Life cycle analysis of the dominant planktonic copepod *Metridia okhotensis* based on samples collected by deep-ocean water pumping in the southern Okhotsk Sea

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1. Introduction

The calanoid copepod *Metridia okhotensis* is the predominant species of zooplankton community in the southern Okhotsk Sea. However, limited information is available on the life cycle of *M. okhotensis* in this area. Rausu Town on the southern Okhotsk Sea collects deep-ocean water by pumping from a depth of 356 m at 2.78 km from Rausu fishing port. The particles contained in the deep-ocean water (mainly zooplankton) are removed using a strainer. Since deep-ocean water pumping was made frequently year-round, analyses on these zooplankton samples allow us to examine seasonal changes in zooplankton with fine temporal resolution. This study analyzed time-series zooplankton samples collected by the deep-ocean water pumping in Rausu, and evaluated the life cycle patterns of the dominant copepod *M. okhotensis*.

2. Material and Methods

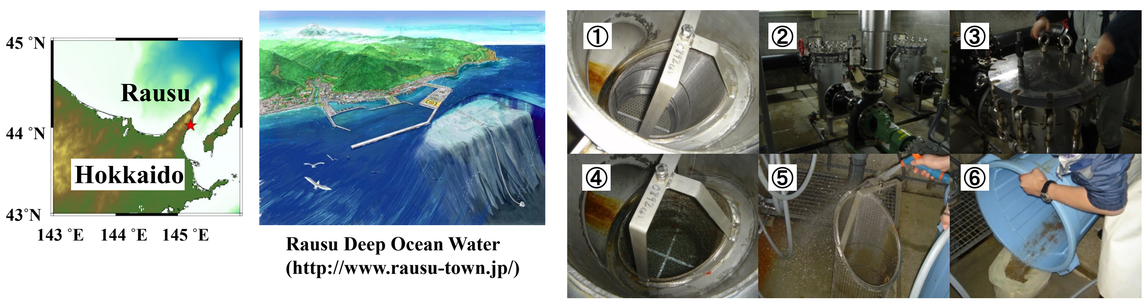


Fig. 1. Sampling site at Rausu, eastern Hokkaido, Japan. Deep Ocean Water (DOW) was collected from 356 m depth out of the harbor. Panels numbered 1-6 indicate procedures of zooplankton sampling.

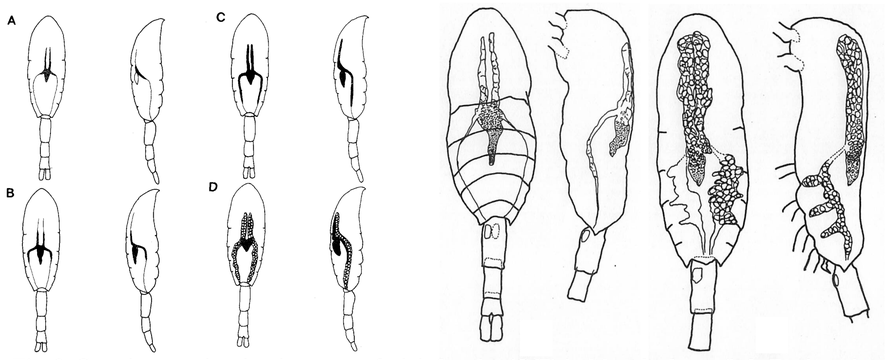


Fig. 2. Gonad maturation developments of adult females (C6F) in *Metridia longa* (left, Tande and Grønvik, 1983) and *Metridia pacifica* (right, Batchelder, 1986).

