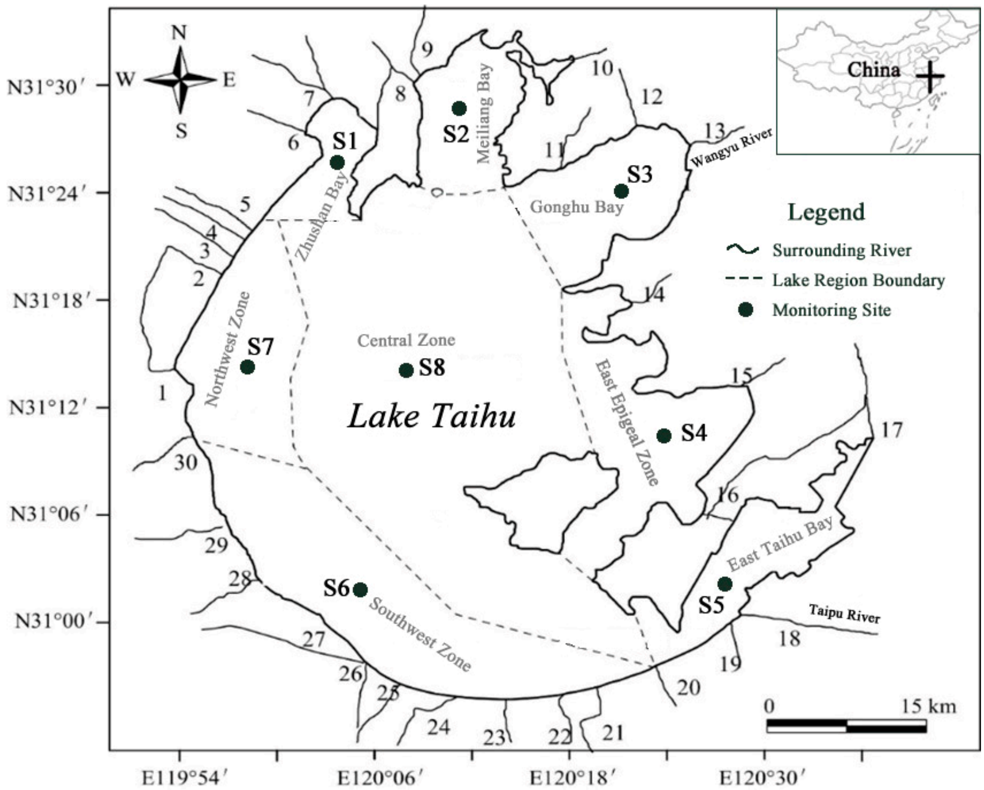


Figure 1. Sampling sites in eight areas of Lake Taihu.

Chl-a water samples were filtered through a glass fiber membrane (pore size 0.45 μm) and then determined using the acetone extraction method. TN and TP were determined by the sulfate oxidation method and the digestion-ascorbic acid method, respectively [22].

2.2. Primary Productivity Estimation Based on Vertically Generalized Production Model (VGPM)

Dark and white bottle oxygen measurement is a traditional method for estimating the primary productivity of phytoplankton, but its operation steps are cumbersome and time-consuming [22]. Therefore, some models using chlorophyll-a concentration and related ecological factors to calculate phytoplankton primary productivity have been proposed [23–25]. Among them, the vertically generalized production model (VGPM), proposed by Behrenfeld and Falkowski (1997), comprehensively considers chlorophyll content, daily surface light intensity, water temperature, depth of euphotic layer, and other factors [25]. This model underwent long-term validation in different waters and has been widely used to estimate the primary productivity of phytoplankton in lakes [26].

