Contribution of fecal pellet-like dinoflagellates to the carbon sequestration in the seasonal ice zone of the Southern Ocean

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Ice edge phytoplankton bloom is an important factor affecting on the food web and the carbon sequestration in the seasonal ice zone of the Southern Ocean. As a sinking particulate organic carbon (POC), zooplankton fecal pellets, marine snow, and phyto-detritus are known as important drivers for export carbon flux from surface layer. To investigate composition of sinking particles and those variability with sea ice melts, sinking particles have been recovered in off Wilkes land since the austral summer in 2016. In the preliminarily observation, we found a large number of fecal pellet (FP)-like dinoflagellates (FLDs) containing phytoplankton in the trap samples at 50 m taken in 2016. The export fluxes in this season would be underestimated to assess FLDs as FP. In the present study, we investigated on FLD's dynamics during the melting of sea ice.

Sediment traps were deployed at 50 m depth (63°52' S, 109°87' E) from December 10, 2016 to January 8, 2017, at 50 m and 80 m (63°29' S, 110°00' E) from January 17-18, 2017, at the 60 m and 150 m (63°29' S, 109°59' E) from January 14 to 19, 2019, at the 60 m and 150 m (64°16' S, 116°58' E) from December 10, 2019 to January 20, 2020. Sinking particle samples were fixed in neutral Lugol's solution (final conc. 5-20%) and stored at 4℃ until analysis. After removing zooplankton swimmers, FLDs and FPs were identified into several groups based on their morphological characteristics. Numbers and lengths of them were counted and measured under the optical microscope. POC fluxes were estimated using numbers and volumes of FLDs and FPs. To reveal the organisms predated by the FLDs, the eukaryotic community structures were analyzed by high throughput sequencing of 18S rRNA gene amplicons (V9 region) using the total DNA of FLDs. Taxonomic affiliations were assigned using PR2 database.

Based on morphological features such as protrusions and grid-like patterns on the cell membrane, FLDs were found in all samples except for short term observation in January 17-18, 2017. As similar cells have been found in the other Antarctic waters, which were tentatively identified to be dinoflagellates, the FLDs was also assumed to be a type of dinoflagellates. FLDs, which were covered by thin membrane were resolved and released ellipsoidal FPs. The POC fluxes of FLDs and its derived ellipsoidal FPs was 5.1 ±5.4 mg C m^{-2} day^{-1} in the spring of 2016 at depth of 50 m and were 1.3 ±0.8 mg C m^{-2} day^{-1} and 0.2 ±0.2 mg C m^{-2} day^{-1} in the summer of 2019 at depths of 60 m and 150 m. These values were almost equal to depths of 60 m and 150 m from the spring of 2019 to the summer of 2020. Those results indicate the melting sea ice season and the dynamics of FLDs are closely, and the FLDs still contribute to the carbon transport even one month after sea ice melting. In the analysis of the eukaryotic community structure of FLDs, 69 ±32% of the total OTU was identified to a dinoflagellate *Gyrodinium rubrum*, which was estimated to be FLDs itself. The remaining OTUs, the contents of the FLDs mainly consisted of other species of *Dinoflagellata* (37 ±25%), *Ochrophyta* (36 ±27%), unidentified Eukaryota (16 ±27%). The eukaryotic communities of the ellipsoidal FPs showed similar structures, suggesting that the ellipsoidal FPs were derived/discharged from FLDs, which is consistent with the microscopic observation as mentioned above. Comparison of the eukaryotic community structure of FLD contents with that in seawater indicated that FLDs were estimated to be an opportunistic feeder.

In this study, dinoflagellates, which are similar to fecal granules were found, and they contributed to carbon sequestration into the depth layers in conjugation with the occurrence of ice bloom. It is essential to further investigate the physiology and ecology of this species to deeply understand the carbon transport in the Southern Ocean.

Keywords: Southern Ocean, carbon sequestration, fecal pellet-like dinoflagellates, sediment trap, Gyrodinium rubrum

