Photoadaptation of photosynthetic pigments and light absorption of ice algal community

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Light availability is a major limiting factor for ice algal production at the bottom of sea ice. In addition to the reduced light intensity, spectral composition of light reached to the ice algal layer of sea ice is also narrowed to blue and green regions. Ice algae are showed specific photophysiological adaptation to low light intensity and narrowed spectral distribution, i.e. the obligatory shade adaptation in the light absorption and accessory photosynthetic pigments (APS) composition for ice algae. Ice algal communities are widely distributed in sea ice between high latitude (polar sea ice) and middle latitude (temperate sea ice) in the northern hemisphere. Latitudinal difference results in difference in the spectral composition and intensity of irradiance reached to the ice algal layer of sea ice between polar and temperate sea ice. These latitudinal differences may be expected to affect on photophysiological adaptation of seasonally well established ice algal communities. This study aims to investigate photophysiological adaptation in the temperate sea ice, and to compare their photophysiological adaptation to light condition at their habitat in polar sea ice. *In situ* incubations were conducted in the light and dark bottles at the undersurface of sea ice at the end of ice season in Saroma-ko Lagoon, Hokkaido, Japan. Dominated species, the ratio of APS to chlorophyll *a* and chlorophyll *a* specific light absorption ($a*_{ph}$) were investigated for the ice algal community. The ice algal communities in both years were dominated by diatoms. The similar relative abundance of APS to Chl *a* were observed in both years (Table 1). Chlorophyll *a* specific absorption coefficients at 440nm, 675nm, and the average of $a*$ for PAR ($a*_{ph[440]}$, $a*_{ph[675]}$, and $a*_{ph[PAR]}$) were about 2 fold higher in 2007 than those in 2006. The APS serve the role of light adaptation in the region from 450 to 550 nm. The ratios of Fuco to Chl *a* and Chl *c* to Chl *a* obtained in the present study corresponded to only 30 to 50% of those reported in the polar ocean (Table 1). These results might suggest that the ice algae in Saroma-ko Lagoon are adapted to the flatter spectral composition of light reached to their habitat and that they do not necessarily enhance the light-harvesting capacity at the shorter wavelengths of PAR such as that in polar sea ice. The adaptation to low light intensity can be associated with high package effect. The package effect is usually observed when cellular Chl *a* contents are increased under low light intensity, resulting in the decrease of $a*_{ph}$. The Chl *a* specific absorption coefficients at 675 nm ($a*_{ph[675]}$) in the present study are within the range reported in the polar sea ice. These comparison may suggest that $a*_{ph[675]}$ in the present study may be lowered by the accumulation of Chl *a* in the cells. The adaptation to low light intensity can be also observed in the pigment composition. The relative abundance of Chl *a* is high for diatoms which adapt to low light intensities. However, the proportion of Chl *a* to total pigments for the shade-adapted ice algae in polar sea ice was lower than that in temperate sea ice (Table 1). This discrepancy could be explained by the further adaptation which a relative abundance of APS increase for enhancing the light-harvesting capacity at the shorter wavelengths of PAR to both low and blue-dominated light (Fig.2). The photophysiological characteristics of ice algal community in the temperate showed the adaptation to low light intensity, while those in the polar sea ice showed both the shorter-wavelength of PAR and low light intensity. This latitudinal difference in the photophysiological adaptation could be related with ice structure.

Table 1. Photophysiological characteristics related to light-harvesting for ice algal communities in polar and temperate sea ice.

Spectral		Intensity	
Fuco (mol/mol)	Chl *c*	Chl *a* (%)	References
Polar sea ice			
1.24	0.41	37	Robinson et al. (1995)
1.62	0.45	-	Robinson et al. (1998)
1.25	0.37	-	Lazzara et al. (2007)
Temperate sea ice (Saroma-ko Lagoon)			
0.42	0.21	57	Kudoh et al. (2003)
0.55	0.20	54	This study

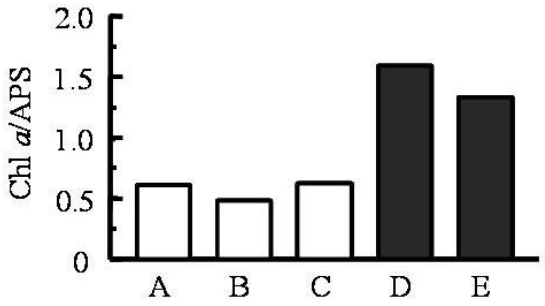

Fig. 1. The ratio of Chl *a* to APS (Chl *a*/APS) for ice algal community in polar (white bars) and temperate (dark bars). Data sources are as follows: (A) Robinson et al. (1995), (B) Robinson et al. (1998), (C) Lazzara et al. (2007), (D) Kudoh et al. (2003), (E) this study.