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Usefulness of deep-ocean water pumping for the seasonal monitoring of mesozooplankton

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HIGHLIGHTS

- Seasonal zooplankton monitoring was achieved by deep-water pumping at 2.5-day intervals.
- Zooplankton abundance, biomass and biovolume were highly correlated with each other.
- Benthopelagic zooplankton was quantitatively collected by deep-water pumping.
- Deep-water pumping may be useful for the collection of rare species and materials.

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ABSTRACT

The Okhotsk Sea is the southernmost seasonally ice-covered ocean in the Northern Hemisphere. Because of the ice coverage during winter, seasonal monitoring of zooplankton is difficult by ordinary ship-board observation. To overcome this issue, zooplankton monitoring of samples collected by deep-ocean water pumping may be useful. In this study, we evaluated seasonal changes in the zooplankton community based on the samples collected by deep-ocean water pumped from a 350-m depth off of Rausu Harbor in the southern Okhotsk Sea at 2.5-day intervals over two and a half years. Zooplankton abundance and biomass ranged from 20–550 inds. m^{-3} and 6–902 mg WM m^{-3}, respectively. Both parameters showed similar seasonal changes throughout the study period. Copepods were the most dominant taxa throughout the year and accounted for 90% and 76% of the annual mean zooplankton abundance and biomass, respectively. A total of 20 genera and 33 copepod species were observed. *Metridia okhotensis* and *M. pacifica* accounted for 61% and 12% of the annual mean copepod abundance, respectively. In general, the abundance and biomass of zooplankton collected by pumped-up deep-ocean water were lower than they were in the epipelagic layer (both characteristics of the former corresponded to approximately 60% of the latter). The combined effects of low zooplankton density at the deep layer (350 m) and the low filtering rate of deep-water pumping are considered to be a possible cause of the low zooplankton abundance and biomass in the pumped-up deep-ocean water. For the zooplankton samples from pumped-up deep-ocean water, there was a high abundance of benthopelagic mysids and copepods (*Xanthocalanus* spp.). Because the water inlet of the deep-ocean water pumping is located near the sea bottom, the collected samples may be useful for the evaluation of seasonal changes in the population structure of the less-studied benthopelagic species.

1. Introduction

The Okhotsk Sea is the southernmost seasonally ice-covered ocean in the Northern Hemisphere (Parkinson and Grantz, 1983). In the Okhotsk Sea, phytoplankton bloom is observed during the spring, and zooplankton (mainly composed by copepods) ingests phytoplankton and grows during that time (Pinchuk and Paul, 2000). Zooplankton is preyed upon by pelagic and demersal fish, marine birds and mammals; thus, they play an important role in energy transfer between primary producers and higher trophic levels (Dulepova, 1998; Volkov, 2000; Tamura and Fujise, 2002). Monitoring zooplankton with fine temporal resolution is difficult by ordinary ship-board observation during periods when temporal ice covers the ocean. As a result, all of these studies were conducted during ice-free seasons.

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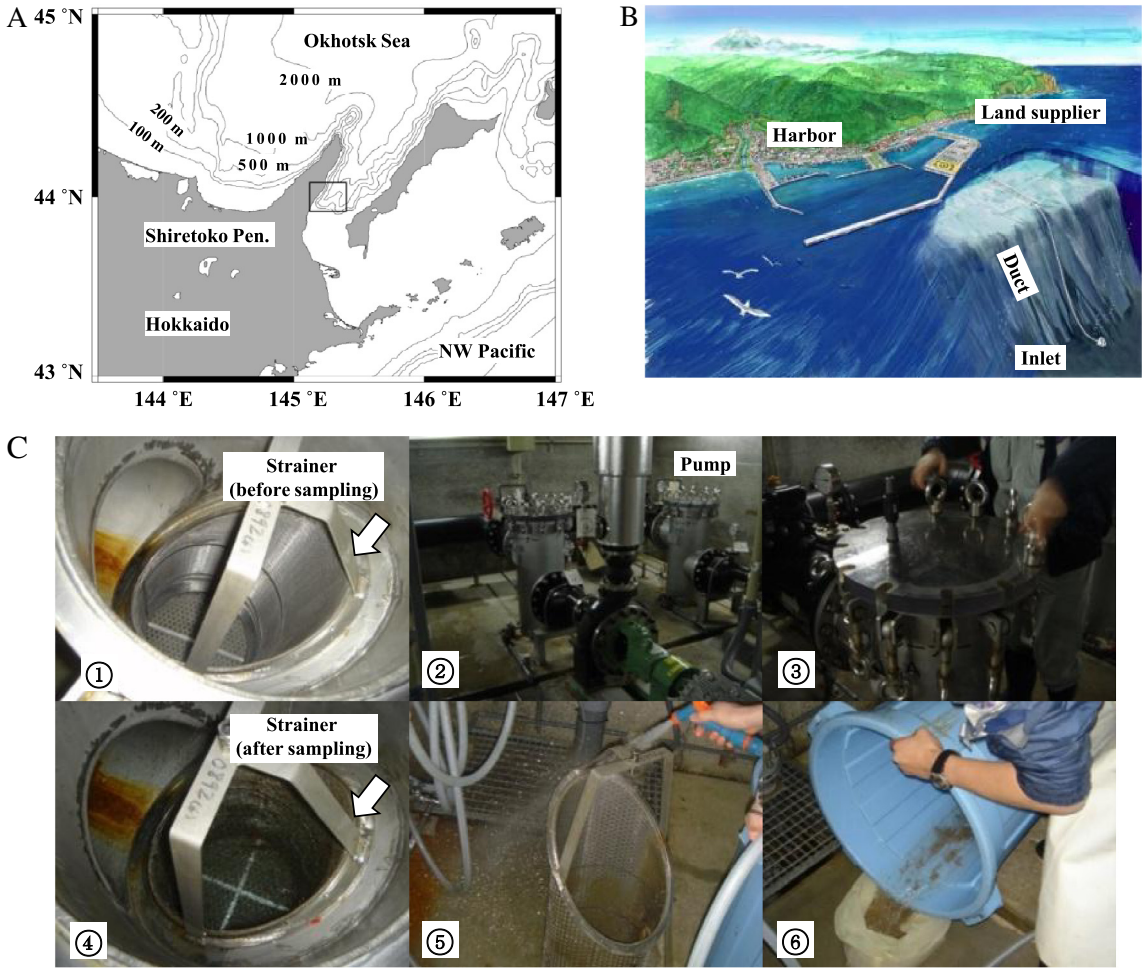

