—研究ノート—
Scientific note

Phytoplankton cell flux under fast ice near Syowa Station, Antarctica, in austral summer 1991/1992

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1991/1992 年夏季の南極昭和基地周辺の定着氷下における植物プランクトン細胞フラックス

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要旨: 1992 年 1 月 7 日から 2 月 6 日の期間，南極昭和基地周辺の定着氷下にセジメントトラップを設置し，沈降粒子を採集した．得られた試料を基に顕微鏡観察を行い，植物プランクトン細胞数のフラックス（**PN**）及び細胞体積から換算した植物プランクトン炭素フラックス（**PC**）を見積もった．**PN** フラックスは，1 月上旬に低く，1 月末から 2 月初めに最も高く，その時間変動は過去の報告と一致した．しかしながら，その値は過去の報告値に比べ数倍低く，上層の植物プランクトン現存量の年変動に起因するものと考えられた．**PC** フラックスも，**PN** フラックスと同じような時間変動を示した．以前に報告したクロロフィルフラックスの値と **PC** フラックスを比較すると，**PC** : クロロフィル比は，文献値に比べやや低い約 17 と見積もられた．

Abstract: Settling particles were collected using sediment traps, which were deployed beneath fast ice near Syowa Station, Antarctica, from January 7 to February 6 1992. Fluxes of phytoplankton cell number (PN) and carbon (PC) were estimated based on microscopic observation and determination of cell volume. During the present study period, PN flux was low in the early half of January and reached a maximum at the end of January or the beginning of February. Although patterns of temporal change of PN flux were consistent with a previous study, the values were several times lower in the present study than in the previous report. Interannual variation of phytoplankton biomass in the surface layer seems to result in differences in phytoplankton flux. The temporal variation of PC flux was similar to that of the PN flux. Comparing PC flux and chlorophyll *a* (Chl *a*) flux, which was reported in a previous study, a PC : Chl *a* ratio of about 17 was estimated. This value is slightly lower than literature PC : Chl *a* ratios.

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1. Introduction

Settling of organic matter from the surface productive layer is a significant food source for benthic organisms (*e.g.,* Carey, 1987), and consequently, it is important to estimate the vertical flux of organic matter in considering their food supply. The first attempt to collect settling particles under fast ice near Syowa Station was carried out by Fukuchi and Sasaki (1981) using sediment traps. Sasaki and Hoshiai (1986) pointed out that phytoplankton sinking during the summer growing season have a high probability of reaching the sea floor.

Few authors have estimated sinking particle flux under fast ice near Syowa Station based on microscopic observation (Saito *et al*., 1998; Ishikawa *et al*., 2001). Information on settling particle composition is limited. Investigation of the sinking particle composition is important not only for understanding the carbon cycle in the ecosystem, but also for evaluating the nutritional value for benthic organisms. Saito *et al*. (1998) showed that the phytoplankton flux in terms of cell number was higher in early summer (November to December) than in early spring (August to September). Ishikawa *et al*. (2001) revealed the temporal variation in phytoplankton cell flux during the summer of 1997/1998 (January to early February) and reported a maximum flux of 1300×10^6 cells $m^{-2} d^{-1}$. However, there are no comparable data on phytoplankton flux at a similar site during summer. Suzuki *et al*. (1998) suggested that there is considerable interannual variation in the vertical flux of sinking particles in terms of dry weight and total organic carbon under fast ice near Syowa Station. Hence it is expected that phytoplankton flux would also vary from year to year.

The present study aims to show phytoplankton flux in terms of cell number and carbon in the austral summer of 1991/1992 for comparison with data previously collected at similar sites (Saito *et al*., 1998; Ishikawa *et al*., 2001).

2. Materials and methods

Sinking particles were collected using sediment traps, which were deployed beneath fast ice near Syowa Station, Antarctica, from January 7 to February 6 1992 (Fig. 1). The depths at which the sediment traps were deployed were 10, 30, 50, and 200 m at Site 33A, 10, 25, and 30 m at Site 33B, and 10, 20, and 25 m at Site 33C. The dimensions of the trap have been described by Ishikawa *et al*. (2001). In the present study, samples from 30 m at Site 33A, and 25 m at Sites 33B and 33C, were used.

