

General occurrence of coccolithophorids in sediment trap Stn. 40N, northwestern North Pacific

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General occurrence of coccolithophorids was studied under a scanning electron microscope (SEM) in sediment trap Stn. 40N, moored at 1000 m water depth in the northwestern North Pacific. During the investigation period from February 2000 to May 2001, high coccolithophore fluxes were shown in spring and early summer, whereas low fluxes were shown in autumn and winter. The coccolith assemblages during the whole experiment period were predominated by *Emiliania huxleyi*, accompanied with *Gephyrocapsa oceanica*, *Coccolithus pelagicus*, *Calcidiscus leptoporus* and *Syracosphara* spp. Some intraspecies morphologic variations were recognized, particularly for the species *E. huxleyi*.

Keywords : sediment trap, northwestern North Pacific, seasonal coccolithophore flux, species composition, shell morphologic variation

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1. Introduction

The subarctic Pacific and its adjacent marginal seas are considered to be one of the highest biological productivity regions and act as an important CO₂ sink through the biological pump¹⁾²⁾. In order to verify the efficiency of the biological pump and its role in the uptake of atmospheric CO₂ in the northwestern North Pacific (NWNP), sediment trap experiments have been carried out since 1997³⁾. Time-series data on the variability of marine phytoplankton obtained from the sediment traps are essential for understanding the biogeochemical cycles. This paper reports the flux and species composition of coccolithophorid, a calcareous phytoplankton, in one of the traps moored at the subarctic front, NWNP, during the year 2000-2001.

2. Material and method

2.1. Material

Time-series sediment traps with 21-cup collectors and a collection area of 0.5m² were deployed at Stn. 40N (40° N/165° E), northwestern North Pacific (Fig. 1), and were recovered during the MR01-K03 cruise. The traps were moored at 1000 m, 3000 m and 5000 m water depths. The opening-closing of all cups was synchronized with sampling intervals of 23.14 days, and 21 samples were collected from February 2000 to May

2001 at each mooring depth. Table 1 shows the opening and closing date of every sample (cup No. 1~No. 21). Samples were poisoned with 5% formalin solution buffered with sodium borate. The coccolithophorids were studied only from samples at 1000 m depth.

2.2. Sample processing

In laboratory, the trap samples were wet-sieved through a 1 mm mesh to remove large particles. The <1 mm fraction was split into several aliquots using a high precision rotary splitter (McLane WSD-10 wet-sample divider). Studied aliquots ranged between 1/1000 and 1/5000, depending on particle content of the source material. The aliquots were wet-sieved over 32 μm mesh, while disintegrating fecal pellets and aggregates with a small soft brush. The fraction <32 μm was then filtered through a Millipore filter (0.45 μm pore size, 47 mm diameter) using a water pump. After filtering, the

Table 1 Opening and closing date of the sample cups in sediment trap Stn. 40N.

sample cup	opening date	closing date
1	2000.2.1	2000.2.24
2	2000.2.24	2000.3.18
3	2000.3.18	2000.4.10
4	2000.4.10	2000.5.3
5	2000.5.3	2000.5.26
6	2000.5.26	2000.6.18
7	2000.6.18	2000.7.11
8	2000.7.11	2000.8.4
9	2000.8.4	2000.8.27
10	2000.8.27	2000.9.19
11	2000.9.19	2000.10.12
12	2000.10.12	2000.11.4
13	2000.11.4	2000.11.27
14	2000.11.27	2000.12.20
15	2000.12.20	2001.1.13
16	2001.1.13	2001.2.5
17	2001.2.5	2001.2.28
18	2001.2.28	2001.3.23
19	2001.3.23	2001.4.15
20	2001.4.15	2001.5.8
21	2001.5.8	2001.5.31

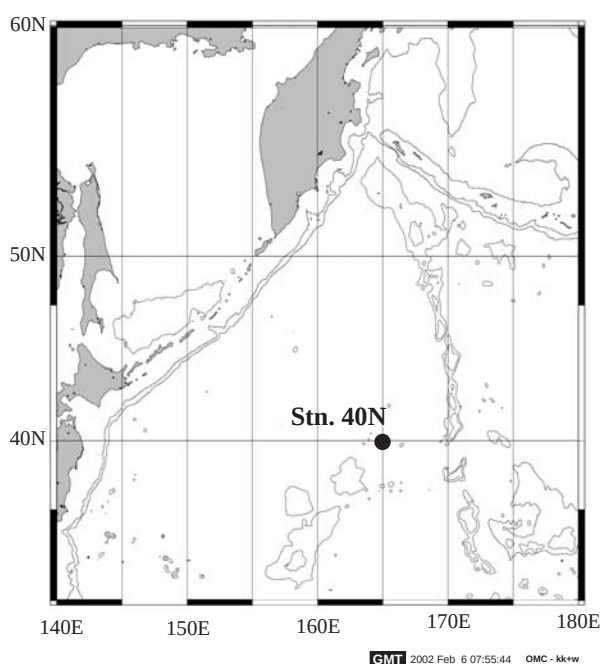


Fig. 1 Location map of sediment trap Stn. 40N at northwestern North Pacific.

filters were put into a desiccator, and air dried for more than 1 day.

