Phytoplankton Community Structure and its Relationship with Environmental Factors In Shenquan Bay

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Abstract: In order to understand the relationship between phytoplankton community structure and environmental factors in the Shenquan Bay, and the potential indication of phytoplankton community structure to the current situation of the marine environment, the phytoplankton species and dominant species composition, abundance distribution, community diversity distribution and environmental physical and chemical factors were investigated and analyzed in the spring of April 2023, and the systematic cluster analysis and Pearson correlation analysis methods were used. The results showed that 93 species of phytoplankton belonging to 24 families and 4 phyla were identified, and the dominant species in spring belonged to *Bacillariophyta* The phytoplankton abundance ranged from 4.14×10^5 cells/m^3 to 1.43×10^7 cells/m^3 in the Shenquan Bay, and the horizontal distribution characteristics showed a decreasing trend from the coastal area to the offshore area. Pearson correlation analysis showed that the nutrient and salinity changes caused by terrestrial input of rivers had an important influence on the phytoplankton community structure and abundance distribution in the sea area. The diversity index (*H'*) and the results of hierarchical cluster analysis can be used as reference indicators to characterize the differences in environmental status between different waters to a certain extent.

Keywords: Phytoplankton; Community Structure; Environmental Factors; Cluster Analysis; Correlation Analysis

1. Introduction

Shenquan Bay is located in the northern sea area of the South China Sea. It is an open bay, where Longjiang River, Leiling River and Yanling River converge into the sea[1]. The bay has the largest natural port in eastern Guangdong, namely Huilai Shenquan Port. It is a national first-class fishing port with a large number of ships entering and leaving the port every year. In addition, the sea area of Huilai Shenquan Port is relying on the unique natural conditions of the sea area, comprehensively developing and building modern marine pastures, laying a large number of deep-water cages, and develop the marine blue economy[2, 3]. Therefore, the water environment in Shenquan Bay is very worthy of attention. Phytoplankton is an important primary producer in the marine ecosystem and an important indicator of changes in the marine environment[4], which can reflect the environmental health status of the sea area to a certain extent. However, there is a lack of relevant research on the phytoplankton community structure and its environmental impact factors in the Shenquan Bay. Therefore, our study can provide a basis for reflecting the ecological environment status and pollution control of the sea area.

2. Research Methods

2.1 Research Area and Sample Collection

In April 2023 (spring), six stations were set up in the Shenquan Bay to collect water samples. Phytoplankton samples were collected from the bottom to the surface by vertical trawl with shallow water type III plankton net. Water quality and chlorophyll a were collected from the bottom of the table with a small water sampler.

The phytoplankton samples were fixed with Lugol 's iodine solution and preserved at low temperature and brought back to the laboratory. The species were identified and counted by concentration counting method. The water temperature, salinity and water depth were measured on site by CTD method, and the pH was measured on site by pH meter method. The dissolved oxygen, nutrients, oils and chlorophyll a samples were taken back to the laboratory and determined according to the ' Marine Monitoring Specification ' (GB 17378-2007) method.

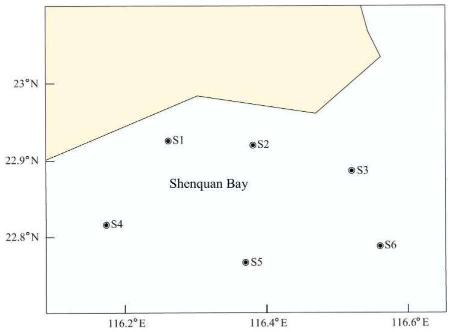

Figure 1. Layout of Survey Stations in Shenquan Bay

2.2 Analysis Method

The Shannon-Weaver diversity index (H') : $H'=-\sum_{i=1}^{S} P_i \log_2 P_i$, Pielou evenness index (J) : J=H′/log2 S, and Margalef richness index (D) : D= （S-1）/log2 N , were used to analyze the biodiversity of the community[5-7]. The dominant species were determined according to the analysis of dominance (Y)[8] : $Y=\frac{n_i}{N}\cdot f_i$. The systematic cluster analysis of phytoplankton community abundance was carried out by Origin2021. The normal distribution test and Pearson correlation analysis of phytoplankton community abundance and environmental factors were performed using IBM SPSS Statistics 25.0.