The simplified VGPM model can be used to estimate the gross primary productivity of the euphotic layer (PP_{eu}, mg C/m^2). The formula is as follows:

$$PP_{eu} = 0.66125 P^B_{opt} \cdot \frac{E_0}{E_0 + 4.1} \cdot Z_{eu} \cdot C_{opt} \cdot D_{irr} \quad (1)$$

where P^B_{opt} is a function of temperature, representing the maximum photosynthetic rate of the water column (mg C/(mg·Chl·h)); its expression is as follows:

$$P^B_{opt} = \begin{cases} 1.13 \ (T \leq -1.0) \\ 4.0 \ (T \geq 28.5) \\ P^B_{opt} \ (-1.0 \leq T \leq 28.5) \end{cases} \quad (2)$$

When $-1.0 \leq T \leq 28.5$, P_{opt}^{B} can be calculated by the following formula:

$$P_{opt}^{B} = 1.2956 + 2.749 \times 10^{-1}\,T + 6.17 \times 10^{-2}\,T^2 - 2.05 \times 10^{-2}\,T^3 + 2.462 \times 10^{-3}\,T^4 - 1.348 \times 10^{-4}\,T^5 + 3.4132 \times 10^{-6}\,T^6 - 3.27 \times 10^{-8}\,T^7 \quad (3)$$

In Equation (1), E_0 is the photosynthetically active radiation intensity on the lake surface. Previous research has reported that the annual photosynthetically active radiation in the middle and lower reaches of the Yangtze River is 2200 MJ/m^2 [27]; thus, $E_0/(E_0 + 4.1)$ is calculated as 0.87. Z_{eu} refers to the depth of the euphotic layer, which can be calculated using the formula Z_{eu} = 1.7239 × SD + 0.1685 (R^2 = 0.8408); the depth of the euphotic layer can be represented by water depth, while the latter is less than the former [27]. C_{opt} is the chlorophyll concentration at the depth with maximum carbon fixation rate, which can be denoted by the Chl-a concentration measured in the surface layer. D_{irr} means the light cycle. The sunrise and sunset times of the sampling points can be calculated according to the latitude and longitude to obtain the light cycle data. The D_{irr} value of Lake Taihu is represented by the day length in Wuxi city.

2.3. Trophic Level Index (TLI) Method

The TLI method was proposed by the China Environmental Monitoring Station in 2001 and has been widely used for lake eutrophication assessment in China [28]:

$$TLI = \sum_{i=1}^{m} Wj \cdot TLIj \quad (4)$$

$$Wj = r_{ij}^2 / \sum_{i=1}^{m} r_{ij}^2 \quad (5)$$

where m indicates the number of nutrient parameters used in this evaluation and W_j means the weight of the *TLI* for the *j*th parameter. r_{ij} represents the relation of Chl-a with other nutrient parameters, which has been summarized as shown in Table 1 (for lakes in China) [29].

Table 1. The relationship between chlorophyll-a (Chl-a) and total phosphorus (TP) and total nitrogen (TN) for lakes in China.

Parameters	Chl-a	TP	TN
r_{ij}	1	0.84	0.82
$r_{ij}{}^2$	1	0.7056	0.6724

TLI_j is the trophic level index (*TLI*) for the *j*th parameter. Chl-a, TP, and TN are considered the three most important parameters for *TLI* evaluation [30]; their expressions are as follows:

$$TLI\ (\text{Chl-a}) = 10\ (2.5 + 1.086 \ln \text{Chl-a}) \quad (6)$$

$$TLI\ (\text{TP}) = 10\ (9.436 + 1.62 \ln \text{TP}) \quad (7)$$

$$TLI\ (\text{TN}) = 10\ (5.453 + 1.69 \ln \text{TN}) \quad (8)$$

There are five levels of trophic status: oligotropher ($TLI < 30$), mesotropher ($30 \leq TLI \leq 50$), light eutropher ($50 < TLI \leq 60$), middle eutropher ($60 < TLI \leq 70$), and hyper eutropher ($TLI > 70$).

2.4. Data Processing and Analysis

An independent sample nonparametric test (Kruskal–Wallis one-way ANOVA) was used to analyze the differences in environmental factors in different seasons, and Pearson correlation was used to analyze the relationship between PP_{eu} and environmental factors. After the standardization of PP_{eu}, multiple stepwise regression was used to analyze the main physical and chemical factors affecting this. All the above analyses were completed using SPSS Statistics 23.0 (IBM, Armonk, NY, USA). The spatial distribution maps were obtained using inverse distance weighting (IDW) interpolation in ArcGIS 10.2 (Esri, Redlands, CA, USA), and the data processing was completed using Excel 2019 (Microsoft, Redmond, WA, USA).

