Study On The Relationship Between Phytoplankton Indicator Species With Nutrient Contents In The Southern Ocean

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Abstract — It's reported that the composition of phytoplankton indicator species and correlation between them and the nutrient contents in the Antarctic Bay - Antarctic water - South Atlantic - South Indian Ocean. The results showed that there was significant negative correlation between phytoplankton and nutrients investigation. Distribution of phytoplankton cell abundance was Antarctic Bay (18.6×10^4cells/dm^3) > Antarctic water (8.3×10^4cells/dm^3) > South Atlantic (4.5×10^4 cells/dm^3) > South Indian Ocean (3.1×10^4cells/dm^3); Nutrient (N, P, Si) content in the South Atlantic waters was highest in the investigation areas. Phytoplankton indicator species were mainly diatoms components of Chaetoceros dichaeta, Corethron criophilum, Fragilariopsis curta, Fragilariopsis kerguelensis, Nitzschia barkleyi, Proboscia alata, Rhizosolenia styliformis, Trichotoxon reinboldii, Thalassiosira antarctica, etc.; other dinoflagellates components of Gymnodinium gracile, Gymnodinium baccatum, Gyrodinium lachryma, Protoperidinium archiovatum, Protoperidinium obovatum in the Southern Ocean.

Keywords-phytoplankton; indicator species; nutrient contents; the Southern Ocean.

I. INTRODUCTION

The phytoplankton is the primary producer and plays an important role in the ocean ecosystem. They almost have no activity or very weak activity, and drift together with water. Different types of species have different environmental requirements and thus they may be as the indicator of the aquatic environment. The photosynthetic plankton in Southern Ocean is the material base to maintain and supply the huge euphausiids source, and its standing crop in seawater and the primary productivity directly reflect the food web structure and energy transformation level of ocean ecosystem, and is an important link in study on the ocean ecosystem. The photosynthesis of ocean phytoplankton fixes huge amount of carbon dioxide and thus it plays an important role in regulating global climatic change. Hence, the study of Southern Ocean phytoplankton not only has important theoretic meaning to the study on the structure and function of Southern Ocean ecosystem and global cycle, but also has important practical meaning to study of abundance and distribution of euphausiids. Many scholarships studied the phytoplankton in a water nearby Southern Ocean[1-24].This approach will provide scientifically comparable basis for the study on a relationship between phytoplankton and nutrient in different sea areas of Antarctic Bay - Antarctic water - South Atlantic - South Indian Ocean.

II. MATERIALS AND METHODS

A. Sampling

During Chinese Antarctic scientific research period from 1998 to 2013, the surface water samples were collected totally from 78 measurement points (Figure 1) from South Indian Ocean, the South Atlantic, Drake Passage, eastern sea of South America, Chile Punta Arenas Port, Drake Passage, Great Wall Bay, South Atlantic, South Indian Ocean Prydz Bay, round voyage, Zhongshan Bay and Davis Bay. The surface seawater was collected on specified time with plastic cylindrical barrel for analysis of water temperature, salinity, and concentration of nutrients, phytoplankton species and cell abundance.

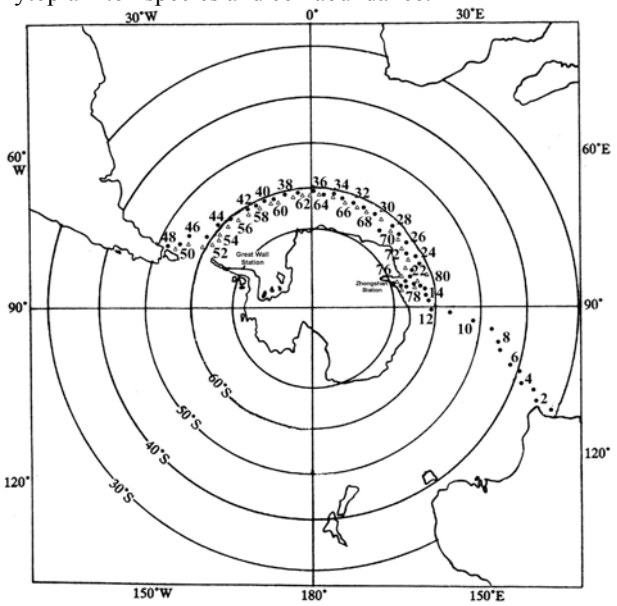


Fig.1 Sampling locations of studied sea area

B. Methods

For observation of phytoplankton cell abundance and dominant species, 500cm^3 water sample is taken, added with 2% neutral formalin for storage, and after thickening is carried to lab for counting the phytoplankton cell and verifying the species with Olympus bio-microscope.

