Silicon limitation on primary production and its destiny in Jiaozhou Bay, China
VI: The ecological variation process of the phytoplankton*

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Abstract The combination effect of light, water temperature and nutrients on phytoplankton growth in Jiaozhou Bay is studied in this paper. The order of importance of the influence on phytoplankton growth is determined as nutrients, water temperature, and light. The influence of these factors unveiled the mechanism of the influence, and revealed the variation process of the nutrients limiting phytoplankton primary production, and of the water temperature influencing the phytoplankton reproduction capacity, and hence influencing the structure of phytoplankton assemblage. Temporal and spatial quantification shows different stages of the influence by water temperature and nutrients on the phytoplankton growth. Moreover, the authors expatiated the ideal state of the phytoplankton growth and the reason of red tide occurrence. People should consider in their activity the input of nutrient Si first, and then the variation of water temperature, advocating sustainable development manner.

Key words: nutrient, water temperature, phytoplankton, temporal-spatial variation, harmful algae bloom (HAB), Jiaozhou Bay

1 INTRODUCTION

In a marine area, temporal and special variation in phytoplankton growth is closely related with that of light, water temperature and nutrient. The key study in this paper is how environmental factors including light, water temperature and nutrients control the temporal and special variation in phytoplankton growth.

The phytoplankton growth in the Jiaozhou Bay of China is studied in primary production and reproduction capacity with the understanding of the relationship and function of environmental and biological factors, and the mechanism of the influence.

1.1 Study area

Jiaozhou Bay (35º 55'–36º 18' N, 120º 04'–120º 23' ) is a small partly-closed coastal waterbody surrounded by cities of Qingdao, Jiaozhou and Jiaonan in the south of Shandong Peninsula (Fig.1), 390 km² in area and 7 meters in depth in average (maximum of 50 m). Development in industry and agriculture in its watershed area has led to the influx of a large amount of sewage from point and non-point sources having brought various nutrients to Jiaozhou Bay.

Water temperature of Jiaozhou Bay has an obvious seasonal variation from 4–5°C in February to 26–28°C in August. Level distribution of it shows that the water temperature outside the bay is higher than inside in autumn and winter, and vise versa in spring and summer. The seasonal variation in salinity is 31.4–32.3, lower inside than outside. Since

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Jiaozhou Bay is shallow, the vertical variation in water temperature and salinity is small. The difference in temperature between bottom and surface is within 2°C, and in salinity, within 0.2 (Zhang and Wang, 2001).

Dagu River is the largest river bringing most Si into the bay. As the flows of the rivers into bay have been reduced in recent years, the Si input to it also dropped greatly. Included are other rivers such as Haipo River, Licun River and Yanghe River etc, they are small or even no natural runoff but industrial and household discharges in middle and lower reaches, taking in more and more N and P into the bay year by year. The changes in the environment for phytoplankton in the bay had greatly taken place.

In recent years, as urbanization has been developing quickly, a large amount of sewage from mariculture, industry and household sources were released to the bay resulting in a worsening water and sedimentary environment near the coastal areas, especially the eutrophication of the bay. Main pollutants are nutrients, COD and oils, among them the nutrients was most serious. An alarming fact is that some previously 150 kinds of invertebrate species in the east coast of the bay were decreased to 38 species, and the habitat and reproduction field of important economical fish, shrimp and seashell have disappeared. Harmful marine damage by HAB and diseases frequently occurred, and the ecological environment of mariculture suffered seriously, causing resource depletion and economic benefit drop-down.

1.2 Influences of light, water temperature and nutrients on phytoplankton growth

The function of marine ecosystem in the whole world depends almost only on the energy fixed by the photosynthesis from marine phytoplankton. The most of the energy comes from the fixation by tiny phytoplankton near surface. Because those marine plants are tremendously importance for all the habitats in the sea, finding out the special conditions of enhancing or restraining their productions is very important. This is the first step toward the direction to understand how the sea reacts and functions on charge of the conditions.

1.2.1 Light

The phytoplankton photosynthesis depends on light. The larger the light intensity in a sea, the higher ratio of the photosynthesis. In addition, the depth of respiration rate of floating plants is in fact a constant, which means the deeper the algae cells in the waters, the larger the values of the respiration rate. The photosynthesis rate largely falls with the weakness of the intensity of light until it is equal to the respiration rate at certain depth.

In the range of proper light intensity, the photosynthesis rate of most phytoplankton is almost in a linear function to the intensity of light. However, near the water surface, the intensity of light is stronger, the photosynthesis increase naturally. Most algae species can keep the photosynthesis at a certain limit, because of the restrain by high intensity of light, or the photosynthesis having reached saturation, at which the photosynthesis could not be enhanced any more. The different plants have different relationships between photosynthesis and light intensity. The maximum value of photosynthesis depends on different most-appropriate intensities of light, which provides a clue in studying the role of photosynthesis in seasonal succession.

The cell division rate is related to the carbon produced by photosynthesis, and further to the intensity of light. Phytoplankton changes the pigment quantity and photosynthetic enzyme quantity in the cells to adapt to the variation in light intensity. When the sea bottom is within the reach of light, the primary production is high, even at high turbidity condition (Odum and Wilson, 1962). Diatoms need only a little light, they can live in the deep waters with very weak light (Fott, 1971).

Light as an ecological factor is no doubt obvi-