3. Analysis Of Results

3.1 Distribution Characteristics of Environmental Physical and Chemical Factors

In this paper, 11 physical and chemical factors of water quality environment in Shenquan Bay in spring were measured. The water depth was 10.5-33.2 m, the water temperature was 22.43-23.95 °C, the salinity was 33.50-34.49, the pH was 8.20-8.25, and the dissolved oxygen (DO) was 6.995-7.680 mg/L in spring. Among them, the overall trend of water depth and salinity distribution at the station is consistent, both showing a gradual increase from the nearshore to the offshore sea area (Fig.2a). The concentrations of ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), inorganic nitrogen (DIN), active phosphate (PO_4-P) and oil were 0.0114-0.0230 mg/L, 0.0014-0.0048 mg/L, 0.0222-0.0522 mg/L, 0.0356-0.0799 mg/L, 0.0016-0.0088 mg/L and 0.0035-0.012 mg/L, respectively. Except for oil, the concentrations of ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, inorganic nitrogen and active phosphate all showed a decreasing trend from nearshore to offshore (Fig.2b).

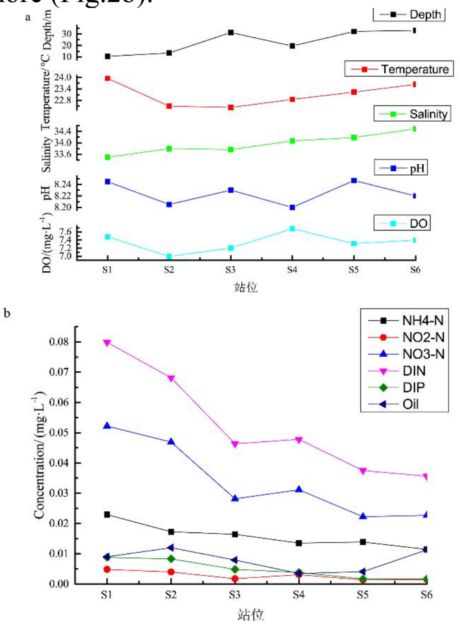

Figure 2. Distribution Characteristics of Environmental Physical and Chemical Factors

3.2 Species and Dominant Species Composition

A total of 4 phyla, 5 classes, 12 orders, 24 families and 93 species of phytoplankton were identified in this survey. Bacillariophyta was the most abundant, with a total of 14 families and 67 species, accounting for 72.04 % of the total species. The species of *Pyrrophyta* were the second, with a total of 8 families and 23 species, accounting for 24.73 % of the total species. There were 1 family and 2 species of Cyanobacteria, accounting for 2.15 % of the total species. A total of 1 family and 1 species, accounting for 1.08 % of the total number of species (Fig.3).

Based on the dominance index $Y \geq 0.02$, there were 9 dominant species of phytoplankton in Shenquan Bay in spring, which belonged to *Bacillariophyta*, including *Chaetoceros lorenzianus*, *Bacteriastrum hyalinum*, *Thalassiosira sp.*, *Chaetoceros curvisetus* and so on. Among them, *Chaetoceros lorenzii* is the first dominant species, which is absolutely dominant in S3 and S4 stations. *Thalassiosira* sp. is absolutely dominant in S2 station, and *Pseudo-nitzschia delicatissima* is absolutely dominant in S1 station.