Aliquots of samples collected in the traps were fixed with neutral formalin (5% v/v). Depending upon density, 1/33 to 1/400 of the original samples were observed using an inverted microscope. Phytoplankton cells (PN) were counted and major parts were measured. In the present study, species were not identified in detail since emphasis was on the estimate of cell volume. Phytoplankton cell volume was determined assuming an appropriate representative shape (*e.g.,* cylinder, sphere, cone, ellipsoid or combination). Phytoplankton carbon (PC) was estimated using the carbon to volume relationship established by Menden-Deuer and Lessard (2000).

Using other aliquots of the samples, Odate *et al*. (2004) has determined the chlorophyll *a* (Chl *a*) fluxes. The samples collected at the other depths were used for

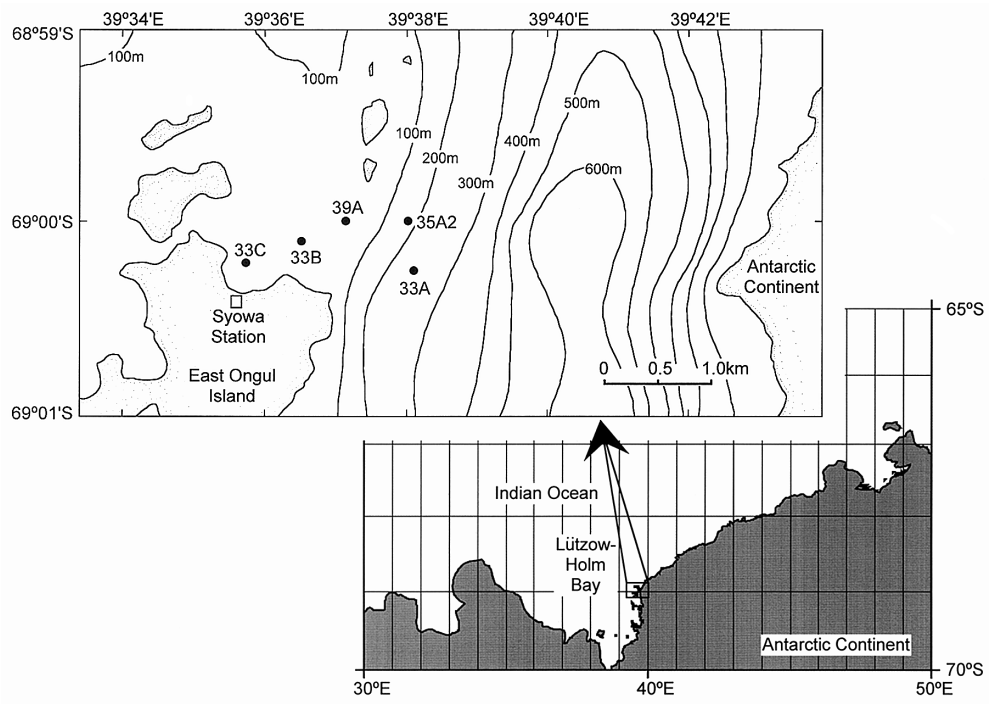

Fig. 1. Location of sampling sites in Lützow-Holm Bay, Antarctica (33A, 33B and 33C). Similar studies were conducted by Saito et al. *(1998) at Site 35A2 and Ishikawa* et al. *(2001) at Site 39A. Submarine topography is redrawn after Fujiwara (1971).*

determination of the particulate organic carbon (POC) fluxes, which have been published (Suzuki *et al*., 1998). Sea-ice condition and deployment of the sediment traps have been described by Odate *et al*. (2004).

3. Results and discussion

During the present study period, PN fluxes varied between 4.3×10^6 and 440×10^6 cells $m^{-2}\,d^{-1}$ (Table 1). Relatively low PN fluxes occurred in the beginning to middle parts of January, while relatively higher fluxes were observed at the end of January and the beginning of February. The temporal variation of the PN flux was consistent with that of the Chl *a* flux, which was previously shown by Odate *et al*. (2004). They pointed out that the elevated Chl *a* flux resulted from the development of phytoplankton blooms in the surface water (Odate *et al*., 2004).

