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The relationship between cyanobacteria and environmental factors in the Bering Sea

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Abstract During the first Chinese Scientific Expedition to the Arctic in July - September 1999, cyanobacteria in the Bering Sea were measured by epifluorescence microscopy. Cyanobacterial abundance varied from 0 to 7.93×10^3 cell/ml and decreased along a northerly directed latitudinal gradient in horizontal distribution. Cyanobacteria did not occur at station B1 - 12 (north of 60 °N). Vertically, high cyanobacterial abundance appeared in the upper 25 - 50 m and decreased rapidly below 50 m. There were no cyanobacteria at the 150 m. Seawater temperature and NH_4^+ - N are suggested to affect the distribution of cyanobacteria.

Key words cyanobacteria, biomass, Bering Sea.

1 Intrduction

Marine cyanobacteria (*Synechococcus* spp. cells < 2 μm in size) are a group of small unicellular autotrophic procaryotes. Since their investigation by Waterbury *et al.* (1979) and Johnson and Sieburth (1979), it has become evident that cyanobacteria are abundant and widespread in the world's ocean. Cyanobacteria are considered to be significant contributors to primary production in many different marine environments, particularly in oligotrophic oceanic waters (Stockner and Antia 1986; Murphy and Haugen 1985; Iturriaga and Mitchell 1986; Olson *et al.* 1990) and they are a key component of the microbial foodweb (Li *et al.* 1983; Caron *et al.* 1991; Burkill *et al.* 1993). There are a number of studies about cyanobacterial abundance, contribution and function in the cycling of organic matter in the ocean. In contrast to that, little is known about cyanobacteria in the polar seas. Cyanobacterial abundance decreases along a northerly directed latitudinal gradient. The decline correlates with decreasing temperature in the North Atlantic (Murphy and Haugen 1985), and *Synechococcus* seems to be absent from the regions of the polar seas where the water temperature remains below 5 °C throughout the year (Waterbury *et al.* 1986). However, Cyanobacteria are discovered in Antarctica from the Prydz Bay to the Great Wall Station, and to Zhongshan Station (water temperature -0.3 °C - 2.1 °C), and their abundance is related to temperature (Ning *et al.* 1996). The distributions of cyanobacteria have also been little studied in the Bering Sea. During the first Chinese expedition to the Arctic in July-September/1999, the variations of cyanobacterial abundance and their relations with environmental factors in the Bering Sea were studied.

2 Materials and methods

Water samples were collected during the first Chinese expedition to the Arctic on 20 – 31 July 1999 of the R/V *Xuelong* in the Bering Sea (Fig. 1). Water samples were obtained from surface, 25 m, 50 m, 100 m and 150 m at each station. A rosette containing twelve 5L Niskin bottles was mounted on the CTD to take water samples. Water (100 ml) for cyanobacterial enumeration was transferred to sterile brown bottles was fixed at a final concentration of 1 % glutaraldehyde, and then held at 4 °C in the dark until counted (within one month). Cyanobacteria were enumerated by epifluorescence microscopy (OPTON II with oil immersion objective 40 ×, HBO 50 W and BP450 – 490, FT510, LP520 filter block) using 25 mm diameter black Nuclepore filters of 0.2 μm pore size through which a known volume (10 – 100 ml) of water had been filtered at < 100 mmHg vacuum (Waterbury *et al.* 1979; Wood *et al.* 1985). Cyanobacterial numbers were converted to biomass by multiplying by 294 fgC/cell (Cuhel and Waterbury 1984; Gallager *et al.* 1994).

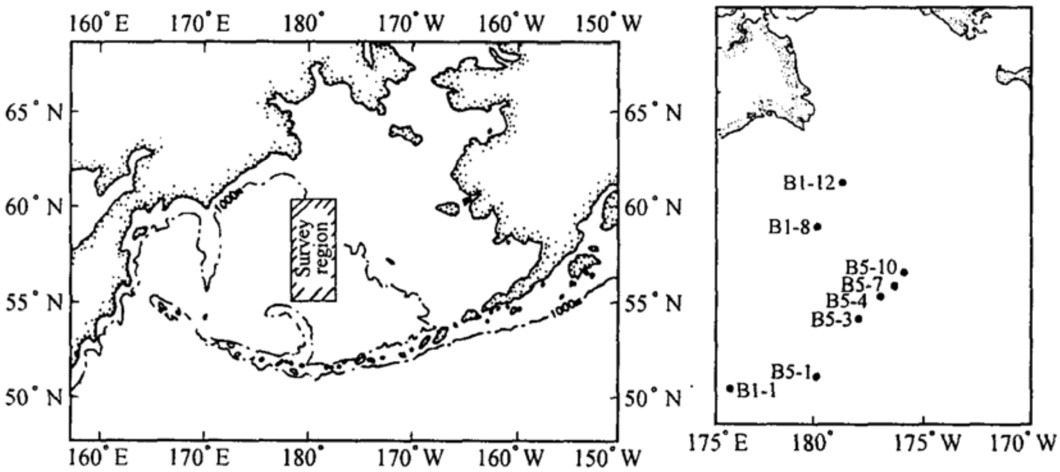

Fig. 1. Location of the investigation area and stations in the Bering Sea.

