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Bacterioplankton and picophytoplankton abundance, biomass, and distribution in the Western Canada Basin during summer 2008

Jianfeng He [a,b,*], Fang Zhang [a], Ling Lin [a], Yuxin Ma [b], Jianfang Chen [c]

[a] SOA Key Laboratory for Polar Science, Polar Research Institute of China, Shanghai 200136, China
[b] College of Environmental Science and Engineering, Tongji University, Shanghai 200092, China
[c] Key Laboratory of Oceanic Ecosystem and Biogeochemistry, Second Institute of Oceanography, State Oceanic Administration of China, Hangzhou 310012, China

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ABSTRACT

During the R/V *Xuelong Arctic* cruise in summer 2008, we investigated bacterioplankton and picophytoplankton abundance, biomass, spatial distribution, and these variables' relationship with environmental variables in the Western Canada Basin. The bacterioplankton and picophytoplankton abundances in the upper 200 m of the water column were 0.17–8.38 $\times 10^5$ cells ml^{-1} and 0.01–17.71 $\times 10^6$ cells L^{-1}, respectively. The average integrated bacterioplankton and picophytoplankton biomasses in the upper 100 m of the water column were 413.3 and 118.8 mg C m^{-2}, respectively. Microbial biomass was comparable with previous reports and distributed mainly in the upper 50 m of the water column.

The bacterioplankton and picophytoplankton biomasses decreased with increasing latitude. Compared with eastern transects, which were strongly influenced by an influx of Pacific water, the western transects had relatively low temperature, high salinity, high nutrients, and high biomass. No significant relationships were detected between assemblages and water temperature or salinity, expect for one between bacterioplankton and salinity in the latitudinal transects. However, a significant negative correlation between picophytoplankton and nutrients and a significant positive correlation between bacterioplankton and picophytoplankton were observed. We suggest that this was mainly caused by the relatively low picophytoplankton biomass, occurrence of heavy stratification (nutricline), and the subsurface chlorophyll maxima (SCM) in study area. Heavy melting of sea ice in summer increases the stratification, which obstructs nutrient supplementation from deep waters, and this might increase the role of microbial assemblages in the upper water column in the Arctic basin area.

1. Introduction

Satellite data have shown that the extent of sea ice in the Arctic Ocean declined quickly in recent summers. The minimum sea ice extent was recorded on September 14, 2007 (4.1 $\times 10^6$ km^2, Comiso et al., 2008). The rate of coverage decline has been much higher than expected (Stroeve et al., 2007), and a recent modeling study showed that the Arctic Ocean would be ice free in summer 2037 (Wang and Overland, 2009). This change in sea ice coverage will deeply influence the Arctic Ocean ecosystem and carbon cycling (e.g., Kirchman et al., 2009; Cai et al., 2010). Melting sea ice causes temperature increases and salinity decreases in the upper water column, which stimulate the growth of bacterioplankton and picophytoplankton (Li et al., 2009; Rokkan Iversen and Seuthe, 2011), and thus melting promotes the dominance and ecological role of these assemblages in the planktonic ecosystem of the Arctic Ocean.

Marine bacterioplankton play important roles in marine ecosystems and carbon cycling (Azam et al., 1983; Arrigo, 2005). Bacterioplankton and picophytoplankton play important roles in the Arctic Ocean microbial loop (Sherr et al., 1997), and they sustain high metabolic activities even in low temperatures (Rich et al., 1997; Rokkan Iversen and Seuthe, 2011). Studies in the Arctic Ocean indicate that picophytoplankton dominates the phytoplankton community for most of the year (Booth and Horner, 1997; Vidussi et al., 2004; Not et al., 2005; Schloss et al., 2008), and maintains its biomass and metabolic activities in winter (Lovejoy et al., 2007; Garneau et al., 2008; Terrado et al., 2008). Bacterioplankton and picophytoplankton research has mainly focused on the continental shelf area (e.g., Cota et al., 1996; Garneau et al., 2008; Schloss et al., 2008), and there is only limited data for the basins (e.g., Sherr et al., 2003; Steward et al., 2007; Li et al., 2009).

* Corresponding author at: SOA Key Laboratory for Polar Science, Polar Research Institute of China, Shanghai 200136, China. Tel.: +86 21 58712091; fax: +86 21 58711663.
E-mail address: hejianfeng@pric.gov.cn (J. He).

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The Canada Basin is subject to both significant sea ice variation and Pacific water inflow. Bacterioplankton and picophytoplankton dominate this oligotrophic region (e.g., Terrado et al., 2008; Tremblay et al., 2009). In summer 2008, we investigated the basic environment and bacterioplankton and picophytoplankton assemblages in the Western Canada Basin (Chukchi Plateau and its northern region) onboard R/V *Xuelong*. The purpose of this study is to identify the abundance, biomass, and distribution of bacterioplankton and picophytoplankton assemblages in this area, to analyze the relationships between biotic and abiotic variables, and to provide a better understanding of the possible response of these two assemblages to environmental change.

2. Materials and methods

2.1. Investigation period and area

During the Chinese R/V *Xuelong* 2008 Arctic cruise, two longitudinal transects (B24–P23 and P37–B33) and three latitudinal transects (B77–B85A, D84–D80, and N01–P31) with 33 stations in total were investigated in the Canada Basin between 11 August and 4 September. The transects and station locations are shown in Fig. 1.

2.2. Measurements of marine environmental variables

Sea ice thickness and concentration were visually observed from the bridge following the guide compiled by the Antarctic Sea Ice Processes and Climate (ASPeCt) program (Worby et al., 2008). Water temperature and salinity were measured onboard with a SBE 911 plus CTD underwater unit. Photosynthetically active radiation (PAR) data were collected with a PRR-800 profiling reflectance radiometer, and measurements were taken at 12 stations located south of 80°N.

