西部北太平洋亜寒帯域に生息する植物プランクトンに対する鉄・光制限

Effects of light and iron availability on the photophysiology of phytoplankton in the western subarctic Pacific

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The western subarctic Pacific is known as one of the major High Nutrient Low Chlorophyll (HNLC) regions (e.g., Tsuda et al., 2003; Suzuki et al., 2009; Hattori-Saito et al., 2010; Sugie et al., 2013; Fujiki et al., 2014). This region is, on the other hand, the largest CO_2 sink by biological carbon pump activity (Takahashi et al., 2001; Honda et al., 2003; Kawakami et al., 2004; 2015). These characteristics can be related to the active photosynthesis by phytoplankton (Isada et al., 2010; Yoshie et al., 2010; Suzuki et al., 2011). Nishioka et al. (2013; 2014) suggested that intermediate water transport processes supply sedimentary iron (Fe) from the continental shelf of the Sea of Okhotsk through the Kuril straits to the Pacific. Yoshimura et al. (2010) and Suzuki et al. (2014), on the other hand, discussed that deep intertidal mixing in the straits (e.g. Yagi and Yasuda, 2012) induces Fe limitation due to Fe-light co-limitation (*sensu* Sunda and Huntsman, 1997). In this study, effects of Fe supply on the photophysiology and community composition of phytoplankton in the western subarctic Pacific, near the Kuril Islands and the eastern Kamchatka Peninsula, were investigated by conducting on board Fe-manipulated incubation experiments during the R/V *Professor Multanovskiy* expedition in summer in 2014. Photophysiology of phytoplankton was assessed by measuring photosynthesis-irradiance (*P-E*) curves and variable chlorophyll (chl) *a* fluorescence. Community composition was investigated with pigment analysis with an ultra-high performance liquid chromatography (UHPLC) (Suzuki et al., 2015) and scanning electron microscopy (SEM). Additionally, at stations with the deepest (an offshore station near the eastern Kamchatka Peninsula) and the second shallowest (an offshore station near the Urup and the Bussol’ Strait) mixed layer depths (MLD), on board Fe-manipulated bottle incubation experiments were carried out with the following four treatments: Initial (Time-zero); Control (without Fe addition); +Fe (10 nM Fe added); and +DFB (1 μM Fe chelator DFB added). During the expedition, chl *a* concentrations were > 5 mg m^{-3} at stations in the Sea of Okhotsk and in the Bussol’ Strait at the beginning of the expedition, whereas low chl *a* concentrations (< 1 mg m^{-3}) were found at the other stations. Interestingly, considerable amounts of chl *a* derivatives (pheophorbides and chlorophyllide *a*) were observed at stations near the Kamchatka Peninsula and the Kruzenshtern Strait, suggesting that the high abundance of senescent algal cells and/or high activity of zooplankton grazing. These indicated that the expedition was conducted in the latter half of the bloom. Diatoms accounted for 40–96% in the chlorophyll biomass, and the SEM suggested that the genus *Chaetoceros* was exclusively dominant with some resting spores in the diatom community throughout the expedition. Although *in situ* Fe concentrations did not show any correlation with photophysiological parameters (p>0.05, Spearman-Rank correlation), primary productivity was positively correlated with euphotic depths (i.e., 1% light depths) and E_k (light saturation indices of the *P-E* curves) (p <0.05; Spearman-Rank correlation), suggesting that light availability could be a driving factor for primary production during the expedition. The E_k values reflected the MLD at the bottle incubation stations, in short, the low E_k was observed at the deepest MLD station, and vice versa. At the second shallowest MLD station, Fe addition did not affect the biomass and maximum quantum yields of photosystem II (F_v/F_m),

whereas those values were significantly enhanced by the Fe addition ($p<0.05$) at the deepest MLD station. These results suggested Fe-light co-limitations could occur near straits of the Kuril Islands in summer.

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