3. Results and Discussion

3.1. Variations of Environmental Factors in Wet and Dry Seasons

The statistical results of the physicochemical factors and primary productivity of Lake Taihu in wet and dry seasons are shown in Table 2. The physicochemical factors of Lake Taihu significantly changed in different seasons. Among them, the water depth (D), transparency (SD), pH, temperature (T), chlorophyll-a (Chl-a), total phosphorus (TP), and primary productivity (PP_{eu}) values were significantly higher in the wet season than in the dry season, while the dissolved oxygen (DO), total nitrogen (TN), and total suspended solids (TSS) values in the dry season were higher than those in the wet season.

Table 2. Statistical physicochemical parameters of wet season and dry season in Lake Taihu (mean ± standard deviation).

Parameters	Wet Season	Dry Season
D/m	2.55 ± 0.26	1.94 ± 0.23
SD/m	0.63 ± 0.04	0.44 ± 0.03
pH	9.40 ± 0.18	7.86 ± 0.19
T/°C	30.58 ± 2.54	9.35 ± 0.67
DO/(mg/L)	6.09 ± 0.25	11.36 ± 0.55
Chl-a/(mg/L)	45.57 ± 3.11	15.81 ± 1.28
TP/(mg/L)	0.14 ± 0.02	0.10 ± 0.02
TN/(mg/L)	1.83 ± 0.26	2.75 ± 0.42
TSS/(mg/L)	43.14 ± 5.29	51.47 ± 4.37
PP_{eu}/(mg C/(m^2·d))	1586.83 ± 542.01	320.82 ± 110.34

Lake Taihu is in midsummer in August (wet season), at which point the temperature (T) significantly increases. At this time, phytoplankton rapidly grows and reproduces, the chlorophyll concentration (Chl-a) significantly increases, and the primary productivity (PP_{eu}) also reaches the highest value (Table 2). In addition, with the increase in rainfall and runoff, a large amount of exogenous nutrients are imported into the lake, which also provides favorable conditions for the growth and reproduction of phytoplankton. As the water level (D) rises, the transparency (SD) of the water body also improves because it is more difficult for the suspended solids (TSS) to reach the upper layer. The photosynthesis of algae consumes CO_2 in the water body, thus increasing the pH. For the total phosphorus (TP), growing algae need to consume the dissolved phosphorus in the early and middle stages of algal blooms, but then, the decomposition of algae will release a large amount of phosphorus to the water body and eventually lead to an increase in TP in summer [31].

