6. Short-time Variation in Low Trophic Level Productivity and Hydrographic Conditions in Funka Bay

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Abstract

A short-time (2-4 days) sediment trap experiment and a current meter were deployed simultaneously in central Funka Bay from October, 1996 until June, 1997, to examine the relationship between short-time variations in hydrographic conditions and the flux of settling particles.

The flux of settling particles varied temporally with two periods of extremely high value from late November to early October, and from mid- to late April, in each case showing a short-time increase and decrease. This temporal variation in the flux of settling particles was influenced by short-time changes in the hydrographic conditions, such as the intrusion of Oyashio Water, vertical mixing and changes in current direction.

Introduction

Variations in hydrographic condition in subarctic regions directly or indirectly influence low trophic productivity, *i.e.*, primary productivity and secondary productivity (DiTullio and Laws, 1991). In particular, it is thought that the processes involved in the occurrence and the maintenance of a spring bloom in Funka Bay are related to hydrographic conditions caused by the almost simultaneous intrusion of the Oyashio Water into Funka Bay (Tanaka, 1984; Odate, 1987). Hydrographic conditions caused by changes of current vectors accompanied by a strong seasonal wind may also influence processes of phytoplankton production in Funka Bay, as described by Ohtani and Deguchi (1981, 1983).

Results on vertical flux and the composition of settling particles obtained from sediment trap experiments have provided valuable information about the processes of primary and secondary production (Eppley and Peterson, 1979; Deuser et al., 1980; Suess, 1980; Lee et al., 1983; Lorenzen *et al.*, 1983; Betzer *et al.*, 1984; Maita *et al.*, 1986). As a result, it is possible to base temporal variation in low trophic productivity and/or the mechanisms of the occurrence and the continuance of a spring bloom on data from sediment traps.

The objective of this study was to study the relationship between short-time variations in hydrographic conditions and the flux of settling particles in Funka Bay.

Methods

Zooplankton production followed the primary production as did the abundance of some sediment particles. The intrusion and vertical mixing in turn influenced phytoplankton production and subsequent zooplankton production. While, southward flows caused the supply of the resuspended sediment particles. A time-series sediment trap (interval; 2-4 days) was deployed successively at a depth of 50 m in Station 30 (42°16.2' N, 140°36.0' E; water depth 92 m) of central Funka Bay from October, 1996 until June, 1997. Current meters were also deployed simultaneously at 20 m and 80 m depths at the same station. The variations in temperature and salinity depth profiles were measured using weekly or monthly CTD casts during the sediment trap experiment.

Results

Hydrographic Conditions

The water column in central Funka Bay was well mixed vertically from the surface to the bottom from late November, and then cooled gradually from 10°C to 5°C until early February (Fig. 1). The water column was occupied by the winter Funka Bay water (Fw; Ohtani, 1971) during this period. In early February, the upper 20 m of the water column was occupied by the water mass originating in the Oyashio Water (temperature; below 4°C, salinity; about 33.3 psu) (Ohtani, 1971). As a consequence, a weak stratification was formed in the 20-40 m layer. The upper 30 m depth in early March had a lower temperature (below 3°C) and lower salinity (33.3 psu) as a result of the continuous intrusion of the Oyashio Water. Weak stratification had also been established in the 30-50 m layer during March. After March, the weak stratification disappeared, as the water column became to occupy by the Oyashio Water from the surface to near the bottom, with a gentle density gradient. After late May, there was a strong vertical gradient in density as a result of increased water temperature and a decline in salinity.

Generally, northward flows were dominant, corresponding to prevailing northwesterly winds (Fig. 2), although southward flows accompanied by southeasterly winds occurred at times (*e.g.*, late November through early December, late December, late February, mid-March, during April, and mid-May).

Sediment Trap Experiment

The mass fluxes, including both organic and inorganic particles, were extremely high during two periods; from late November to early October and from mid- to late April (Fig. 2). The mass fluxes from mid-December to late February were extremely low. From early March the mass fluxes increased sluggishly and then increased dramatically in early April. After that, the mass fluxes decreased followed by a second short-time increase and decrease.

The fluxes of particulate organic carbon also varied temporally with extremely high value from mid- to late April, with a second short time increase and decrease during the sediment trap experiment. The temporal variation in the fluxes of particulate organic carbon from early December until early May nearly agreed with those in the mass fluxes. Namely, the fluxes of particulate organic carbon remained extremely low from mid-December to late February, echoed the sluggish increase from early March, and then the dramatic increase in early April. However, the fluxes of particulate organic carbon from late November to early December were relatively lower, whereas the mass fluxes were extremely high. Furthermore, after April, there was no significant correlation between the temporal variation in particulate organic carbon fluxes and the temporal variation in the mass fluxes, although both fluxes were relatively high.