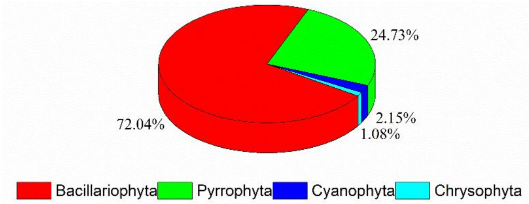

Figure 3. Phytoplankton Species Composition Ratio Diagram

Table 1. Dominant Species of Phytoplankton and Their Dominance and Abundance

Specie	Phylum	Y	Average abundance /×10^5 cells/m^3	Frequency of occurrence
Chaetoceros lorenzianus	Bacillariophyta	0.174	5.34	1.00
Bacteriastrum hyalinum	Bacillariophyta	0.171	7.16	1.00
Thalassiosira sp.	Bacillariophyta	0.084	3.03	1.00
Chaetoceros curvisetus	Bacillariophyta	0.043	4.66	0.50
Chaetoceros borealis	Bacillariophyta	0.040	0.79	0.83
Rhizosolenia styliformis	Bacillariophyta	0.037	0.88	1.00
Pseudo-nitzschia delicatissima	Bacillariophyta	0.033	11.33	0.17
Coscinodiscus granii	Bacillariophyta	0.031	0.75	1.00
Eucampia zodiacus	Bacillariophyta	0.024	1.29	0.83

3.3 The planar distribution characteristics of abundance

The distribution of chlorophyll a concentration and total phytoplankton abundance in each station in Shenquan Bay was quite different. Chlorophyll a ranged from 0.54 to 6.33 mg/m^3, with an average of 2.45 mg/m^3. The total abundance of phytoplankton ranged from 4.14×10^5 to 1.43×10^7 cells/m^3, with an average of 3.89×10^6 cells/m^3. From the perspective of plane distribution, the total abundance of phytoplankton and the overall distribution trend of chlorophyll a are the same, both showing a trend of gradual decrease from offshore waters to offshore waters, and the highest abundance appears at station S1 (Fig.4, 5).

According to the phylum, *Bacillariophyta* were collected in all 6 survey stations. The abundance of *Bacillariophyta* ranged from 3.38×10^5 to 1.41×10^7 cells/m^3. The abundance of *Pyrrophyta* ranged from 3.92×10^4 to 1.65×10^5 cells/m^3. The abundance of other groups (including *Cyanophyta* and *Chrysophyta*) ranged from 9.22×10^2 to 3.43×10^4 cells/m^3. From the perspective of horizontal distribution, the abundance of *Bacillariophyta* and *Pyrrophyta* showed a trend of gradually decreasing from inshore to offshore waters, and the highest abundance appeared at station S1 (Fig.5). The abundance of other groups (including *Cyanophyta* and *Chrysophyta*) showed the opposite trend and the highest abundance appeared at station S6 (Fig.5).

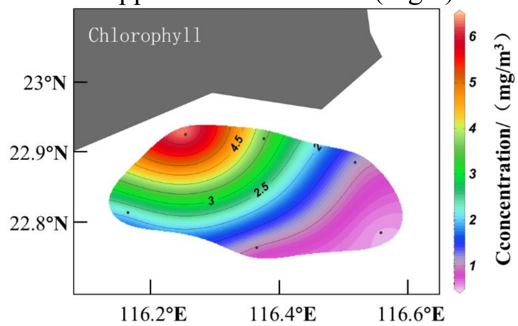

Figure 4. Plane Distribution Characteristics of Chlorophyll a Concentration

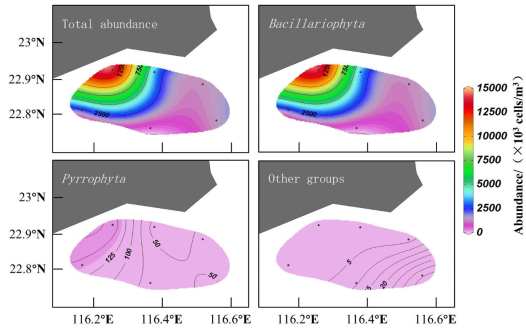

Figure 5. Planar Distribution Characteristics of Phytoplankton Abundance

3.4 Distribution Characteristics of Community Diversity

The Shannon-Weaver diversity index (H') of phytoplankton in Shenquan Bay ranged from 2.25 to 4.25, with an average of 3.19. The Pielou evenness index (J) ranged from 0.41 to 0.75, with an average of 0.57. The Margalef richness index (D) ranged from 1.85 to 2.73, with an average of 2.31. The diversity index (H'), evenness index (J) and richness index (D) all showed a trend of lower values in offshore stations and higher values in offshore stations. The highest values appeared at S5 station and the lowest values appeared at S1 station.