- Totally 515 zooplankton samples were collected from the Rausu deep-ocean water pumping from September 2007–September 2009 and September 2022–September 2023.
- After 3–135 hours of deep-ocean water pumping at a speed of 98 $m^3\ h^{-1}$, the collected zooplankton by the strainer (mesh size: 420 μm) was preserved with 5–10% formalin (Fig. 1).
- Within the 515 samples, microscopic observation was made for the 88 samples selected to cover the approximately 2-week intervals throughout the sampling period.
- For each sample, subsamples (1–3% of the total volume) were made with a wide-bore pipette, and taxonomic identification and enumeration were performed.
- *M. okhotensis* was sorted and counted with stages as the most dominant copepod species composed 58.3 ± 15.8% (mean ± 1sd).
- For adult females (C6F), gonad maturation was observed with borax carmine or fast green staining and scored into five categories (Fig. 2).

3. Results and Discussion

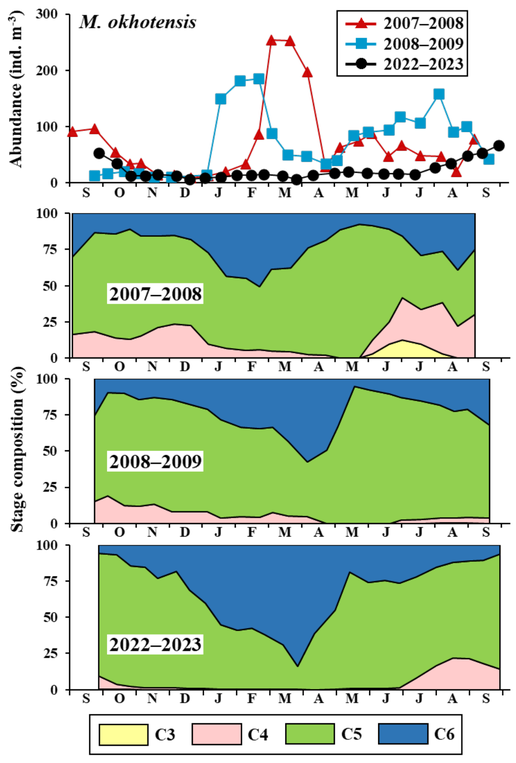


Fig. 3. Seasonal changes in abundance and their stage composition of *Metridia okhotensis* in the Rausu Deep-Ocean Water (depth 356 m) during three periods: September 2007 to September 2008, September 2008 to September 2009, and September 2022 to September 2023.

- There were clear seasonal changes in the abundance and population structure of *M. okhotensis* (Fig. 3). The seasonal changing patterns were common for the three years. Adults (C6) were the most abundant in population structure from January to April.

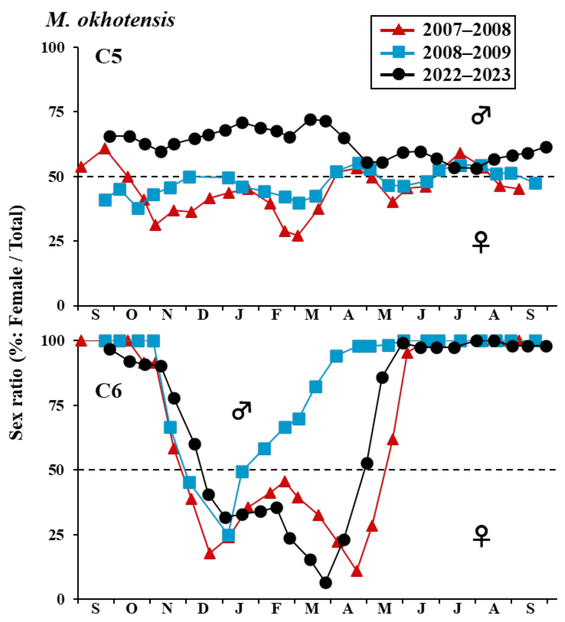


Fig. 4. Seasonal changes in the sex ratio of *Metridia okhotensis* C5 and C6 in the Rausu Deep-Ocean Water (depth 356 m) during three periods: September 2007 to September 2008 (red line), September 2008 to September 2009 (blue line), and September 2022 to September 2023 (black line).

- For the sex ratio, females and males were nearly equal in C5 throughout the year (Fig. 4).
- While in C6, females predominated from June to November, males rapidly increased their compositions in December, and males outnumbered females from December to April.