The water temperature was measure with surface thermometer, the salinity measured with coupling induction salinity meter, and chemical nutrients (PO_4^{3-}, NO_3^- and SiO_3^{2-}) tested in accordance with the standing method of seawater analysis-marine investigation specified in "The specification for marine monitoring".

III. RESULTS AND DISCUSSION

A. Indicator species compositions of phytoplankton

Phytoplankton indicator species were mainly diatoms compositions of Chaetoceros dichaeta, Corethron criophilum, Fragilariopsis curta, Fragilariopsis kerguelensis, Nitzschia barkleyi, Proboscia alata, Rhizosolenia styliformis, Trichotoxon reinboldii and Thalassiosira antarctica etc.; other dinoflagellates components of Gymnodinium gracile, Gymnodinium baccatum, Gyrodinium lachryma, Protoperidinium archiovatum and Protoperidinium obovatum in the Southern Ocean (Figure 2).

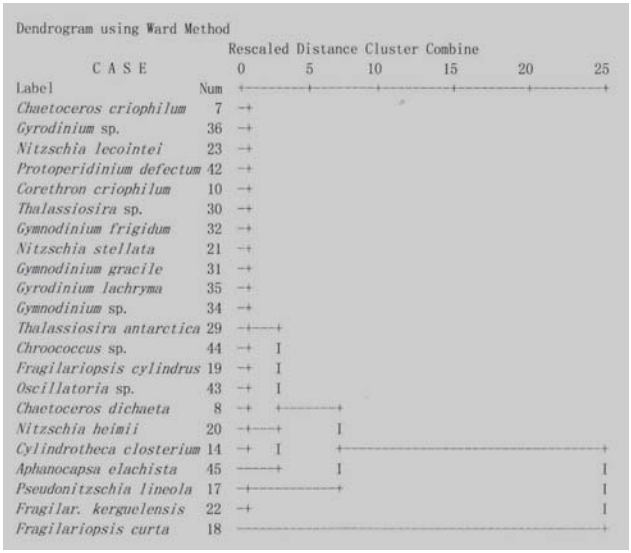


Fig .2 Indicator species composition of phytoplankton

B. Regional characteristics of phytoplankton and nutrients

The high value and low value of phytoplankton abundance occurs in Antarctic coastal gay and in South Indian Ocean at west of Prydz Bay respectively, and the abundance distribution of phytoplankton in different sea areas has obvious regional characteristics. In Antarctic Bay, the mean phytoplankton abundance is 18.6×10^4cells/dm^3, the variation range is 17.6×10^4~21.0×10^4cells/dm^3, the mean content of nutrient (Si) is 54.47mg/L, and the variation range is 50~58mg/L. The mean content of nutrient (N) is 12.16mg/L, the variation range is 10.4~13.6mg/L, the mean content of nutrient (P) is 1.12mg/L, and the variation range is 0.76~1.29mg/L. In Antarctic water, the mean phytoplankton abundance is 8.3×10^4cells/dm^3, the variation range is 7.8×10^4~9.5×10^4cells/dm^3, the mean content of nutrient (Si) is 29.19mg/L, the variation range is 26.12~30.26mg/L, the mean content of nutrient (N) is 40.40mg/L, the variation range is 35.6~42.8mg/L, the mean content of nutrient (P) is 1.50mg/L, and the variation range is 1.32~1.62mg/L. In South Indian Ocean, the mean phytoplankton abundance is 3.14×10^4cells/dm^3, the variation range is 2.58×10^4~3.80×10^4cells/dm^3, the mean content of nutrient (Si) is 47.2mg/L, the variation range is 36~56mg/L, the mean content of nutrient (N) is 36.6mg/L, the variation range is 32.1~40.8mg/L, the mean content of nutrient (P) is 1.63mg/L, and the variation range is 1.34~1.92mg/L. In South Atlantic, the mean phytoplankton abundance is 4.5×10^4cells/dm^3, the variation range is 2.4×10^4~6.8×10^4cells/dm^3, the mean content of nutrient (Si) is 74.5mg/L, the variation range is 52~94mg/L, the mean content of nutrient (N) is 32.47mg/L, the variation range is 28.0~38.0mg/L, the mean content of nutrient (P) is 1.78mg/L, and the variation range is 1.40~2.30mg/L. The phytoplankton cell abundance distribution is in the sequence of Antarctic Bay > Antarctic water > South Atlantic > South Indian Ocean, the nutrient (Si) content distribution is in the sequence of South Atlantic > Antarctic Bay > South Indian Ocean > Antarctic water, the nutrient (N) content distribution is in the sequence of Antarctic water > South Indian Ocean > South Atlantic > Antarctic Bay, and the nutrient (P) content distribution is in the sequence of South Atlantic > South Indian Ocean > Antarctic water > Antarctic Bay (Figure 3).