Under fast ice near Syowa Station, phytoplankton biomass usually reaches an annual maximum between the middle of January and the beginning of February (*e.g.,* Hoshiai, 1969). Odate and Fukuchi (1996) showed that in 1991/1992 summer the maximum phytoplankton abundance in the surface water column occurred on 17 January at Site 33A, on 23 January at Site 33B, and on 22 January at Site 33C, decreasing toward February. Consequently, it is expected that the annual maximum in

the PN flux occurs during this season. The PN fluxes of 6.9×10^6 cells $m^{-2}d^{-1}$ at 25 m at Site 33C between January 7 and 13 and 4.3×10^6 cells $m^{-2}d^{-1}$ at 25 m at Site 33B between January 9 and 19 were one order of magnitude higher than the PN flux at 20 m at Site 35A2 (Fig. 1) in August–September of 1994 (Saito *et al.*, 1998) (Table 1). During August–September, phytoplankton abundance was extremely low on a seasonal basis (Hoshiai, 1969). The PN fluxes at the beginning of the present study were about half or one third of the PN fluxes at the depth of 20 m in November–December of 1994 (Saito *et al.*, 1998). Suzuki *et al.* (1998) showed that the flux of POC, which contains phytoplankton, decreased with depth. Applying the vertical gradient of POC flux shown by Suzuki *et al.* (1998), our PN fluxes at 25 or 30 m depth would become greater (up to *ca.* 150%) compared to the PN fluxes at a depth of 20 m. In this case, the difference between the PN fluxes at the beginning of the present study and in November-December (Saito *et al.*, 1998) becomes small.

Ishikawa *et al.* (2001) reported one order of magnitude higher PN flux than in the present study in the beginning of January 1998 at the depth of 20 m at Site 39A (Table 1). This order of magnitude difference could not be explained by the vertical gradient in the PN flux. Ishikawa *et al.* (2001) observed that phytoplankton biomass increased twice during the austral summer of 1997/1998. The first increase was noted Starting in late December 1997 to early January 1998 (Ishikawa *et al.*, 2001), although phytoplankton biomass was low at the beginning of January 1992 (Odate and Fukuchi, 1996).

The PN fluxes increased from early January to mid-January by 100×10^6 cells $m^{-2}d^{-1}$ at Site 33A (January 19–26) and 160×10^6 cells $m^{-2}d^{-1}$ at Site 33B (January 19–23) (Table 1) when phytoplankton biomass in the surface water column increased (Odate and Fukuchi, 1996). The highest PN flux in the present study (440×10^6 cells $m^{-2}d^{-1}$ at Site 33B between January 30–February 6) was about one third of the maximum PN flux in 1998 (Ishikawa *et al.*, 2001). Even if the vertical gradient of the

Table 1. Phytoplankton cell number (PN) flux observed under fast ice near Syowa Station.

Period	Site	Depth (m)	PN flux ($\times10^6$ cells m^{-2} d^{-1})	Reference
Jan. 7 - Jan. 13, 1992	33C	25	6.9	Present study
Jan. 9 - Jan. 19, 1992	33B	25	4.3	Present study
Jan. 12 - Jan. 19, 1992	33A	30	72	Present study
Jan. 19 - Jan. 23, 1992	33B	25	160	Present study
Jan. 19 - Jan. 26, 1992	33A	30	100	Present study
Jan. 23 - Jan. 30, 1992	33B	25	170	Present study
Jan. 26 - Feb. 1, 1992	33A	30	130	Present study
Jan. 30 - Feb. 6, 1992	33B	25	440	Present study
Aug. 12 - Sep. 12, 1994	35A2	20	0.22	Saito *et al.* (1998)
Nov. 27 - Dec. 17, 1994	35A2	20	13	Saito *et al.* (1998)
Jan. 2 - Jan. 8, 1998	39A	20	88	Ishikawa *et al.* (2001)
Jan. 8 - Jan. 14, 1998	39A	20	180	Ishikawa *et al.* (2001)
Jan. 14 - Jan. 21, 1998	39A	20	510	Ishikawa *et al.* (2001)
Jan. 21 - Jan. 28, 1998	39A	20	880	Ishikawa *et al.* (2001)
Jan. 28 - Feb. 2, 1998	39A	20	1,300	Ishikawa *et al.* (2001)