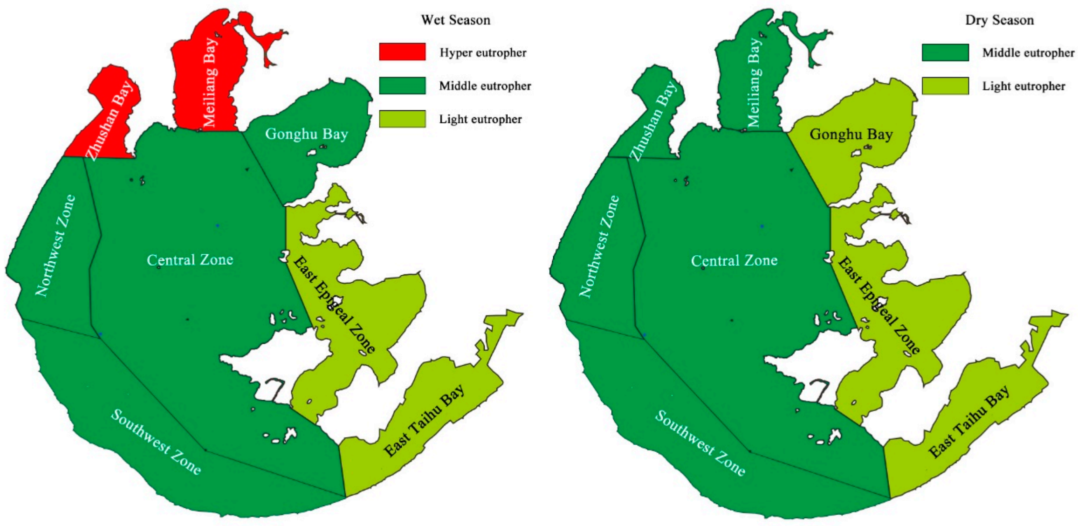
The dry season is in winter (December), at which point the temperature drops and the growth of phytoplankton is slow. Some algae such as cyanobacteria are in a dormant state and settle to the bottom of the water column, resulting in a low level of primary productivity. Lake Taihu is large but very shallow; it has been reported that the hydrodynamic force of Lake Taihu is mainly affected by wind waves [32,33]. Therefore, the TSS increases with the decrease in water level in the dry season. The dissolved oxygen (DO) in the dry season (11.36 mg/L) is nearly twice as high as in the wet season (6.09 mg/L) because the growth and death of algae are very large during the bloom period (wet season) and the decomposition process consumes a large amount of DO. At the same time, the formation of the bloom inhibits atmospheric reoxygenation. Different from TP, the nitrogen (TN) is significantly higher in the dry season than in the wet season, which is consistent with previous research findings [34]. The main reasons for this are as follows: (1) the water level of the lake will drop due to there being less rainfall in the dry season, which will further concentrate the nitrogen; (2) the use of chemical fertilizers during spring ploughing will cause many nitrogen-containing substances to enter the lake, increasing the nitrogen concentration; (3) the high temperature in summer promotes denitrification and consumes nitrogen in the lake. Furthermore, an increase in rainfall in the wet season will dilute the nitrogen concentration in the lake to a certain extent, leading to there being a higher TN content in winter [35].

3.2. Trophic Status of Lake Taihu in Wet and Dry Seasons

Based on the trophic level index method, the TLI values of eight lake areas in Taihu were calculated as shown in Table 3; the relevant distribution is presented in Figure 2. Most of the lake areas are in the middle eutropher regardless of the season; only a small part of the lake is in the light eutropher or hyper eutropher levels. There are three lake areas where the trophic status changes with the seasons. Zhushan Bay and Meiliang Bay are hyper-eutrophic areas in the wet season and become middle eutrophic in the dry season, Gonghu Bay is in the middle eutropher level in the wet season and changes to the light eutropher level in the dry season. East Epigeal Zone and East Taihu Bay are always in the light eutrophic state. The degree of eutrophication in the eastern region is less than that in the western region, and the southeast region has the lightest degree of eutrophication, while the northwest region has the heaviest degree of eutrophication.

Table 3. Trophic level index (TLI) for different lake areas in Taihu.

TLI	S1	S2	S3	S4	S5	S6	S7	S8
Wet season	71.73	70.10	67.53	56.02	54.59	60.79	65.88	63.64
Dry season	66.67	60.78	57.12	56.00	54.78	60.40	63.17	60.94



(**a**) (**b**)

Figure 2. Trophic levels of different lake areas in Taihu in wet (**a**) and dry (**b**) seasons.

The reason for the above distribution is that there are dense ports in the northwest area entering the lake, including Taige Canal, Caoqiao River, Chendong Port, Dapu Port, and Shuangqiao Port, which are the main sources of pollution in Lake Taihu. This area has been affected by developed cities, industry and agriculture, and domestic sewage; therefore, the rivers entering the lake have serious pollution levels. Furthermore, the southeast wind prevails in Lake Taihu during the summer bloom period, causing the serious accumulation of cyanobacterial blooms in this area, which aggravates a further deterioration in water quality. In addition, this is the lake bay area, with a long water retention time and poor circulation; therefore, the self-purification ability of the water is poor. In contrast, the southeast lake area has the best water quality and is used as a drinking water source. East Epigeal Zone and East Taihu Bay are typical grass-type lake areas with a strong self-purification ability and less blooms [29]. After the drinking water crisis in 2007, Gonghu Bay became the focus of prevention and control of cyanobacteria bloom in Lake Taihu; the water quality in this area improved after a series of treatment and protection measures [20].