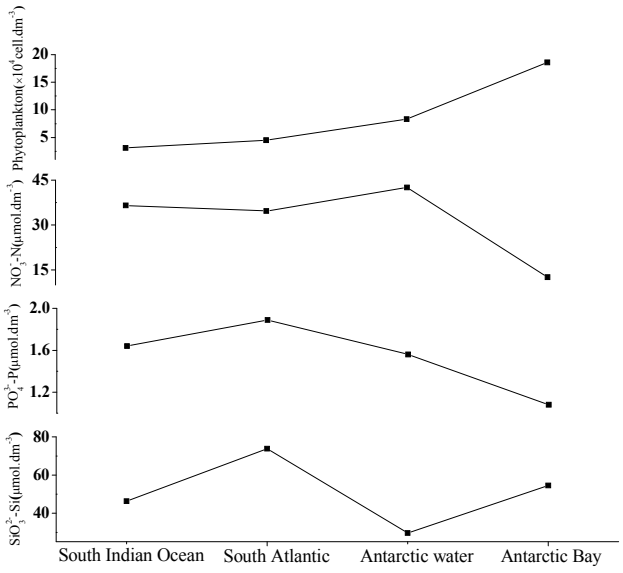
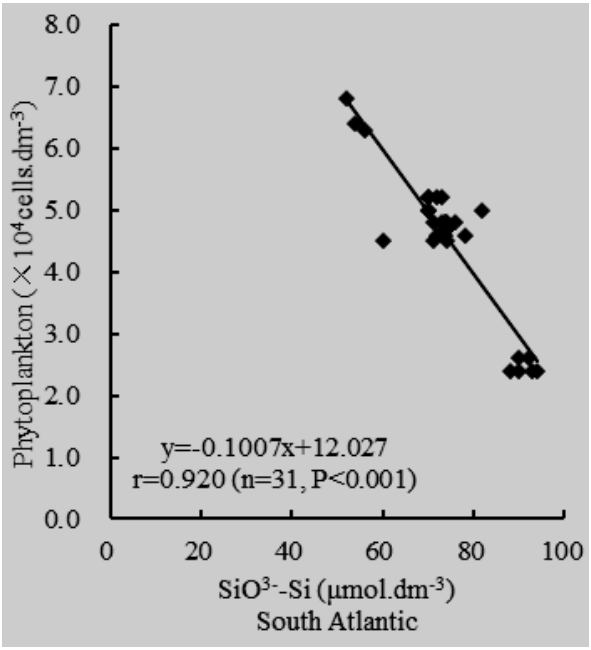