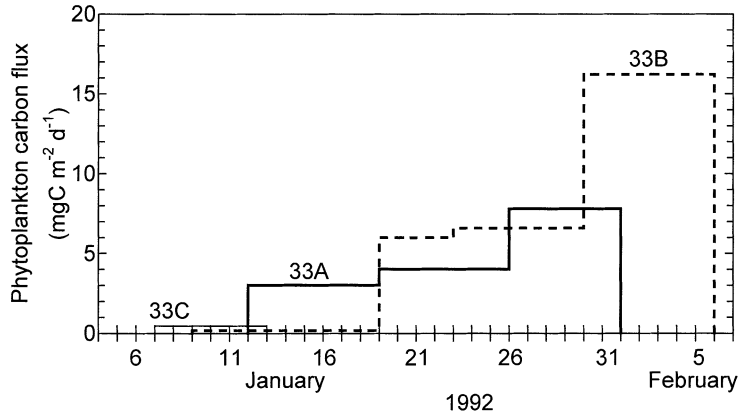

Fig. 2. Temporal variations in phytoplankton carbon fluxes at the depth of 30 m at Site 33A (thick solid line), 25 m at Site 33B (broken line), and 25 m at Site 33C (thin solid line).

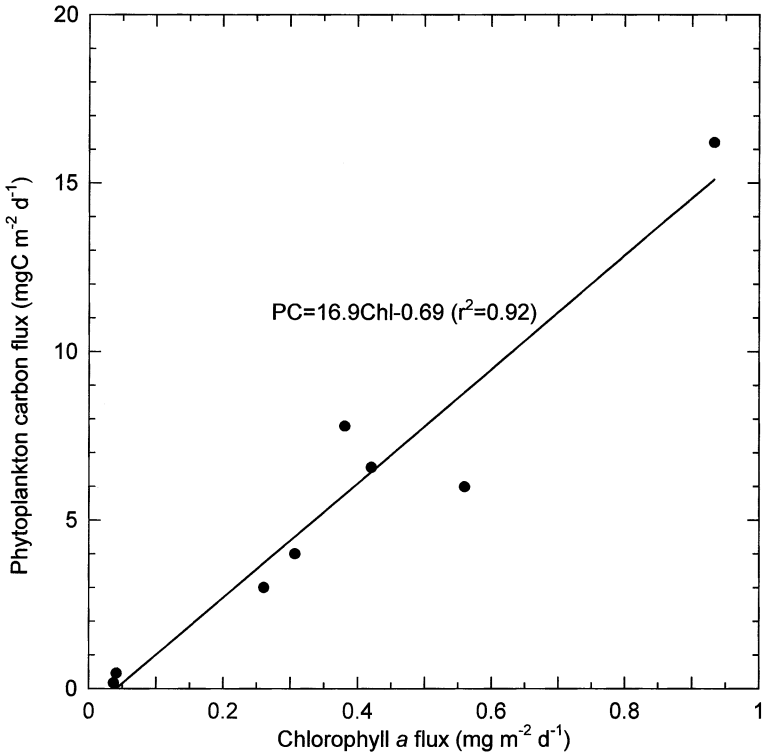

Fig. 3. Relationship between phytoplankton carbon flux (present study) and chlorophyll a flux (Odate et al., *2004).*

PN flux were taken into account, the PN fluxes would be higher in 1997/1998 than in 1991/1992 austral summer. Interannual variation of phytoplankton biomass in the surface water column seems to result in a difference in the PN flux.