3.3. Spatial Distribution of Primary Productivity in Wet and Dry Seasons

The spatial distribution of phytoplankton primary productivity in Lake Taihu in different seasons was analyzed based on ArcGIS. The results are shown in Figure 3. The primary productivity in the wet season varies from 725.25 mg C/(m^2·d) to 2237.71 mg C/(m^2·d), which is much higher than that in the dry season (changes from 207.67 to 477.71 mg C/(m^2·d)). The average value of primary productivity in the wet season (1586.83 mg C/(m^2·d)) is about five times larger than that in the dry season (320.82 mg C/(m^2·d)) (Table 2). Zhushan Bay (S1) and Meiliang Bay (S2) always have the largest PP_{eu} values, which are significantly higher than those of other lake areas, while East Epigeal Zone (S4) and East Taihu Bay (S5) have the lowest PP_{eu}, regardless of the season. In the wet season (Figure 3a), the spatial distribution of primary productivity is inhomogeneous, and the difference is obvious. The PP_{eu} of the entire northern half of the lake is relatively high, while Zhushan Bay (S1), Meiliang Bay (S2), Northwest Zone (S7), Gonghu Bay (S3), and the upper half of Central Zone (S8) also have large PP_{eu} values (1714.69–1958.80 mg C/(m^2·d)). In contrast, the PP_{eu} of the southern part of Lake Taihu is relatively low. Different from the situation in the wet season, the distribution of PP_{eu} in the dry season (Figure 3b) is uniform in different lake areas and does not show significant differences. Except for Zhushan Bay and Meiliang Bay, all the other six areas have similar primary productivity levels (about 200–300 mg C/(m^2·d)). The reasons for the above distribution characteristics in PP_{eu} are similar to the analyses of the TLI distribution in Section 3.2.

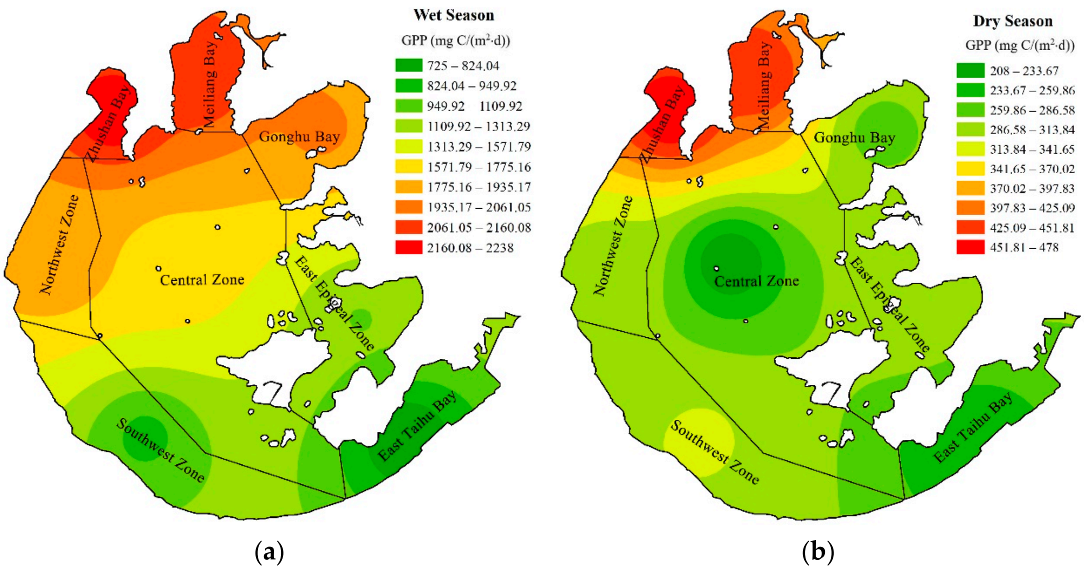


Figure 3. Spatial distribution of phytoplankton primary productivity in Lake Taihu in wet (**a**) and dry (**b**) seasons.