Fig.3 Phytoplankton cell density and nutrient salts in different areas

Due to large-scale turbulent mixing of the ascending

flow and the upper layer water column in Southern Ocean, the nutrient concentration of Antarctic water body is kept at a high value, and even in case of biological consumption of high biological standing crop, the upper layer of water still keeps a relatively high nutrient concentration[19,20] and thus it was characterize by high biomass and high nutrient concentration. Due to the obvious affect of terrigenous on the offshore waters, the dark brown seawater consistent with the red tide, the difficult filtering of seawater and chlorophyll *a* concentration up to 4.28μg/dm^3 were once observed in South America offshore waters. The analysis of low concentration of nutrients of the water (SiO_3^{2-}-Si, 7.42μmol/dm^3, PO_4^{3-}-P, 1.05μmol/dm^3, and NO_3^--N, 6.75μmol/dm^3), 6.4 of N/P ratio and 7.0 of Si/P ratio shows that the low-silicon is possibly the commonest restriction factor of main nutrients for diatom growth[5]. In the area, the mean value of chlorophyll *a* is 1.96±1.56μg/L. Bay has excellent geographic environment, and stable water body, ice and snow in Antarctic melts in summer, and a great amount of ice alga is released into seawater. In South Atlantic, the mean chlorophyll *a* concentration is (1.64±1.00μg/dm^3) and is higher than that of South Indian Ocean (0.98±1.14μg/dm^3) and Drake Passage (0.40±0.20μg/dm^3), which is mainly attributed to the fact that the water in South Atlantic is fertile and rich in nutrients, and especially silicate content (73.84±22.15μmol/dm^3) is much higher than that of other sea areas. The islands in South Atlantic such as Elephant Island, South Orkney Islands, and South Sandwich Islands ceaselessly transport terrigenous N, P, Si, and Fe nutrient elements to ocean and makes the nutrient there extremely rich, and even in peak period of massive growth of phytoplankton, the nutrient concentration is still higher than the limited value necessary for biological growth[4].

The chemical nutrients in South Indian Ocean are the lowest, and the mean concentration of PO_4^-, SiO_3^{2-} and NO_3^- is merely 0.53, 2.46 and 5.22μmol/dm^3 respectively, which denotes that the sea area is an open oligotrophic sea area. The PO_4^{3-} and NO_3^- of South Indian Ocean waters in Sub-Antarctic water are 1~2 times higher than that in subtropical waters, while the SiO_3^{2-} concentration somewhat drops (1.94μmol/dm^3). The seawater nutrients of four sea areas in Antarctic water is remarkably increases, the mean PO_4^{3-} concentration is higher than 1.50μmol/dm^3, the NO_3^-, and the SiO_3^{2-} (except for SiO_3^{2-} in Drake Passage) is 20μmol/dm^3, and the mean SiO_3^{2-} concentration in Drake Passage is merely 7.25μmol/dm^3. The concentrations of various nutrients outside Great Wall Bay are relatively high (PO_4^{3-} : 2.55, SiO_3^{2-} : 53.36, and NO_3^- : 31.80μmol/dm^3). In four sea areas of Antarctic water, the nutrients in South Atlantic are the richest, especially its SiO_3^{2-} is much higher than that of other sea areas else. The nutrients near the sea areas (such as South Atlantic Elephant Island, South Orkney Island, and South Sandwich Islands) are extremely rich, and even in peak period of massive growth of phytoplankton, the nutrient concentration is still higher than the limited value necessary for biological growth[4]. The SiO_3^{2-} in Southern Ocean is possibly the commonest restriction factor of main nutrients for diatom growth[5]. In Davis coastal water, the chlorophyll *a* content is inversely proportional to the content of nitrate, silicate, and phosphate[3]. In summer when the phytoplankton is at most blooming, the nutrient content drops, which denotes that great amount of nutrients is consumed for phytoplankton growth. In Davis coastal water, the individual number of phytoplankton is inversely proportional to the concentration of nitrate, and silicate[7]. In Antarctic Davis coastal, due to relatively high nutrient, massive excreta from coastal seabirds and seal and destruction of abundant moss and algae, the nutrients in coastal waters can to replenish timely, and thus the rich nutrients in Antarctic sea can fully meet the demand for phytoplankton growth[4]. In Antarctic sea areas, the nutrients are extremely rich, their contents exceed the demand for phytoplankton, and even in peak period of phytoplankton growth when nutrients are massively consumed, the concentration are still above the limited value[5]. Antarctic coastal areas are abundant in nutrients, and the nutrient is generally not considered as the restriction factors for phytoplankton growth. The surface water sample of sea areas adjacent to Prydz Bay shows that the mini-type phytoplankton cell abundance is remarkably negatively correlated with N, P, and Si concentration [Zhu et al. 1998a,b]. The result of our analysis is consistent with the negative relationship of author's analysis of relationship between annual Southern Ocean phytoplankton and nutrients[24].



