Competition Among Dinoflagellate *Alexandrium tamarense*, Raphidophyte *Heterosigma carterae* and Diatom *Skeletonema costatum* under Combinations of Two Temperatures and Five Salinities

YAN Tian (颜天), ZHOU Mingjiang (周名江)
(Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China)

QIAN Peiyuan (钱培元)
(Biology Department, Hong Kong University of Sciences and Technology, Hong Kong, China)

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Abstract Competition among HAB (Harmful Algal Bloom) species Dinoflagellate *Alexandrium tamarense*, Raphidophyte *Heterosigma carterae*, and Diatom *Skeletonema costatum* was studied in the laboratory. Experiments with these three major HAB species under combinations of different salinities (10, 18, 25, 30, 35) and temperatures (19 ℃, 25 ℃) were carried out. The results showed that *S. costatum* successfully competed with the other two species at salinities of 18, 25, 30, and 35 at temperatures of 19 ℃ and 25 ℃. However, *H. carterae* showed its advantage at low salinity of 10 and became the single dominant species at salinity 10 and 25 ℃. *A. tamarense* could not compete successfully with the other two species especially at low salinities. However, it could remain at low density in the presence of higher densities of other algae.

Key words: *Alexandrium tamarense*, *Heterosigma carterae*, *Skeletonema costatum*, Harmful Algal Bloom, competition, temperature, salinity

INTRODUCTION

Frequent occurrence of HAB (Harmful Algal Blooms) has been observed in China since the 1970’s. The great harm to the marine ecosystem and potential threat to human health caused by HAB have become a major concern. However, the mechanism of HAB formation is still poorly understood.

Both physical and chemical factors are considered as main causes for HAB formation, because under optimal temperature, salinity and nutrient conditions, HAB species grow fast and are more likely to form blooms. Changes in these environmental factors may lead to a shift in dominating species within a phytoplankton community. However, biological factors including grazing, competition and interaction among algae are also important for understanding the HAB formation mechanism. Some scientists realized the role of competition among several different species (Cannon, 1996; Davidson et al., 1999). In order to better understand the role of competition in the HAB formation
mechanism and to establish mathematical models locally, three contrasting HAB species Dinoflagellate *Alexandrium tamarense*, Raphidophyte *Heterosigma carterae* and Diatom *Skeletonema costatum* were chosen for the present study. These three HAB species have different harm mechanisms and distribute in southern to northern Chinese waters (Qian et al., 1983; Wang, 1989; Guo, 1994; Li and Xia, 1995). *A. tamarense* is a species potentially producing PSP (Paralytic Shellfish Poison) toxic to humans; *Heterosigma carterae* is a main fish killing species found all over the world; and *S. costatum* is a species causing most frequent HAB in the world, and is sometimes harmful to marine organisms due to oxygen depletion during the decay process of this non-toxic species. A study on the combined effects of temperature, irradiance and salinity on each of the above species was reported (Qian and Yan, 2000). This paper reports the results of research on the competition among these three species in mixed cultures under different combinations of temperature and salinity.

**MATERIALS AND METHODS**

*A. tamarense* (Lebour) Balech (ATHK) isolated from Daya Bay, Guangdong Province, China, was provided by Prof. Qi; *H. carterae* (Hulburt) Taylor was collected from Jiaozhou Bay, Shandong Province, China; *S. costatum* (Greville) Cleve was obtained from a culture of CC-MP1332 (Culture Center for Marine Phytoplankton, Maine, USA). The experiment was conducted in the Biology Department, Hong Kong University of Science and Technology. Cultures were grown in enriched seawater (Harrison et al., 1980). One part of natural seawater blended with two parts of artificial seawater (Harrison et al., 1980) was used to provide natural trace substances for algal growth. To avoid precipitation during autoclaving, the medium was passed through 0.2 μm filter (142 mm) under gravity pressure for sterilization using 316 stainless steel sanitary filter holder. Sterilized 50 ml glass test tubes with caps were used for culturing the specimens. Incubators (Powers Scientific SD 33SE) were used at the 4 designated temperatures. Medium of different salinities were obtained by diluting with double distilled water or adding salt according to artificial seawater recipe when mixing natural and artificial seawater before enrichment. ATAGO hand refractometer was used for salinity measurement. Ostrum Lumilux cool white fluorescent tubes were used to provide 14h: 10h (L:D) light. Irradiance was measured by Licor model LI 185 meter with 2B collector.

Experiments on competition among *A. tamarense*, *H. carterae* and *S. costatum* were conducted with a 2-factor design at combinations of 2 temperature levels (19°C, 25°C) and 5 salinity levels (10, 18, 25, 30, and 35). Irradiance was fixed at $1.6 \times 10^{16}$ quanta/(cm$^2$·s). Each treatment was done in four replicates. Inoculation of the cultures with each species was initiated at equal density (500 cells/ml) in 45 ml fresh medium. One ml sample was taken at day 2, 3, 4, 5, 6, 7, 10, 13, 15, and 22, and fixed with Logol’s solution for counting under inverted microscope using Utermoehl’s technique.

**RESULTS**

**Growth of each algal species in the mixed cultures**

Fig. 1 shows the growth of *A. tamarense*, *H. carterae* and *S. costatum* in the mixed culture under combinations of two different temperatures (19°C, 25°C) and five salinities (10, 18, 25,