3 Results and discussion

Cyanobacterial abundance ranged from 0 to 7.93×10^3 cell/ml, decreased along a northerly directed latitudinal gradient in horizontal distribution. Cyanobacterium was not found at B1 – 12 station north of 60 °N (Table 1). Cyanobacteria were present in the upper 25 – 50 m and their abundance decreased rapidly below 50 m. There were no cyanobacteria at 150 m (Fig. 2). There was a maximum abundance of cyanobacteria in 25 m at B1 – 1 station.

In the horizontal distribution, cyanobacterial biomass was correlated to water temperature. It was found that a maximum value of cyanobacterial biomass (0.59 mgC/m^3) on the surface was at B5 – 1 station, where the temperature (7.34°C) was lowest (Fig. 3A). The cyanobacterial biomass (2.33 mgC/m^3) was the highest at 25 m of B1 – 1 station, while the temperature (5.63 °C) was the second lowest (Fig. 3B). At 50 m, it was the same case in which highest of cyanobacterial biomass (0.62 mgC/m^3) was found at B5 – 1 station, while the temperature (2.81 °C) was low (Fig. 3C). The vertical distribution of cyanobacterial biomass and temperature was more or less consistent at B1 – 8, B5 – 1, B5 – 3, B5 – 4 and B5 – 7 stations, while it was different at the other two stations (B1 – 1 and B5 – 10). A number of cyanobacteria occurred below the temperature isoline of 5 °C. For instance, in 50 m the average temperature was 3.16 °C (2.32°C–3.77 °C) and the average cyanobacterial biomass was 0.38 mgC/m^3 (0.04 – 0.62 mgC/m^3). This result showed the water temperature was not the only cause that affected the distribution of cyanobacterial biomass.

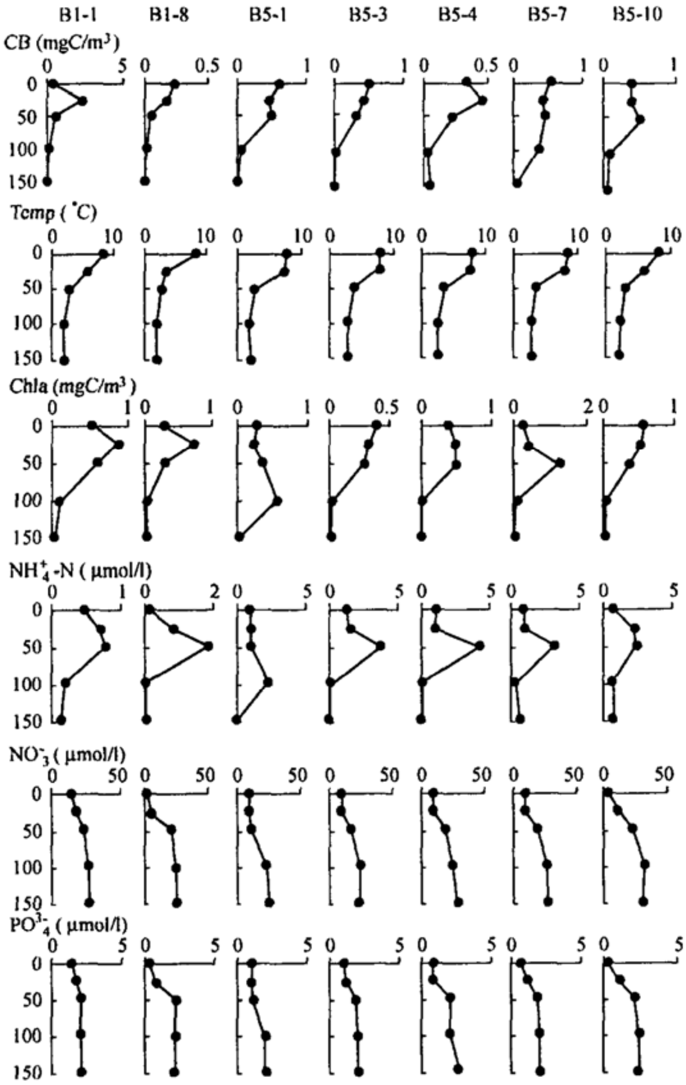

Fig. 2. Vertical distribution of cyanobacterial biomass (CB), Temp, Chl *a*, NH_4^+ – N, NO_3^- and PO_4^{3-} in the Bering Sea 1999.