2.3. Analyzing procedure

A randomly chosen small section of the dried filter (approx. 0.3cm²) was fixed on an aluminum stub and sputtered with Platinum for coccolithophore analysis with a scanning electron microscope (SEM). We used the JEOL JSM-5610 SEM at Mutsu Institute for Oceanography (MIO) for coccolithophore counting, as well as taxonomic identification. Coccoliths, along with coccospheres, were counted on measured transects at 3000 x magnification. The total number of coccoliths counted in each sample was more than 300. Identification generally followed the taxonomy of Jordan and Kleijne⁴⁾.

3. Results

3.1. Total coccolithophore Fluxes

Fluxes of coccolithophorids were calculated as follows: $\text{Flux} = F \times C \times S / A \times D \times O$, where F is the filtration area (mm²); C is the number of coccoliths / coccospheres counted; S is the split factor (reciprocal of split fraction); A is the actual counting area (mm²); D is the sampling interval (days); O is the opening area of the sediment trap (mm²). Total coccolith and coccosphere fluxes of each sample are shown in Fig. 2. The total coccolith flux ranged from 185×10^6 to 1905×10^6 coccoliths/m²/day; the mean value of flux was 542×10^6 coccoliths/m²/day. The coccolith fluxes increased from March 2000 to May 2000. The highest fluxes were recorded from late June to early July 2000, with a maximum of 1905×10^6 coccoliths/m²/day. The flux increased again from late April 2001 to early May 2001. Low fluxes occurred during other periods. The coccosphere flux pattern generally paralleled that of the total coccolith flux (Fig. 2). The mean coccosphere flux was 6.1×10^6 coccospheres /m²/day.

In general, the coccolithophore fluxes were high in spring and early summer, and low in autumn and winter. This flux pattern was closely correlated with that of the total mass flux (Fig. 2) (Honda, unpublished data).

3.2. Occurrence of coccospheres

Most of the specimens are single coccoliths, whereas

intact coccospheres are very few in all samples. The average coccolith/coccosphere ratio is 135:1. Among the intact coccospheres encountered while counting coccoliths, five species were recognized. They are: *Emiliania huxleyi*, *Gephyrocapsa oceanica*, *Coccolithus pelagicus*, *Calcidiscus leptoporus* and *Syracosphaera anthos* (Plate 1).

3.3. Species composition of coccoliths

The coccolith assemblages during the whole trap experiment period were predominated by *E. huxleyi*. Averagely, it occupied more than 75% of the total assemblage (Fig. 3-A). *G. oceanica*, *C. pelagicus*, *C. leptoporus* and *Syracosphaera spp.* were also commonly encountered species, although their relative abundance (percentage frequency) was much lower than that of *E. huxleyi*. These species altogether comprised more than 90% of the total coccolith assemblage. Time-series variations in relative abundance of the common species are