Table 2. Phytoplankton Diversity, Evenness and Richness Index

Station	H'	J	D
S1	2.25	0.41	1.85
S2	2.71	0.49	2.11

Station	*H′*	*J*	*D*
S3	3.14	0.56	2.26
S4	3.20	0.57	2.27
S5	4.25	0.75	2.73
S6	3.59	0.62	2.65
Mean value	3.19	0.57	2.31

3.5 System Cluster Analysis

Based on the systematic cluster analysis of chlorophyll a concentration and phytoplankton community abundance of each station in the survey area, the samples with high similarity will be clustered into one category. The results showed that the samples were divided into two categories according to the similarity. The station S1 was classified as a separate category, and the stations S2 ~ S6 were clustered into one category.

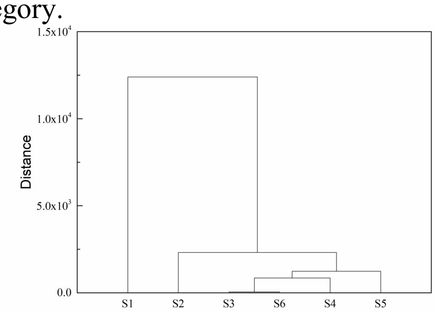

Figure 6. Systematic Cluster Analysis of Chlorophyll a and Phytoplankton Community Abundance Between Stations

3.6 Pearson Correlation Analysis

Pearson correlation analysis of chlorophyll a and phytoplankton (abundance, Shannon-Weaver diversity index) with environmental physical and chemical factors showed that there was a significant negative correlation between chlorophyll a concentration and water depth (r = -0.919, P < 0.01). However, there was a significant positive correlation with ammonia nitrogen (r = 0.915, P < 0.05), nitrite nitrogen (r = 0.952, P < 0.01), nitrate nitrogen (r = 0.954, P < 0.01), inorganic nitrogen (r = 0.970, P < 0.01) and active phosphate (r = 0.887, P < 0.05). The total abundance of phytoplankton and the abundance of *Pyrrophyta* were correlated with ammonia nitrogen (r = 0.890, P < 0.05; r = 0.892, P < 0.05), nitrite nitrogen (r = 0.824, P < 0.05; r = 0.825, P < 0.05), nitrate nitrogen (r = 0.829, P < 0.05; r = 0.831, P < 0.05), inorganic nitrogen (r = 0.864, P < 0.05). There was a significant positive correlation (r = 0.866, P < 0.05). There was a significant positive correlation between the abundance of other groups (including *Cyanophyta* and *Chrysophyta*) and salinity (r = 0.820, P < 0.05). The Shannon-Weaver diversity index of phytoplankton was positively correlated with water depth (r = 0.844, P < 0.05), but negatively correlated with nitrite nitrogen (r = -0.889, P < 0.05), nitrate nitrogen (r = -0.911, P < 0.05), inorganic nitrogen (r = -0.909, P < 0.05) and active phosphate (r = -0.927, P < 0.01).

