Role of fecal pellet-like dinoflagellates in the carbon transport and food webs in the seasonal ice zone of the Southern Ocean

Jaekyeng Han[1], Ayuko Kagesawa[2], Masayoshi Sano[2], Shintaro Takao[3], Ryosuke Makabe[2,4,5], Masato Moteki[4,5], Tsuneo Odate[2,4], Norio Kurosawa[1]

[1]*Soka University*
[2]*The Graduate University for Advanced Studies (SOKENDAI)*
[3]*National Institute for Environmental Studies*
[4]*National Institute of Polar Research*
[5]*Tokyo University of Marine Science and Technology*

Introduction

In the seasonal ice zone of the Southern Ocean, the ecosystem changes in conjunction with a fate of sea ice in each season. The sea ice melts from spring to summer with releasing nutrients and phytoplankton that are incorporated during sea ice formation, causing phytoplankton blooms in the surface layer occasionally. With a salinity decrease by the ice melting, a relatively shallow surface mixed layer is formed. As a result, the material cycle is suppressed vertically with the deeper layer. Under these conditions, particulate organic carbon (POC) represented by phytodetrital materials and fecal pellets (FPs) of zooplankton plays an important role in carbon transport from the surface to the deeper ocean as a form of sinking particles. This carbon transport function is referred to as a biological pump. To analyze in detail what kind of sinking particles produced during summer blooms are transported to the subsurface ocean layer and mesopelagic zone in the seasonal ice zone, and how much POC flux is as the sinking particles, a time-series sediment traps was deployed during the austral summer of 2016. As a result, a large number of FP like dinoflagellates (FLDs) containing a large amount of phytoplankton, mainly diatoms, are found in the traps. According to Okano et al. (2019), the POC flux of FLDs at 50 m depth when sea ice began to melt reached 22 ± 14% (mean ± SD) of the total POC flux, suggesting that FLDs contributed greatly to the biological pump function in this area. We therefore conducted experiments to further examine a role of FLDs in the food web and a contribution of FLDs to the biological pump using sinking material samples collected from time-series sediment traps newly deployed at two depths in the same region during the austral summer of 2019.

Material and Methods

Sinking particles were collected from the 60 m and 150 m (63.29°S, 109.59°E to 63.27°S, 110.1°E) by two time-series sediment traps equipped to a drifter system from January 14 to 19, 2019. Samples were fixed in neutral Lugol's solution (final conc. 5%) and stored in a refrigerator at 4 °C prior to analysis on land. After removing zooplankton swimmers, the FLDs and FPs were counted, and their volumes were measured from shape types under an optical microscope. The numbers and volumes of FLDs and FPs were converted to carbon mass to estimate POC flux using an existing conversion factor (González et al., 1994). To identify the FLDs itself and the community structure of small eukaryotes fed by FLDs, the total DNA extracted from FLDs was applied for PCR amplification of 18S rRNA gene (V9 region) using a eukaryotic universal primer set (1389F and 1510R). Nucleotide sequences of the PCR amplicons were determined by the high throughput sequencing; the operational taxonomic unit (OTU) clustering and analyses of eukaryotic community structures were conducted. The taxonomic affiliations were assigned using PR2 database (version 4. 12. 0, Guillou et al., 2013).

Results and Discussion

Protrusions and fine grid-like patterns that were not found in the FPs were observed in the FLDs (Fig. 1). As similar cells have been found in other Antarctic waters, which were tentatively identified to be dinoflagellates (Buck et al., 1990), the FLDs was also assumed to be a type of dinoflagellates. The POC fluxes of FLDs at depths of 60 m and 150 m were 4.1 ± 2.6 mg C m^{-2} day^{-1} and 0.7 ± 0.4 mg C m^{-2} day^{-1}, respectively. Interestingly, these values are almost equal to those at the time of sea ice melting reported by Okano et al. (2019), indicating that the FLDs still contribute to the carbon transport even one month after sea ice melting. An ellipsoidal content covered by thin membrane was discharged from FLDs by a dissection. This was very similar in shape and size to the ellipsoidal FPs, which had been counted separately from FLDs in this study. Assuming that a large number of the ellipsoidal FPs are derived from the FLDs, the total POC flux of the FLDs and the ellipsoidal FPs corresponds to 34 ± 22% and 50 ± 10% of total carbon flux at depths of 60 m and 150 m, respectively.