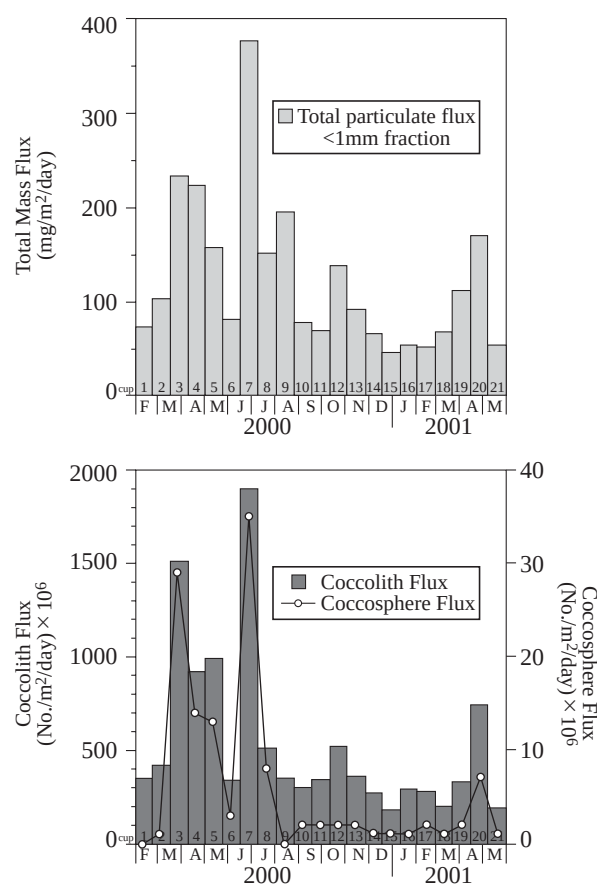


Fig. 2 Seasonal coccolith and coccosphere flux at Stn. 40N, 1000 m water depth, compared with total mass flux (<1 mm fraction; Honda, unpublished data).



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2



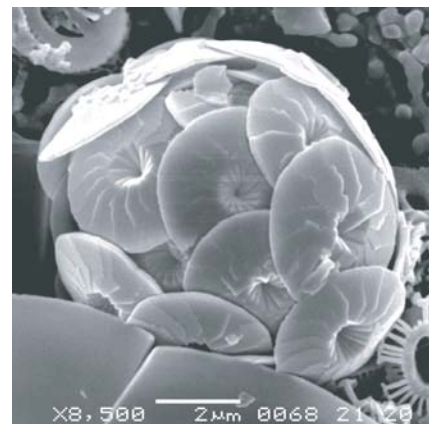
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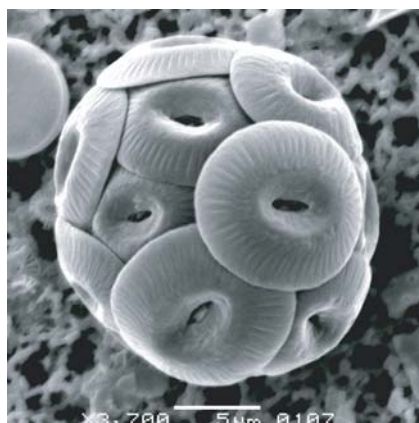
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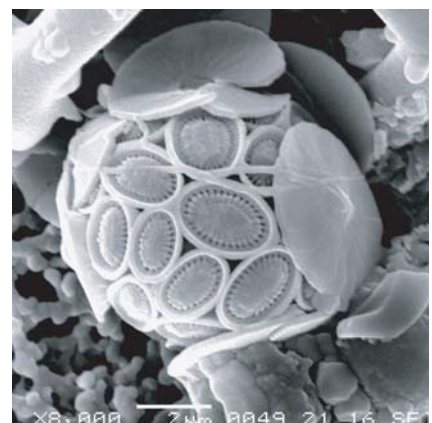
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Plate 1 Scanning electron micrographs of coccospheres from sediment trap Stn. 40N. (1) *Emiliana huxleyi*, type A (Young and Westbrook, 1991); (2) *Emiliana huxleyi*, type C (Young and Westbrook, 1991), with an entirely empty central area; (3) *Emiliana huxleyi*, type C (Young and Westbrook, 1991), with central area occupied by a sheet; (4) *Emiliana huxleyi*, 'closed *E. huxleyi*' type (Beaufort and Heussner, 2001); (5) *Calcidiscus leptoporus* (large form); (6) *Calcidiscus leptoporus* (small form); (7) *Gephyrocapsa oceanica*; (8) *Coccolithus pelagicus*; (9) *Syracosphaera anthos*.

