学 位 論 文 内 容 の 要 約

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学 位 論 文 題 名

Community dynamics and photophysiological capabilities of diatoms
in the water column and sediments of the Pacific Arctic region

（太平洋側北極海の水柱および堆積物中における珪藻類の

群集動態と光生理能力に関する研究）

The Pacific Arctic has a broad shelf region, and the northern Bering and Chukchi Seas display among the highest daily primary productivity in the Arctic. The high primary productivity supports the rich marine ecosystems in this region through the food webs. In winter, sea ice covers the Arctic region, and light availability in the water column is limited, restricting primary production. After light environments are improved as the sea ice retreats, large microalgal blooms occur during spring and summer. Therefore, changes in sea ice dynamics can affect the timing and magnitude of algal bloom. However, few studies investigate the influence of the changes in the sea ice dynamics on the diatom communities, although diatoms often dominate the microalgal communities during blooms. Because the growth characteristics of diatoms differ among species and can affect the assimilation efficiency by zooplankton, a detailed assessment of changes in the diatom community is essential for considering its effects on marine ecosystems. Many diatom species can form resting stages under unsuitable conditions for growth. Since diatoms, including their resting stages, settle to the seafloor due to their heavy silica frustules, many viable diatoms can be found in the sediments, especially in shallow, high-productive regions. However, even though the Pacific Arctic has a shallow shelf area and a significant interaction between the water column and the seafloor, more knowledge is needed on the photophysiological response of viable diatoms in the sediments when the organisms are released into the water column. Hence, the potential of diatoms in the sediments for primary production has yet to be well-studied. In this study, we aimed to evaluate the effects of spatiotemporal changes in sea ice dynamics on the diatom community in the Pacific Arctic region. In addition, we tried to clarify the roles of diatoms in the sediments of this region in the primary production processes by assessing their photophysiology.

Firstly, we investigated the impact of two-year differences in sea ice dynamics on diatom community composition in the northern Bering Sea (chapters 2 and 3). In this region, the timing of the sea ice retreat in 2018 was earlier than in 2017. In chapter 2, we obtained seawater samples in July 2017 and 2018 from a few layers. Diatoms and dinoflagellates in the samples were identified and counted by light microscopy. The microalgal communities were classified by cluster analysis based on the abundance data. As a result, we found that their composition in the Chirikov Basin differed between 2017 and 2018. Typical spring-summer diatom species, such as *Chaetoceros socialis* complex, were dominant in 2017, whereas in 2018, cosmopolitan diatom species often found in the fall season, such as *Thlassionema nitzschioides*, were dominant. These differences in diatom assemblages during summer were most likely related to changes in the timing of the sea ice retreat, but detailed mechanisms of diatom community succession remained unclear. To discuss the mechanisms further in chapter 3, we assumed that viable diatom communities in the sediments reflected those in the water column before the observations and investigated these microalgal cells. The sediments used for the analysis were sampled during the same expedition as in chapter 2. The concentrations and composition of viable diatom communities in sediments were estimated by the most probable number (MPN) method. Consequently, viable diatom communities in the sediments south of St. Lawrence Island showed distinct differences between 2017 and 2018. Sea ice-associated diatoms accounted for a relatively high proportion in 2017, while they were hardly detected in 2018. On the other hand, the development of diatom blooms caused by *Thalassiosira* spp. probably occurred in the water column during 2018. In other words, while the light environment and habitat for sea ice-associated diatoms were unsuitable for their proliferation due to the earlier sea ice retreat in 2018, diatoms such as *Thalassiosira* spp. actively grew in the water column after the sea ice retreat. These results suggest that spatiotemporal changes in sea ice dynamics in the Pacific Arctic region affect the diatom community composition during spring and summer blooms.

We then evaluated the impact of geographic differences in sea ice dynamics on diatom communities (chapter 4). Under the assumptions mentioned above, we investigated the viable diatom communities in sediments over the shelf of the Pacific

Arctic using the MPN method. As a result, in the northern Bering Sea and the Chukchi Sea, where the open-water period is extended, open-water diatoms such as *Chaetoceros* spp. and *Thalassiosira* spp. were dominant. In contrast, sea ice-associated diatoms were prevalent in the southwestern Beaufort Sea, where sea ice existed for a relatively long period. Different diatom taxa may contribute to the bloom in the Pacific Arctic shelf depending on the timing of sea ice retreat and the associated light environment.

Our studies in chapters 3 and 4 revealed the existence of viable diatoms, including their resting stages, with extremely high concentrations in the Pacific Arctic sediments. Diatom resting stages are triggered by light exposure to germinate. Diatoms in sediments can proliferate after light irradiation, but dramatic changes in the light environment may be stressful for the microalgal cells. Therefore, the photophysiological response of diatoms in sediments to light exposure was assessed through laboratory culture experiments using sediments from the Chukchi Sea (chapter 5). We incubated replicated sediment samples suspended by seawater under the two irradiance levels of 30 and 300 μmol photons m^{-2} s^{-1} for 7 days. During the incubation, we investigated diatom concentrations and photosynthetic physiology in terms of pigment composition, the maximum quantum yield of photochemistry (F_v/F_m) in photosystem II, and the photosynthesis-energy (P-E) parameters. After light exposure, diatoms in sediments actively grow throughout the incubation period, with *C. socialis* complex mainly contributing to the increase in the diatom community. Changes in the maximum quantum yield of photochemistry (F_v/F_m) in photosystem II, photosynthesis-energy (P-E) curve parameters, and microalgal pigment composition indicated that the physiology related to photosynthesis and photoprotection responded quickly after light exposure. Even when photosynthetic activity was reduced by intense light, it was restored within a few days, indicating a high degree of physiological plasticity of diatoms in sediments to light changes.

To further study the interaction between diatoms in sediments and the water column, diatom communities in the sea surface and sub-surface of the Chukchi Sea were investigated during the autumn (chapter 6) when the sediments are likely to be resuspended due to strong wind events. First, diatoms were analyzed by scanning electron microscopy and DNA metabarcoding. Then, a correlation network analysis was performed after constructing a dataset with the advantage of both analytical techniques for diatoms. The results revealed that diatom resting stages, which would be of sedimentary origin, were dominant in the surface and sub-surface layers of the southern Chukchi Sea. It also suggests that diatoms in sediments could be transported into the euphotic layer. Therefore, viable diatoms in the sediments of the Pacific Arctic shelf could germinate and proliferate actively due to their high physiological plasticity and the unique environmental characteristics of the shallow shelf.

This thesis suggests that diatoms in the Pacific Arctic shelf significantly contribute to the biogeochemical processes not only through the downward transport of carbon and silicon (i.e., the biological pump) but also through a seeding role of sedimentary diatoms in the water-column primary production. In addition, diatom communities in the water column and sediments can readily alter their composition with changes in sea ice dynamics. Therefore, it is crucial to study how changes in diatom assemblages can affect biogeochemical cycles and marine ecosystems in the Pacific Arctic region, where climate change, including sea ice reduction, has been prominent recently.