Discussion

The spring bloom in central Funka Bay in 1997, judging from the fluxes of particulate organic carbon obtained by the sediment trap experiment, started from early March and ended in late March, with little variation. A pycnocline was formed as a result of the intrusion of the Oyashio Water between 30 m and 40 m depth during this spring bloom period. The occurrence of the pycnocline may provide suitable conditions for phytoplankton production. However, the static stability of the water column and the magnitude of the spring bloom in 1997 were lower than in other years (*e.g.*, 1995). The small magnitude and sluggish variation of the spring bloom in 1997 may have been a consequence of the weak static stability of the water column.

On the other hand, the fluxes of particulate organic carbon from late November to early December were relatively lower, although the mass fluxes were extremely high. According to microscopic observations, the bulk of settling particles during this period consisted of sediment particles having very low carbon content. The physical environment at this time was vertical mixed to just above the sediment, judging from the temperature and salinity profiles obtained by CTD casts. The high mass flux, but relatively lower flux of particulate organic carbon, during this period was caused by the supply of some sediment particles as a result of the vertical mixing in the water column.

We have shown that hydrographic conditions, such as the intrusion of Oyashio Water and vertical mixing, were clearly responsible for the temporal variations in both the mass flux and particulate organic carbon flux in Funka Bay. On the other hand, short-time changes in current vectors caused by the changes in wind direction were also noted in central Funka Bay during this sediment trap experiment. Both mass flux and particulate organic carbon flux tended to be higher when the southward or westward flow dominated. In Funka Bay, the southward or westward flow may transport sediment particles resuspended at the inner part of Funka Bay into central Funka Bay.

Following the bloom (April-June), the settling particles comprised the high organic carbon-content particles, largely derived from zooplankton. However, there is no significant