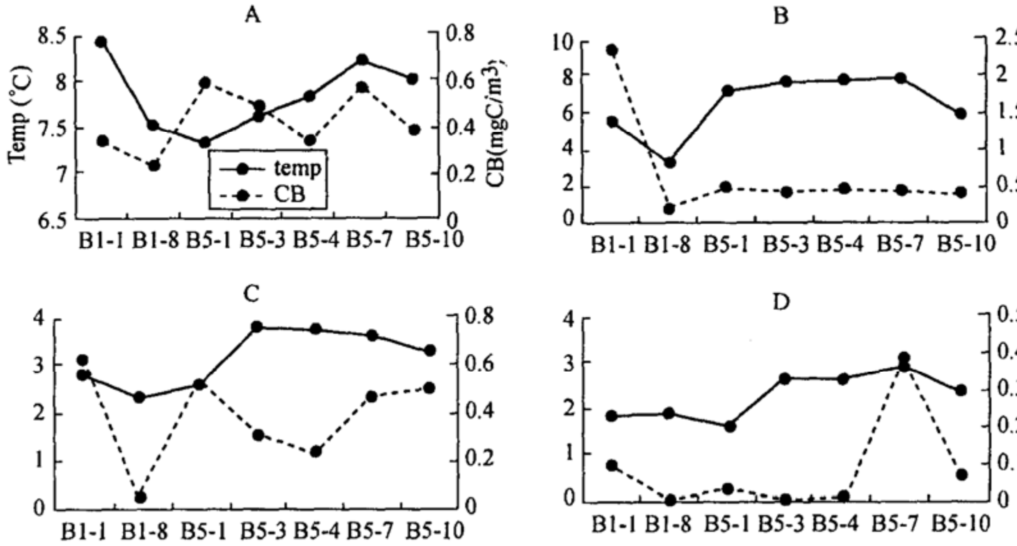

Fig. 3. Horizontal distribution of temperature and cynaobacterial biomass in Bering Sea.
A: surface layer; B: 25 m layer; C: 50 m layer; D: 100 m layer.

The horizontal distribution of cyanobacterial biomass was similar to that of ammonium (NH_4^+ − N) on the surface and that of chlorophyll-*a* in the 25 m (Fig. 4 − 5). The vertical distribution of cyanobacterial biomass was alike to that of ammonium (NH_4^+ − N) and chlorophyll-*a* (Fig. 2). Especially, the vertical distribution of cyanobacterial biomass was similar to that of chlorophyll-*a* at B1 − 1, B5 − 3 stations and that of ammonium (NH_4^+ − N) at B1 − 1, B5 − 4 stations. There was a negative relationship between the vertical distribution of cyanobacterial biomass and that of nitrate (NO_3^- − N) and phosphate (PO_4^{3-} − P). It was similar that main variations of cyanobacteria, chlorophyll-*a* and ammonium (NH_4^+ − N) take place in the water above 100 m. Phytoplankton biomass was estimated from chlorophyll-*a*, using a C:Chl ratio of 37 in the Bering Sea (Kirchman *et al.* 1993). The ratio of cyanobacterial biomass (CB) to phytoplankton biomass (PB) or CB: PB was 0.004 to 0.347 (mean 0.042 ± 0.305, $n = 27$). The cyanobacterial biomass occupied less than 10 % of phytoplankton biomass in all depths (CB: PB was 0.004 to 0.072, mean 0.030 ± 0.042, $n = 26$) except in the 100 m of B5 − 7 station (CB: PB was 0.347). So the cyanobacteria are not an important component of phytoplankton biomass in the Bering Sea. However, the cyanobacterial biomass was positively correlated with chlorophll-*a* (Fig. 6). It is possible that ammonium (NH_4^+ − N) was an important factor that affected the distribution of cyanobacterial biomass in the Bering Sea.

The cyanobacterial abundance varied from 0 to 7.93×10^3 cell/ml in the Bering Sea, which is was lower than that in the North Atlantic (Norfolk-Iceland-Azores, 2.0×10^3 −

11.0×10^3 cell/ml, water temperature 4.9°C–10.9 °C) at the same latitude (Murphy and Haugen 1985), but higher than that in the Drake Strait (Antarctic Ocean, $0.61 \pm 0.50 \times 10^3$ cell/ml, water temperature 4.0 ± 2.89 °C) (Ning *et al.* 1996).