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 consisted of other species of Dinoflagellata (37 ± 25%), Ochrophyta (36 ± 27%), unidentified Eukaryota (16 ± 27%), Fungi (4 ± 9%), and others (6 ± 14%) (Fig. 2a). The eukaryotic communities of the ellipsoidal FPs showed similar structures (Fig. 2b), suggesting that the ellipsoidal FPs were derived 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.

This study revealed that FLD species, *Gyrodinium* sp. plays a significant role in the carbon transport referred to as the biological pump in the seasonal ice zone of the Southern Ocean. This species is also detected in the sea ice in the same area. It is essential to investigate the physiology and ecology of this species, whether it blooms with sea ice melting, to deeply understand the carbon transport in the Southern Ocean.

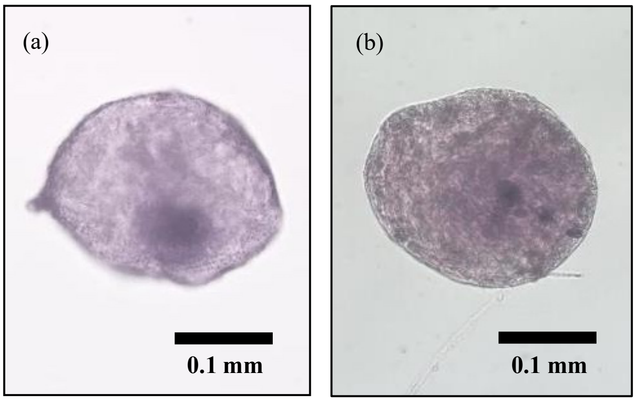

Figure 1. Microscope photos of (a) a fecal pellet-like dinoflagellate and (b) ellipsoidal fecal pellet.

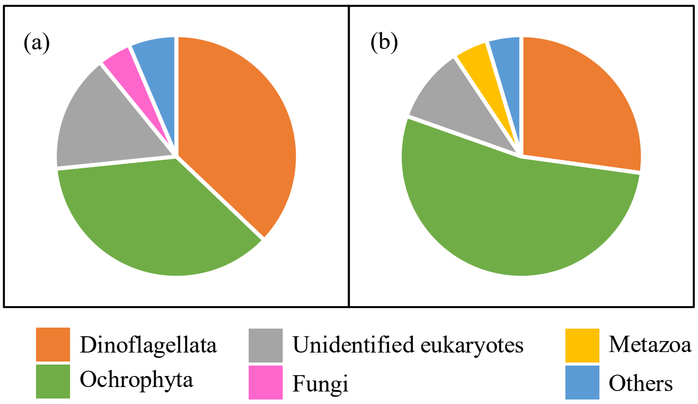

Figure 2. Total eukaryotic community composition of (a) fecal pellet-like dinoflagellate contents and (b) ellipsoidal fecal pellets.

References

Guillou, L., Bachar, D., Audic, S., Bass, D., Berney, C., Bittner, L., Boutte, C., Burgaud, G., de Vargas, C., Decelle, J. et al., The Protist Ribosomal Reference database (PR^2): a catalog of unicellular eukaryote Small Sub-Unit rRNA sequences with curated taxonomy, Nucleic Acids Res., 41, D597-D604, 2013.

H.E. González, S.R. González and G.A. Brummer, Short-term sedimentation pattern of zooplankton, faeces and microplankton at a permanent station in the Bjørnafjorden (Norway) during April-May 1992, Mar. Ecol. Prog. Ser., 105, 31-45, 1994.

K.R. Buck, P.A. Bolt and D.L. Garrison, Phagotrophy and fecal pellet production by an athecate dinoflagellate in Antarctic sea ice, Mar. Ecol. Prog. Ser., 60, 75-84, 1990.

Okano, S., Kagesawa, A., Takao, S., Makabe, R., Moteki, M., Odate, T and Kurosawa, N., Eukaryotic community structure in sinking particles in the seasonal sea ice zone of the Southern Ocean. In: the 10th Symposium on Polar Science; 2019 Dec 3-5; Tokyo, Japan. OBp24. Available from: https://www.nipr.ac.jp/symposium2019/program/OB.html