3.4. Influencing Factors of Primary Productivity and Its Correlation with Environmental Factors

Pearson correlation analysis was conducted of phytoplankton primary productivity and environmental factors in different seasons in Lake Taihu. The results showed that phytoplankton primary productivity was positively correlated with Chl-a, TP, TN, and TSS and negatively correlated with SD in the wet season (Table 4). In the dry season (Table 5), phytoplankton primary productivity had a positive correlation with Chl-a and T and a negative correlation with TSS.

Table 4. The correlations between phytoplankton primary productivity and environmental factors in wet season of Lake Taihu.

	PP_{eu}	SD	pH	T	DO	Chl-a	TP	TN	TSS
PP_{eu}	1								
SD	−0.799 *	1							
pH	0.435	−0.734 *	1						
T	0.583	−0.816 *	0.474	1					
DO	−0.520	0.689	−0.850 **	−0.266	1				
Chl-a	0.975 **	−0.831 *	0.456	0.607	−0.580	1			
TP	0.953 **	−0.775 *	0.392	0.574	−0.545	0.985 **	1		
TN	0.895 **	−0.698	0.331	0.637	−0.386	0.927 **	0.959 **	1	
TSS	0.776 *	−0.949 **	0.756 *	0.704	−0.765 *	0.830 *	0.817 *	0.746 *	1

* Significant values $p < 0.05$; ** significant values $p < 0.01$.

Table 5. The correlations between phytoplankton primary productivity and environmental factors in dry season of Lake Taihu.

	PP_{eu}	SD	pH	T	DO	Chl-a	TP	TN	TSS
PP_{eu}	1								
SD	0.676	1							
pH	0.643	0.151	1						
T	0.829 *	0.661	0.618	1					
DO	−0.511	−0.244	−0.890 **	−0.757 *	1				
Chl-a	0.732 *	0.001	0.644	0.474	−0.702	1			
TP	0.375	−0.039	0.569	0.553	−00.549	0.517	1		
TN	0.585	0.079	0.685	0.573	−00.548	0.734 *	0.902 **	1	
TSS	−0.712 *	−0.914 **	−0.356	−0.767 *	0.463	−0.130	−0.204	−0.296	1

* Significant values $p < 0.05$; ** significant values $p < 0.01$.

As a primary productivity feature, chlorophyll-a is an important factor affecting the primary productivity of phytoplankton, which showed a significant positive correlation regardless of the season [36,37]. In summer, primary productivity was highly correlated with nutrients, with correlation coefficients of 0.953 with TP and 0.895 with TN, which means that nutrients were the main factors affecting primary productivity in the wet season. However, temperature (T) became the most important factor affecting PP_{eu} in the dry season (with a correlation coefficient of 0.829), and the effect of nutrients may be negligible due to the limit of temperature [38]. In addition, the correlation coefficient between PP_{eu} and TP was larger than that between PP_{eu} and TN (0.953 > 0.895) in the wet season, while the results were the complete opposite in the dry season (0.375 < 0.585). This indicates that from summer to winter, the effect of phosphorus on primary productivity decreases, while the effect of nitrogen increases, which is consistent with previous research findings [38].

Primary productivity was positively correlated with TSS and negatively correlated with SD in summer due to the massive growth and death of algae, which results in increased water turbidity (TSS) and reduced transparency (SD). It is worth noting that the correlation between PP_{eu} and TSS was positive in the wet season and negative in the dry season, which indicates that the influence of TSS change on the primary productivity of phytoplankton is not a definite process and can be either promoted or inhibited. Previous studies have shown that suspended solids are mainly disturbed by wind waves, causing the resuspension of lakebed sediments and the release of nutrients, thereby increasing the level of primary productivity in the water column [32,33,39]. However, an increase in TSS concentration will cause a decrease in water transparency and euphotic depth, restricting the level of primary productivity. Harrison et al. (1997) believed that TSS has a great extinction effect, which can inhibit the growth of algae and reduce the level of primary productivity in water bodies [40]. Therefore, the effect of TSS on phytoplankton primary productivity is a contradictory process.