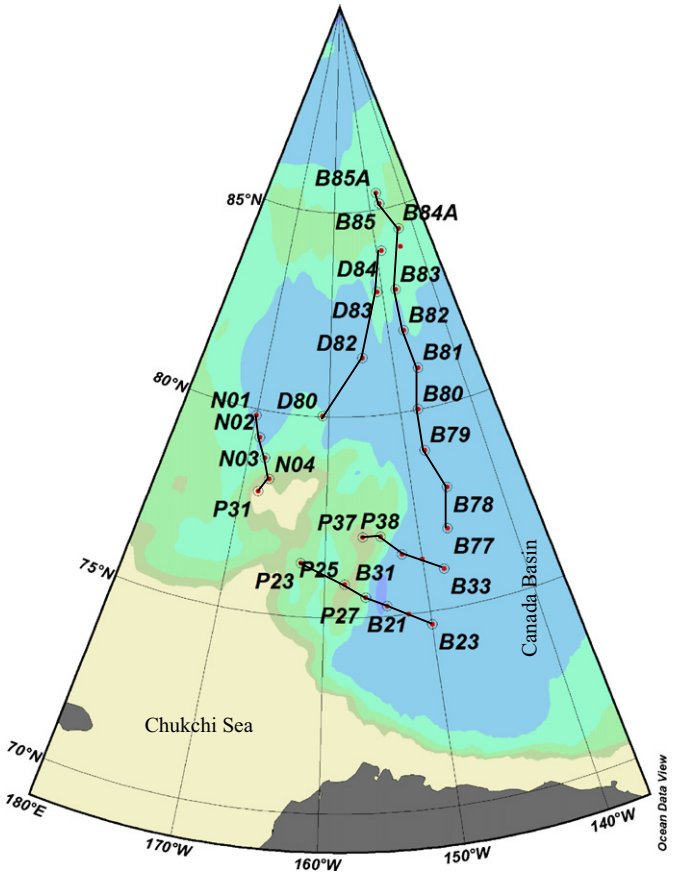

Fig. 1. Sampling stations in the western Canada Basin.

Water samples were collected with the SBE 911 plus CTD unit (equipped with 24 water samplers with a 10 L volume for each) at depths of 0 m, 30 m, 50 m, 75 m, 100 m, 125 m, 150 m, 200 m, and in the layer with the chlorophyll *a* maximum. Subsamples (100 ml) were collected from each layer and filtered through 0.45 μm pore size, 47 mm diameter GF/F glass filters. Filtered water samples were stored at 0.5 °C, and the nutrients (nitrate, nitrite, phosphate and silicate) were measured onboard with a Skalar san++ nutrient autoanalyzer within 48 h using the method of Grasshoff et al. (1999).

For chlorophyll *a* (Chl *a*) concentration measurements, 500–1000 ml water samples were collected at the same depths as nutrient samples, and filtered onto 0.47 μm pore size, 47 mm diameter GF/F glass filters. Each filter was placed into a clean glass tube. Chl *a* was extracted with 10 ml 90% acetone for 24 h in a −20 °C refrigerator, and measured with a Turner Designs 10 fluorometer (Parsons et al., 1984).

2.3. Abundance and biomass of picoplankton

The sampling depths for bacterioplankton and picophytoplankton (with size <2 μm) were the same as those for nutrients and Chl *a*. Pre-filtered water samples (with 50 μm pore size mesh) were collected into 100 ml clean brown PET bottles. Subsamples (3 ml) were pipetted into 5 ml centrifuge tubes, and fixed with a paraformaldehyde–glutaraldehyde mixture (final concentrations of 1% and 0.5%, respectively) for 15 min in the dark. Samples were quick-frozen in liquid nitrogen for 30 min, and stored at −80 °C until analysis (Balfoort et al., 1992). Frozen samples were thawed in the laboratory, and 2 ml subsamples were used to determine the picophytoplankton abundance with a BD FACSCalibur flow cytometer. One milliliter subsamples were added to a 10 μl dose of SYBR Green I (final concentration 1/1000 v/v), and bacterioplankton abundance was detected with the flow cytometer after 15 min of staining in the dark (Binder et al., 1996). Picoplankton abundances were obtained using CellQuest software.

Bacterial carbon was calculated from cell abundance using a conversion factor of 20 fg C cell^{-1} (Lee and Fuhrman, 1987), and picophytoplankton carbon was estimated with a factor of 0.533 pg C cell^{-1} (Booth and Horner, 1997).

The distribution of biological variables and nutrients in the water masses in the study area was analyzed according to the method of Schloss et al. (2008). Pearson correlations among bacterioplankton and picophytoplankton abundances and environmental variables (temperature, salinity, nitrate, nitrite, phosphate, silicate) were analyzed with SPSS 17.0 software.

3. Results

3.1. Basic environmental characteristics

Sea ice coverage ranged from 0% to 100% and the only large open water was observed in the P38–B33 transect (Table 1; Fig. 2a). The sea ice thicknesses were low, and first-year sea ice dominated the study area. Scattered multi-year sea ice was observed mainly in the northwest of the Chukchi Plateau (transect N01–P31). The average ice thicknesses along the cruise were between 0.2 m and 2.5 m. The thicknesses were less than 1.6 m in most stations (Table 1).

Fig. 3 shows the PAR ratio profiles at 6 stations. The depths of the euphotic zone were between 41.8 m and 69.9 m with an average of 60.8 m, and the depths of the euphotic zone east of the