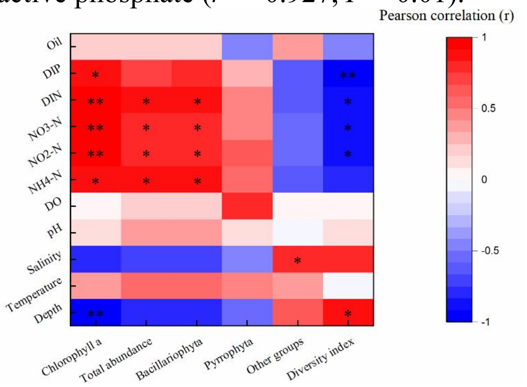

Figure 7. Pearson Correlation Analysis of Chlorophyll a and Phytoplankton Abundance with Environmental Physical and Chemical Factors

4 Discussions

4.1 Phytoplankton Community Composition and Distribution Characteristics of Dominant Species

In the spring survey of phytoplankton in Shenquan Bay, the species composition of phytoplankton community includes four categories: *Bacillariophyta*, *Dinophyta*, *Cyanophyta* and *Chrysophyta*, and *Bacillariophyta* is the main one. At the same time, the dominant species of phytoplankton in this study belong to *Bacillariophyta*, warm-water inshore species such as *Chaetoceros lorenzianus*, *Chaetoceros curvisetus* and *Pseudo-nitzschia debilis*, and widespread species such as *Synedra pellucida* and *Thalassiosira marina*, which are common dominant species in the northern South China Sea[9-13]. Among them, the first dominant species, *Chaetoceros lorenzii*, is a species of *Chaetoceros*, which often appears as a dominant species in the eastern Guangdong sea area in recent years[14-16]. In addition, the dominant species of *Chaetoceros lorenzii*, *Thalassiosira*, *Chaetoceros curvisetus*, *Pseudo-nitzschia flaccidus*, *Rhizoctonia pennata* and *Chaetoceros brevicornis* are all red tide species in the South China Sea[12], indicating that there is a potential risk of red tide in the Shenquan Bay, which may lead to red tide when the environmental conditions are suitable. It is necessary to strengthen the environmental and ecological monitoring of the sea area to prevent and control red tide.

4.2 The Relationship Between the Horizontal Distribution of Phytoplankton Community and Environmental Factors

According to the plane distribution trend of chlorophyll a, total abundance and diversity index of phytoplankton, and their correlation with environmental factors, it was found that the terrestrial input of rivers had an important influence on the structure and abundance distribution of phytoplankton community in this sea area. The low salinity and high nutrient flux caused by river input in the coastal estuary promote the growth of phytoplankton in the estuary, which makes the coastal species of phytoplankton enriched here, and the high nitrogen and low phosphorus make the species mainly diatoms, and the species diversity is less. The offshore area is less affected by terrestrial input, so the species of phytoplankton community are more abundant and the structural differences are greater. The results of this study are basically consistent with previous studies on the influencing factors of phytoplankton community distribution in the northern South China Sea[9, 14, 17].

4.3 Indication of Phytoplankton Community Structure to Water Quality and Environment in the Sea Area

The data analysis results of phytoplankton community in the survey sea area are often used as reference characteristic indexes to evaluate the environmental conditions of the sea area[8]. The Shannon-Weaver diversity index (H') can be used to evaluate the pollution of water bodies in previous studies on the structure of biological communities : if $H' \geq 3$, it represents light pollution or no pollution ; when $1 \leq H' < 3$, it represents moderate pollution ; when $0 \leq H' < 1$, it represents heavy pollution[18]. Combined with the diversity analysis results in this survey, it can be seen that the water environment of S1 and S2 stations is at a medium pollution level, and the water environment of the remaining stations is at a light pollution or pollution-free level. At the same time, the results of systematic cluster analysis distinguished S1 station from the other stations by community division, and classified them into one category alone, indicating that there was a big difference between S1 station community and other station communities. According to the survey results of environmental physical and chemical factors, although the water environmental parameters of each station all reached the national Class I seawater quality standard, the concentrations of nutrients and oils in the waters of S1 and S2 stations were significantly higher than those of the other stations, and these two stations were located in the industrial and urban sea areas in the south of Huilai and the shipping area of Qianzhan port. It can be seen that although the diversity index (H') and the results of systematic cluster analysis cannot fully reflect the environmental conditions of the waters, they can be used as reference indicators to characterize the differences in environmental conditions between different waters to a certain extent.

Acknowledgments

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