Fig. 1. Location of the Rausu harbor (box), Shiretoko Peninsula, eastern Hokkaido (A), schema of the Rausu deep-ocean water sampling site (B), and the procedure for sampling in the land supplier (C). The time course of sampling in the land supplier is shown with circled numbers (1–6).

The town of Rausu, located on the southern coast of the Okhotsk Sea, collects deep-ocean water by pumping it up from a depth of 350 m every day for the purpose of fishery product refrigeration, food processing and other industrial needs (Takahashi and Yamashita, 2005; Takahashi et al., 2014). The particles contained in the deep-ocean water (mainly zooplankton) are removed through straining (mesh size: 420 μm) at the Rausu deep-ocean water sampling site. Because year-around zooplankton samples may be temporally covered by fine time resolution, analysis of these zooplankton samples collected at the deep-ocean water sampling site may provide valuable information on the zooplankton community in the Okhotsk Sea.

In this study, we collected zooplankton samples at the Rausu deep-ocean water sampling site with fine temporal resolution (2.5-day interval in average) over two and a half years during June 2007–December 2009. Based on the preserved zooplankton samples, seasonal changes in zooplankton abundance, biovolume and taxonomic composition were analyzed. The results were compared with those of the pelagic samples collected by net-towing, and the characteristics of the zooplankton community collected by the deep-ocean water pumping are discussed.

2. Materials and methods

2.1. Zooplankton sampling

Seasonal zooplankton samples were collected at the Rausu deep-ocean water-sampling site at the Rausu harbor (44° 00′N, 145° 15′E) in the southern Okhotsk Sea (Fig. 1(A)). This facility can pump up deep-ocean water from an inlet pipe (268 mm diameter) at a depth of approximately 350 m, 2.8 km off from the shore with a maximum speed of 200 m^3 h^{-1} (Fig. 1(B)). The deep-ocean water was filtered through a strainer (mesh size: 420 μm), and the remaining zooplankton was collected (Fig. 1(C)). After 3–135 (mean: 20 h) hours of deep-ocean water pumping at a speed of 106 m^3 h^{-1}, the remaining zooplankton in the strainer was collected and preserved with 5%–10% (v/v) formalin. A total of 352 zooplankton samples were collected during 20 June 2007–18 December 2009 (mean sampling interval: 2.5 days = 897 day/352 samples). The temperature and volume of the filtered water (m^3) were recorded at the same time.

2.2. Sample analysis

In the laboratory, the settling volumes of all of the samples were measured with a precision of 10 ml. Within the 352 samples, microscopic observation was made for the 62 samples selected to cover the approximately two-week interval throughout the sampling period. For each sample, subsamples (1%–3% of the total volume) were taken with the aid of a wide-bore pipette, and identification and enumeration were performed at the taxonomic level. Due to our sampling methods, damaging some of the specimen during collection was inevitable. However, the resulting damage had little effect on the identification of crustacean copepods. For each taxon, the biomass (wet mass: WM) was measured by