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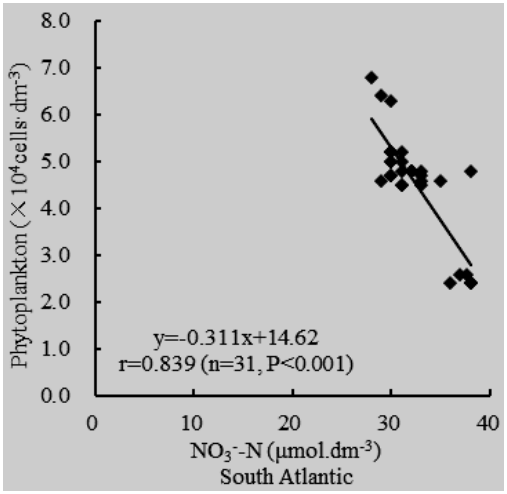

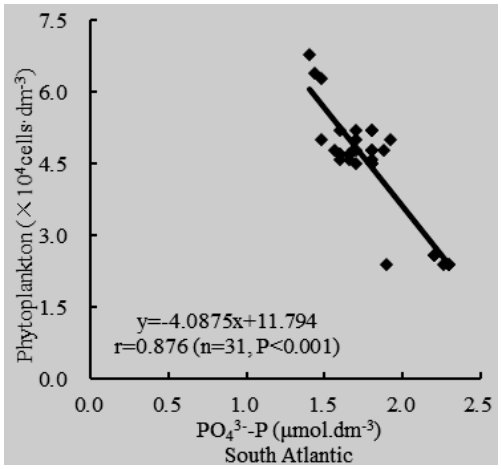

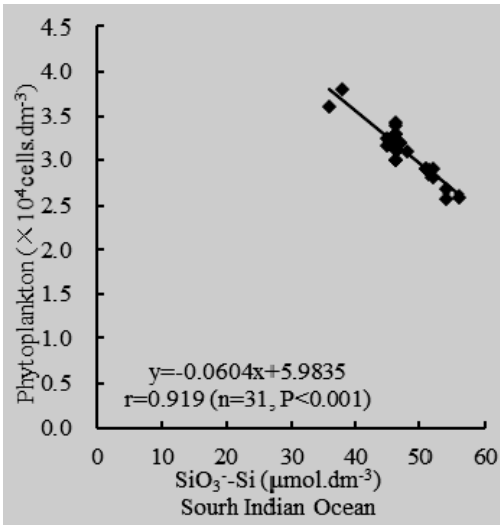