In this study, water temperature greatly affected the distribution of cyanobacterial biomass and ammonium (NH_4^+ − N) seems also to be an important factor. In the North Atlantic (Norfolk-Iceland-Azores), the decrease in cyanobacterial abundance with increasing latitude did also correlate with decreasing water temperature (Murphy and Haugen 1985). In the Antarctic Ocean, the cyanobacterial abundance decreased with increasing latitude and decreasing temperature, while the logarithmic value was positively correlated to the temperature (Ning *et al.* 1996).

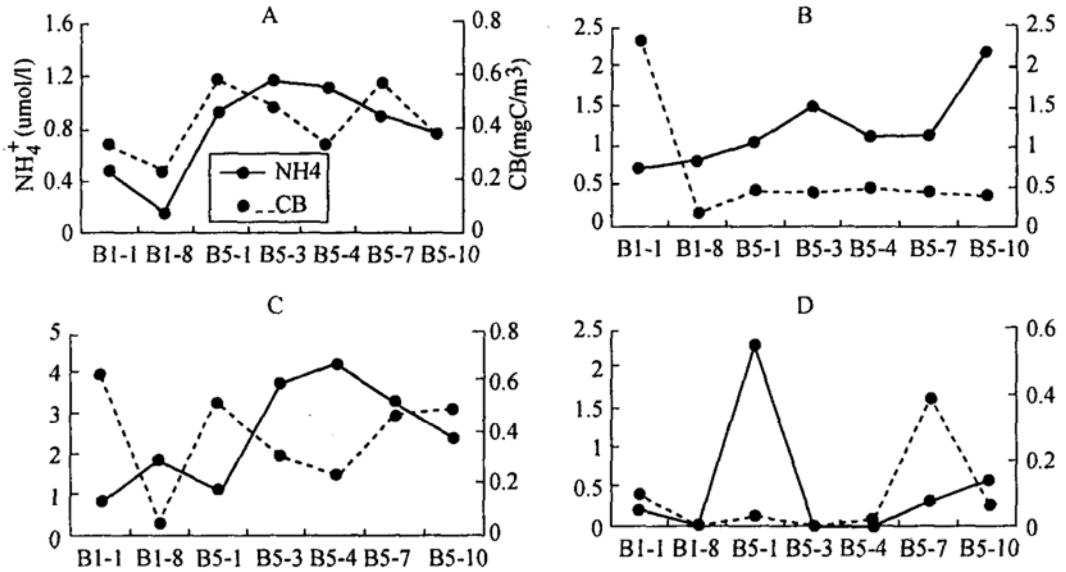

Fig. 4. Horizontal distribution of NH_4^+-N and cynaobacterial biomass in Bering Sea.
A: surface layer; B: 25 m layer; C: 50 m layer; D: 100 m layer.

In the Bering Sea, the cyanobacterial abundance decreased along a northerly latitudinal gradient, but there were some cyanobacteria ($0.06 \times 10^3 - 2.12 \times 10^3$ cell/ml, mean $0.91 \pm 1.21 \times 10^3$ cell/ml, $n = 14$) in the regions where water temperature dropped below 5 °C (1.59°C − 3.22 °C, mean 2.78 ± 1.19 °C, $n = 14$) (Table 1). The result of this study was different the conclusion that a notable exception seems to be the absence of *Synechococcus* from the regions of the polar seas where the water temperature remains below 5 °C throughout the year (Waterbury *et al.* 1986).