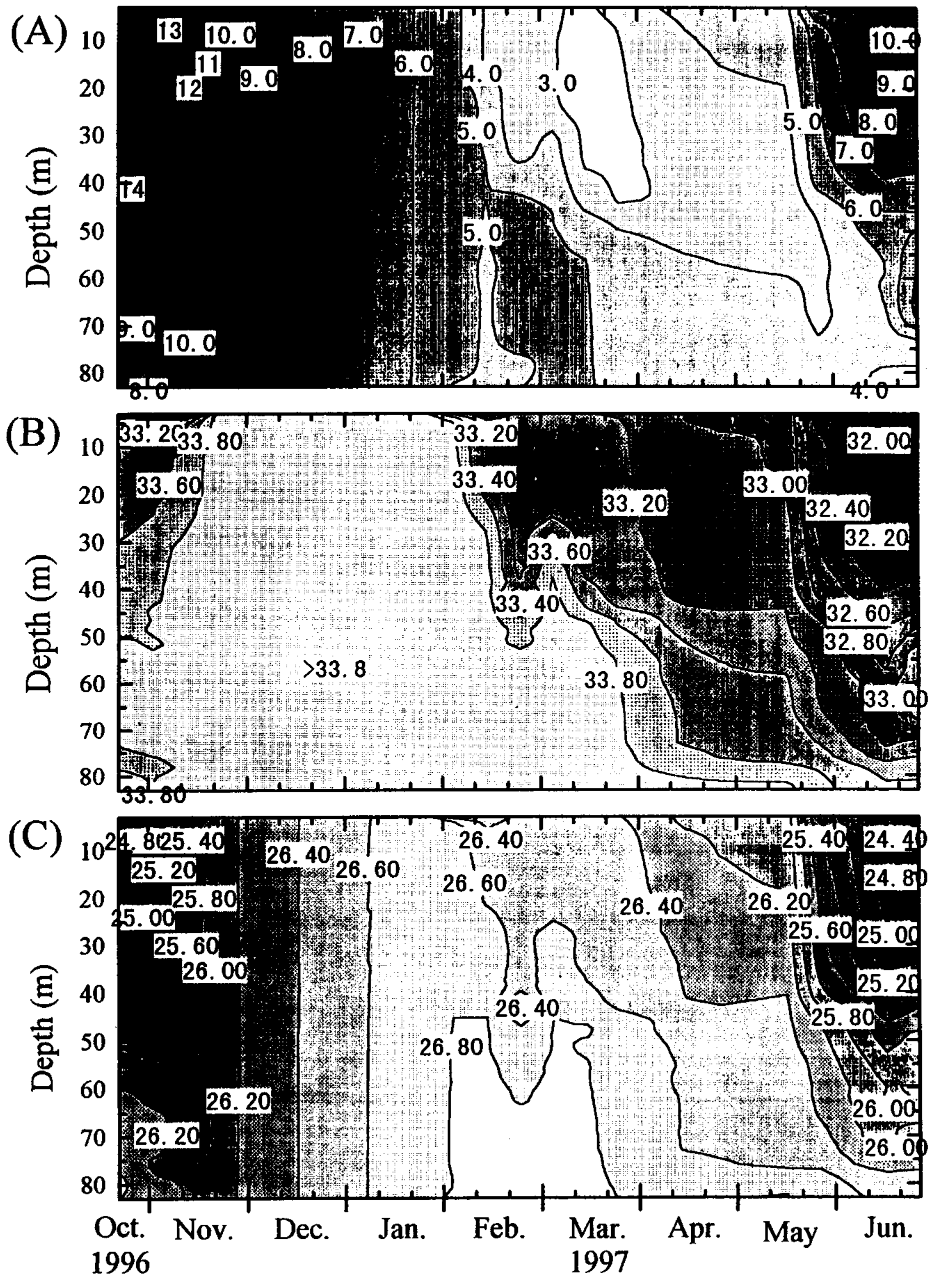

Fig.1. The temporal variations of temperature(A), salinity(B)and sigma-t(C) at station 30 of central Funka Bay, 1996-1997.

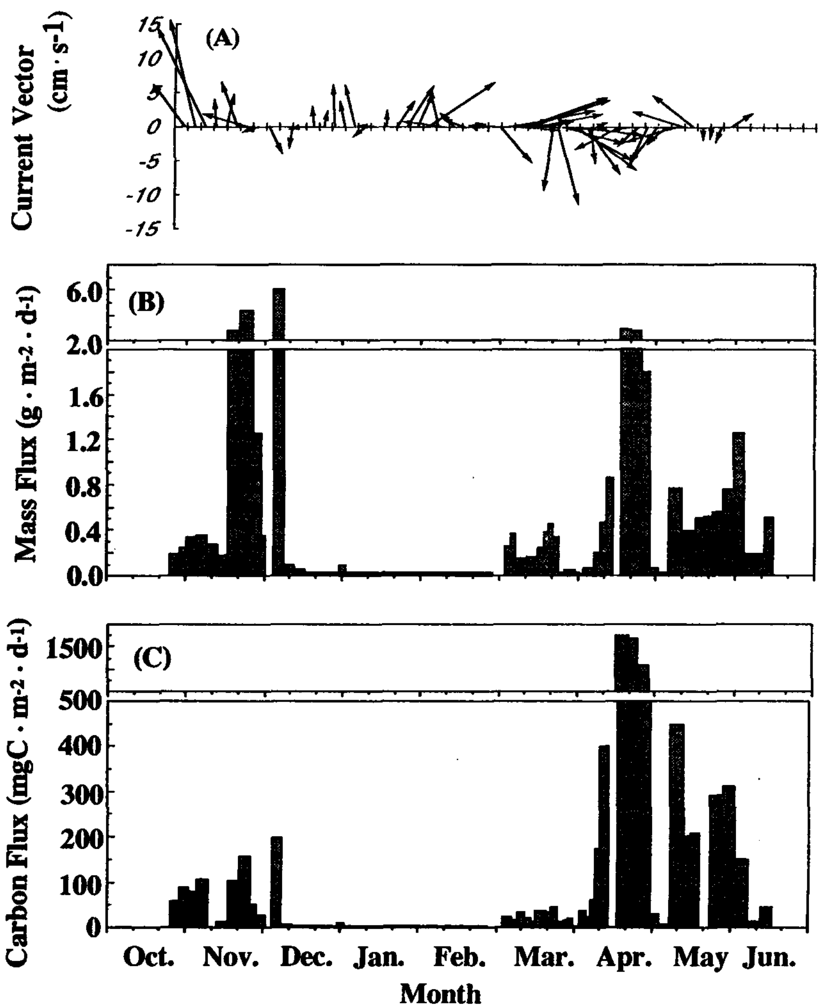

Fig.2 The temporal variations of the current vectors(A), mass flux(B) and carbon flux(C).

correlation between the temporal variation in particulate organic carbon fluxes and the variations in the mass fluxes during this period. This suggests the presence of different settling particles with relatively lower organic carbon content (*e.g.*, sediment particles). The variations in both mass flux and particulate organic carbon flux during the second short-time increase and decrease were probably influenced by horizontal transport of sediment particles in response to short-time variations in the current direction. This is the most probable reason for the absence of a correlation between the mass flux and particulate organic carbon flux at this time.

Consequently, the short-time scale variations in the fluxes of settling particles in Funka Bay were caused by short-time hydrographic changes such as the intrusion of the Oyashio Water, vertical mixing and changes in current vectors. The intrusion and vertical mixing in turn influenced phytoplankton production and subsequent zooplankton production. While, southward flows caused the supply of the resuspended sediment particles.

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