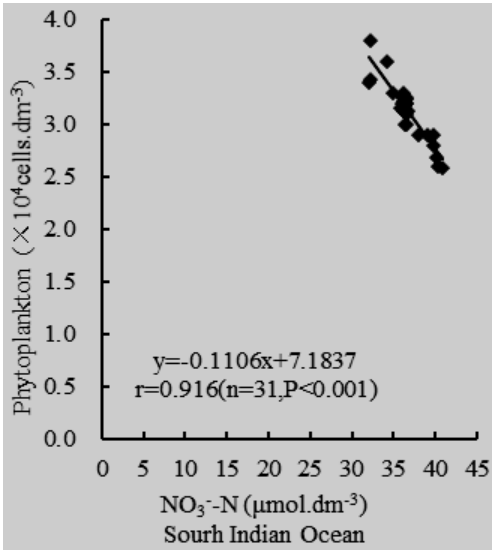

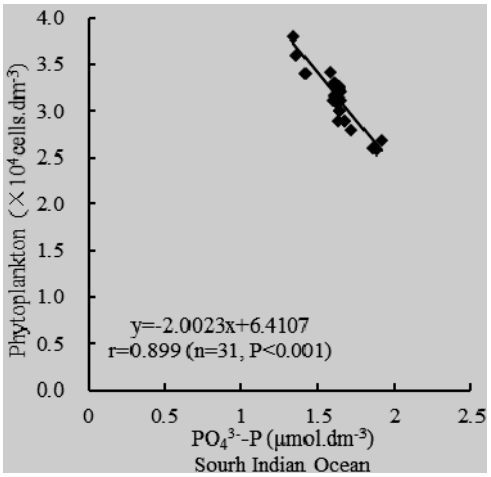

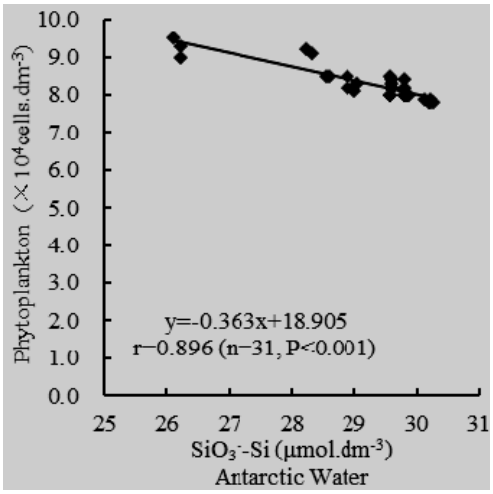

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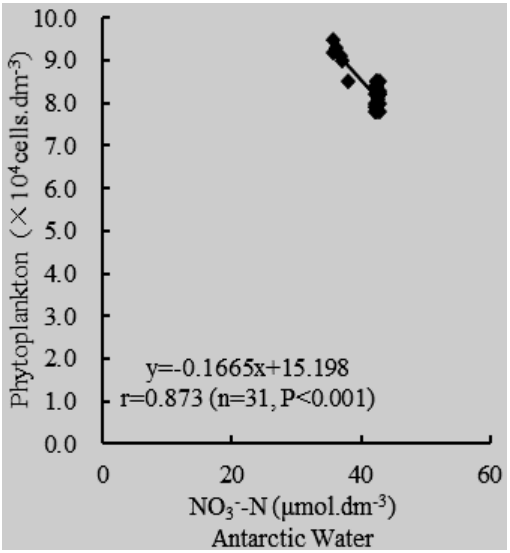