To test the main influencing factors of phytoplankton primary productivity, PP_{eu} and related parameters were standardized and used as the dependent variable and independent variable to carry out multiple stepwise regression. The results are shown in Table 6. Chl-a, T, and SD can be used to estimate phytoplankton primary productivity in different seasons; the regression equation of PP_{eu} in the wet season is: PP_{eu} = 0.658Chl-a + 0.201SD + 0.187T, Chl-a alone accounts for 94.3% of primary productivity. Chl-a, SD, and T jointly account for 99.3% of primary productivity. The regression equation in the dry season is: PP_{eu} = 0.163T + 0.681Chl-a + 0.536SD, accounting for 99.9% of primary productivity (R^2 = 0.999). In the equations, SD can also be expressed by TSS, as they are significantly correlated with each other ($p < 0.01$), with the correlation coefficient of −0.949 in the wet season and −0.914 in the dry season (Tables 4 and 5). Similarly, Chl-a in summer can be represented by TP (0.985, $p < 0.01$) and TN (0.927, $p < 0.01$). In sum, the main influencing factors of primary productivity are Chl-a, TP, TN, and SD/TSS in summer and T, Chl-a, and SD/TSS in winter.

Table 6. Multiple stepwise regression between PP_{eu} and environmental factors.

Period	Multiple Stepwise Regression Equations	R^2	F	p
Wet season	PP_{eu} = 0.975Chl-a	0.943	116.931	<0.001
	PP_{eu} = 0.831Chl-a + 0.233SD	0.972	104.470	<0.001
	PP_{eu} = 0.658Chl-a + 0.201SD + 0.187T	0.993	83.960	<0.001
Dry season	PP_{eu} = 0.840T	0.656	14.377	0.009
	PP_{eu} = 0.619T + 0.466Chl-a	0.823	17.281	0.006
	PP_{eu} = 0.163T + 0.681Chl-a + 0.536SD	0.999	1563.688	<0.001

4. Conclusions

The present study analyzed the characteristics of phytoplankton primary productivity and its relationship with environmental factors in wet and dry seasons in Lake Taihu. The following conclusions can be drawn:

(1) Phytoplankton primary productivity and physicochemical factors in Lake Taihu showed obvious seasonal differences. D, SD, pH, T, Chl-a, TP, and PP_{eu} were significantly higher in the wet season than in the dry season, while DO, TN, and TSS were higher in the dry season than in the wet season.

(2) Most of the lake areas in Taihu are in the middle eutrophic state regardless of the season; there are only three areas (Zhushan Bay, Meiliang Bay, and Gonghu Bay) where the trophic status changes with the seasons. The northwest region has the heaviest degree of eutrophication due to the dense ports, prevailing summer wind, and long water-retention time. The southeast region has the lightest degree of eutrophication, as it is a typical grass-type area with strong self-purification ability and less blooms.

(3) The primary productivity in the wet season is about five times larger than that in the dry season. Zhushan Bay and Meiliang Bay have the largest PP_{eu} values, which are significantly higher than those of other lake areas regardless of the season, while East Epigeal Zone and East Taihu Bay always have the lowest PP_{eu} values. The spatial distribution of primary productivity is obviously inhomogeneous in the wet season, while the distribution of PP_{eu} in the dry season is uniform in different lake areas and does not show significant differences.

(4) Chl-a, T, and SD can be used to estimate phytoplankton primary productivity in Lake Taihu in different seasons, and the regression equation of PP_{eu} in the wet season is: PP_{eu} = 0.658Chl-a + 0.201SD + 0.187T (R^2 = 0.993). The equation in the dry season is: PP_{eu} = 0.163T + 0.681Chl-a + 0.536SD (R^2 = 0.999). The main factors influencing primary productivity are Chl-a, TP, TN, and SD/TSS in summer and T, Chl-a, and SD/TSS in winter.

This research presented a comprehensive analysis of the characteristics of phytoplankton primary productivity and its relationship with environmental factors within an important water source. The findings reported in this paper provide data support for phytoplankton primary productivity research in Lake Taihu, which may have certain theoretical significance for lake eutrophication control and contribute to future monitoring research.

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