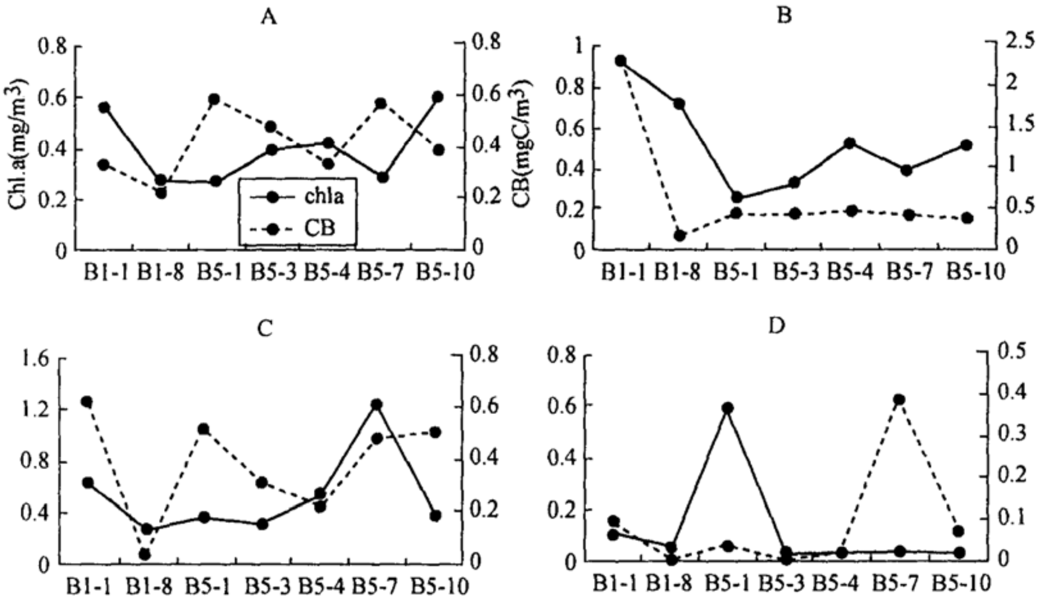

Fig. 5. Horizontal distribution of Chl *a* and cynaobacterial biomass in Bering Sea.
A – surface layer; B – 25 m layer; C – 50 m layer; D – 100 m layer.

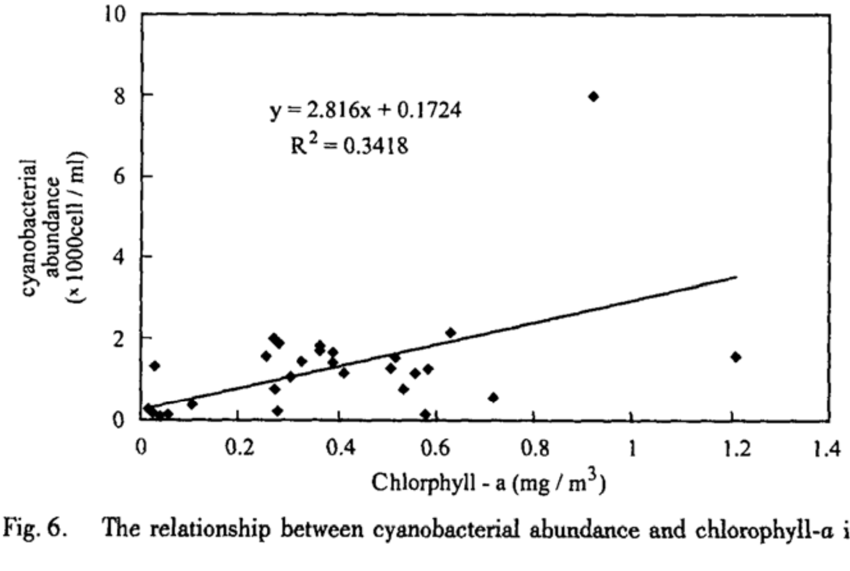

Fig. 6. The relationship between cyanobacterial abundance and chlorophyll-*a* in the Bering Sea.

Table 1. Vertical distribution of cyanobacterial abundance and biomass in the Bering Sea *

Depth	St.	B1 - 1	B1 - 8	B1 - 12	B5 - 1	B5 - 3	B5 - 4	B5 - 7	B5 - 10
	a	1.14	0.79	0	2.00	1.65	1.14	1.93	1.30
1m	b	0.34	0.23	0	0.59	0.49	0.34	0.57	0.38
	t	8.41	7.55	6.59	7.34	7.67	7.79	8.17	8.02
	a	7.93	0.57	0	1.53	1.43	1.56	1.40	1.29
25m	b	2.33	0.17	0	0.45	0.42	0.46	0.41	0.38
	t	5.63	3.22	1.37	7.26	7.59	7.75	7.85	5.98
	a	2.12	0.14	0	1.77	1.04	0.77	1.61	1.69
50m	b	0.62	0.04	0	0.52	0.31	0.23	0.47	0.50
	t	2.81	2.32	1.37	2.59	3.77	3.72	3.61	3.27
	a	0.34	0	0	0.12	0	0.06	1.31	0.23
100m	b	0.10	0	0	0.04	0	0.02	0.39	0.07
	t	1.83	1.92	1.08	1.59	2.65	2.67	2.90	2.43
	a	0	0	0	0.07	0	0.16	0.24	0.14
150m	b	0	0	0	0.02	0	0.05	0.07	0.04
	t	1.83	2.00	1.14	1.93	2.79	2.84	2.84	2.34

* a :cyanobacterial abundance, $\times 10^3$ cell/ml; b: cyanobacterial biomass, mgC/m^3; t: water temperature, °C.

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