The PC flux varied from 0.2 to 16 mg C $m^{-2} d^{-1}$ (Fig. 2). The PC flux accounted for 3–68% of POC fluxes, which were estimated based on the report of Suzuki *et al*. (1998). The percentage increased with time, implying that the POC flux contained more phytoplankton in late summer than in mid-summer. The temporal variation of PC flux was similar to the cell flux (Table 1) and the Chl *a* flux, shown by Odate *et al*. (2004). Indeed, the relationship between Chl *a* and PC fluxes was significant ($P < 0.01$) (Fig. 3). The slope of the regression line implies a PC to Chl *a* ratio of 17, which is about 60% of the minimum POC: Chl *a* ratio of sinking particles during this season (Odate *et al*., 2004).

This PC: Chl *a* ratio is slightly lower than values in the literature (*e.g.,* Swadling *et al*., 1997). Fukuchi and Sasaki (1981) showed that sediment trap samples, which were collected under fast ice near Syowa Station, contained large aggregates of suspended organic matter, as well as phytoplankton. Moreover, Saito *et al*. (1998) showed that fecal pellets were one of the major components of sinking particles and that phytoplankton cells were sometimes observed in fecal pellets. In the present study, phytoplankton cells in aggregates and fecal pellets were not evaluated. This may result in the lower PC: Chl *a* ratio in the present study.

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References

Carey, A.G., Jr. (1987): Particle flux beneath fast ice in the shallow southwestern Beaufort Sea, Arctic Ocean. Mar. Ecol. Prog. Ser., **40**, 247–257.

Fujiwara, K. (1971): Sounding and submarine topography of the glaciated continental shelf in Lützow-Holm Bay, East Antarctica. Nankyoku Shiryô (Antarct. Rec.), **41**, 81–103 (in Japanese with English abstract).

Fukuchi, M. and Sasaki, H. (1981): Phytoplankton and zooplankton standing stocks and downward flux of particulate material around fast ice edge of Lützow-Holm Bay, Antarctica. Mem. Natl Inst. Polar Res., Ser. E (Biol. Med. Sci.), **34**, 13–36.

Hoshiai, T. (1969): Seasonal variation of chlorophyll-*a* and hydrological conditions under sea ice at Syowa Station, Antarctica. Nankyoku Shiryô (Antarct. Rec.), **35**, 52–67 (in Japanese with English abstract).

Ishikawa, A., Washiyama, N., Tanimura, A. and Fukuchi, M. (2001): Variation in the diatom community under fast ice near Syowa Station, Antarctica, during the austral summer of 1997/98. Polar Biosci., **14**, 10–23.

Menden-Deuer, S. and Lessard, E.J. (2000): Carbon to volume relationships for dinoflagellates, diatoms, and other protist plankton. Limnol. Oceanogr., **45**, 569–579.

Odate, T. and Fukuchi, M. (1996): Differences in development of summer phytoplankton bloom under fast

ice around Syowa Station, Antarctica. Proc. NIPR Symp. Polar Biol., **9**, 125–130.
Odate, T., Sasaki, H. and Fukuchi M. (2004): Vertical flux of chlorophyll *a* under fast ice near Syowa Station, Antarctica, in austral summer, 1991/1992. Nankyoku Shiryô (Antarct. Rec.), **48**, 1–6.
Saito, R. Kudoh, S., Sato, T., Watanabe, K. and Fukuchi, M. (1998): Composition of sinking particles collected under fast ice near Syowa Station, East Antarctica, in early spring and early summer, 1994. Nankyoku Shiryô (Antarct. Rec.), **42**, 252–268 (in Japanese with English abstract).
Sasaki, H. and Hoshiai, T. (1986): Sedimentation of microalgae under the Antarctic fast ice in summer. Mem. Natl Inst. Polar Res., Spec. Issue, **40**, 45–55.
Suzuki, H., Sasaki, H., Tanimura, A. and Fukuchi, M. (1998): Variability of export fluxes of sinking particles under the Antarctic fast ice (1992–1994). Nankyoku Shiryô (Antarct. Rec.), **42**, 244–251 (in Japanese with English abstract).
Swadling, K.M., Gibson, J.A.E., Ritz, D.A., Nichol P.D. and Hughes, D.E. (1997): Grazing of phytoplankton by copepods in eastern Antarctic coastal waters. Mar. Biol., **128**, 39–48.