Averaged species composition (%) of coccoliths

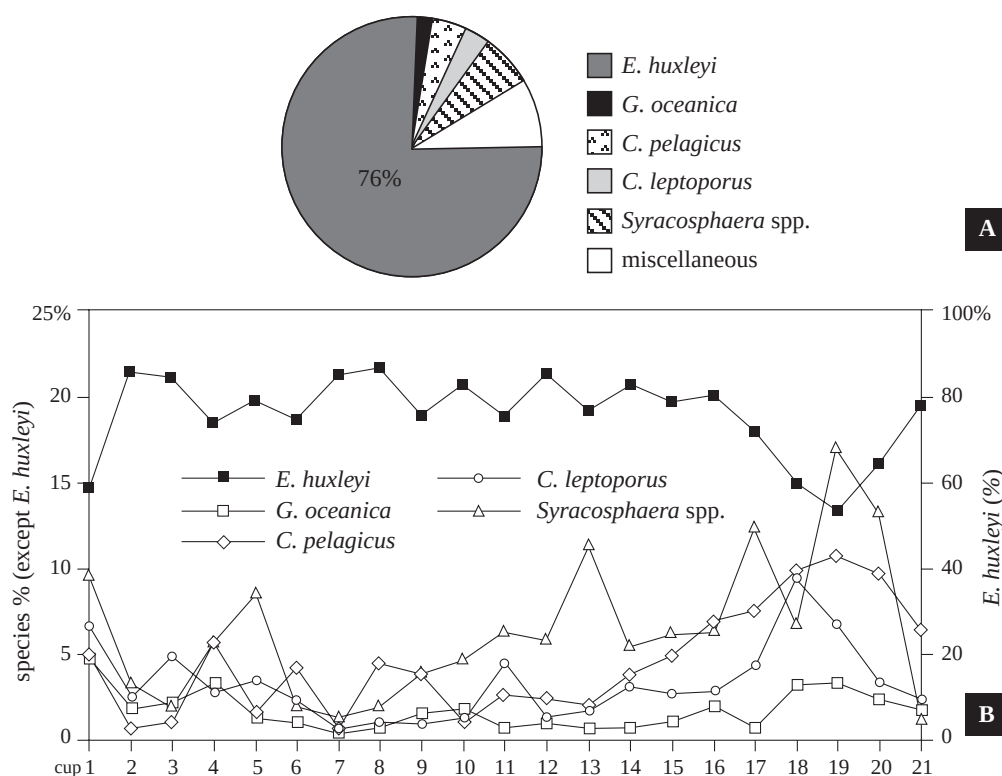


Fig. 3 (A) Averaged species composition of coccolith at Stn. 40N, 1000 m water depth, 'miscellaneous' include rare species and coccoliths unable to identify; and (B) seasonal relative abundance of common coccolith species / species group at Stn. 40N, 1000 m water depth.

shown in Fig. 3-B. Seasonally, the overwhelming majority of *E. huxleyi* was reduced to some extent by the increase of *C. pelagicus*, *C. leptoporus* and *Syracosphaera* spp. at early spring (March to early May, sample cup No. 18~No. 20) in the year 2001.

4. Discussion on intraspecific variations

At least three morphotypes of the species *E. huxleyi* can be distinguished under the SEM based on structural differences of the central area. The first two morphotypes have an open central area, which may be referred to *E. huxleyi* types A and C of Young and Westbrook⁵⁾. The central area of the type A (Plate 1, Fig. 1) is occupied by a grid structure, whereas that of the type C is entirely empty (Plate 1, Fig. 2) or occupied by a sheet (Plate 1, Fig. 3). The distal shield elements of the type C are well separated giving the shield a delicate appearance. The third morphotype is heavily calcified, and has an almost closed central area (Plate 1, Fig. 4). This morphotype may be referred to the 'closed *E. huxleyi*' of

Beaufort and Heussner⁶⁾ who mentioned that this type might be restricted to the Bay of Biscay or the continental shelves. Two morphotypes of *Calcidiscus leptoporus*, 'large form' and 'small form', can be distinguished based on the diameter of their placolith. (larger or smaller than 5 μm , see Plate 1, Figs. 5–6). The same distinction has been made by Knappertsbusch et al.⁷⁾ and Beaufort and Heussner⁶⁾. The morphotypes of *E. huxleyi* and *C. leptoporus* will be further studied by counting a suitable number of coccospheres of them to clarify their seasonal succession in relation to the oceanographic conditions, e.g., the thermo-nutricline.

5. Brief note on the scanning electron microscope in MIO

The scanning electron microscope (SEM) used in this study is JEOL JSM-5610. It was set up at Mutsu Institute for Oceanography (MIO) in September 2001. Since then, it has been continually used by the 1st Research Group in MIO for the observation of marine



SEM (JEOL JSM-5610)

- * Mode: High Vacuum
- * Magnification: $\times 18$ to $\times 300,000$
- * Image mode: SEI, BEI
- * Resolution (SEI): 3.0nm

EDS (JED-2201)

- * Type of detector: minicup EDS detector
- * Detectable element range: Na to U
- * Effective detection area: 10 mm²
- * Liquid N₂ capacity: 0.8 Lit.

Fig. 4 Scanning electron microscope at Mutsu Institute for Oceanography with general specifications, where SEI is the secondary electron image; BEI is the backscattered electron image.

phytoplankton such as coccolithophorids, and zooplankton such as planktonic foraminiferids. Many high-resolution SEM pictures have been obtained for the purpose of both the time series observational study in the North Pacific and the study on the past environmental changes.

JEOL JSM-5610 is a PC-SEM which all operations can be performed by using a mouse of a personal computer. An energy dispersive spectrometer (EDS), JED-2201, which is an X-ray analyzer that employs the energy dispersion method is also attached to the microscope for element analysis. The outward appearance and specifications of the SEM are shown in Fig. 4.

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