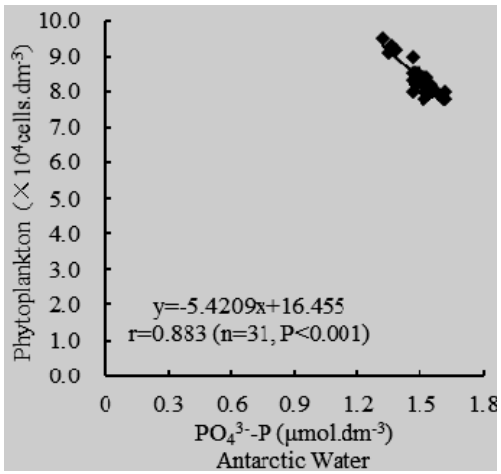

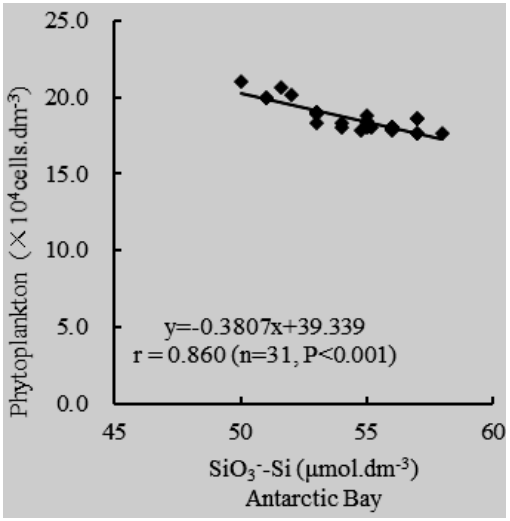

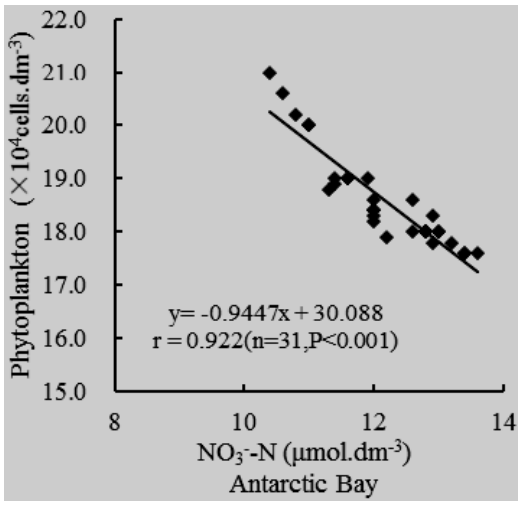

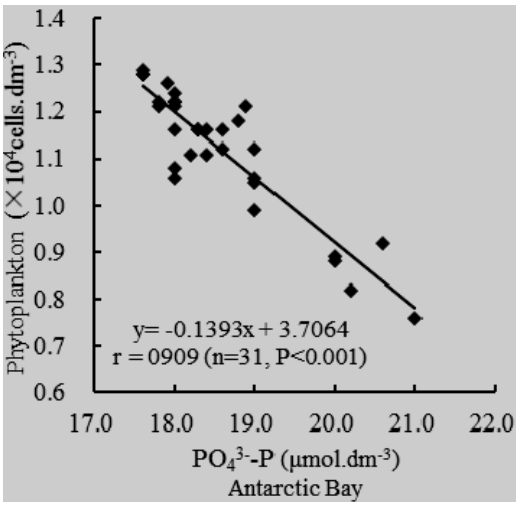

Fig.4 The correlation between phytoplankton and nutrient salts in different areas

The chemical nutrients in South Indian Ocean are the lowest, and the mean concentration of PO_4^-, SiO_3^{2-} and NO_3^- is merely 0.53, 2.46 and 5.22μmol/dm^3 respectively, which denotes that the sea area is an open oligotrophic sea area. The PO_4^{3-} and NO_3^- of South Indian Ocean waters in Sub-Antarctic water are 1~2 times higher than that in subtropical waters, while the SiO_3^{2-} concentration somewhat drops (1.94μmol/dm^3). The seawater nutrients of four sea areas in Antarctic water is remarkably increases, the mean PO_4^{3-} concentration is higher than 1.50μmol/dm^3, the NO_3^-, and the SiO_3^{2-} (except for SiO_3^{2-} in Drake Passage) is 20μmol/dm^3, and the mean SiO_3^{2-} concentration in Drake Passage is merely 7.25μmol/dm^3. The concentrations of various nutrients outside Great Wall Bay are relatively high (PO_4^{3-} : 2.55, SiO_3^{2-} : 53.36, and NO_3^- : 31.80μmol/dm^3). In four sea areas of Antarctic water, the nutrients in South Atlantic are the richest, especially its SiO_3^{2-} is much higher than that of other sea areas else. The nutrients near the sea

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IV. CONCLUSION

Southern Ocean phytoplankton and nutrients are remarkably negatively correlated. The phytoplankton cell abundance distribution is in sequence of Antarctic Bay > Antarctic water > South Atlantic > South Indian Ocean. The nutrient contents of N, P, and Si in South Atlantic areas are higher than that in the other research areas. In Southern Ocean, the phytoplankton indicator species mainly include diatom type Chaetoceros dichaeta, Corethron criophilum, Fragilariopsis curta, Fragilariopsis kerguelensis, Nitzschia barkleyi, Proboscia alata, Rhizosolenia styliformis, Trichotoxon reinboldii, and Thalassiosira Antarctica, and Dinoflagellate type Gymnodinium gracile, Gymnodinium baccatum, Gyrodinium lachryma, Protoperidinium archiovatum, and Protoperidinium obovatum.

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