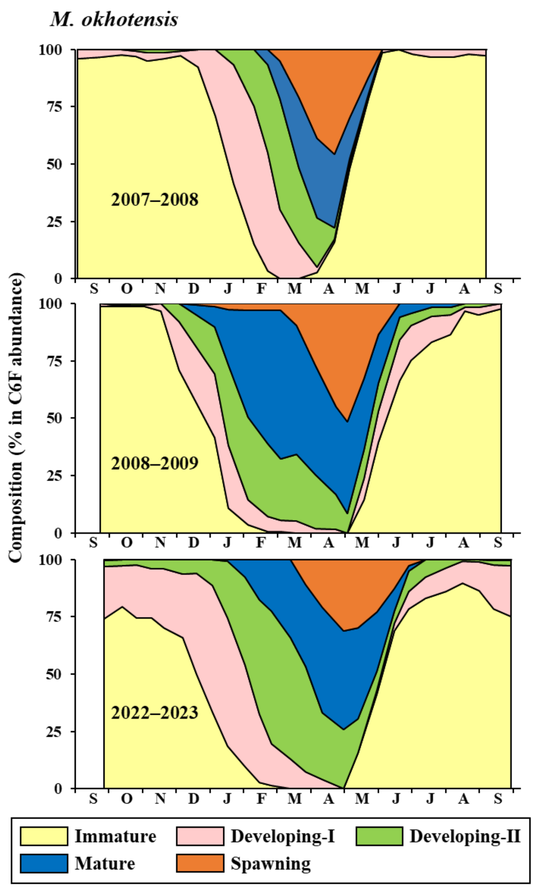
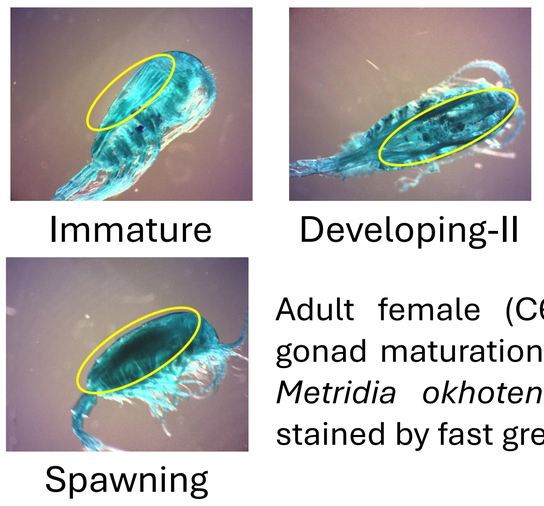


Fig. 5. Seasonal changes in gonad maturation composition of adult female (C6F) of *Metridia okhotensis* in the Rausu Deep-Ocean Water (depth 356 m) during three periods: September 2007 to September 2008 (upper), September 2008 to September 2009 (middle), and September 2022 to September 2023 (lower).



Adult female (C6F) gonad maturation of *Metridia okhotensis* stained by fast green.

- The gonad maturation of C6F also showed clear seasonality. The majority of C6F had immature gonads from July to November (Fig. 5).
- Gonad maturation began rapidly after December, and the spawning individuals were abundant from February to May, with a peak in late April.

Month

	S	O	N	D	J	F	M	A	M	J	J	A	S	O
Population structure					Adult increase									
Sex ratio (C6)	Female		Male dominated								Female dominated			
C6F gonad maturation	Immature					Developing	Spawning		Immature					

4. Conclusion

- Through this study, the life cycles of *M. okhotensis* were summarized as follows: *M. okhotensis* may have a resting phase at C6F with immature gonads and C5M, staying deep layer without diel vertical migration (DVM) during the warm-water period: July to November. Since this corresponds to the warm period, this resting would be termed over-summer.
- After December, C5M initiates molting to C6M, and the sex ratio of C6 is skewed for males. At the same time, the gonad maturation of C6F starts.
- Then, in April, when the phytoplankton blooms occur, they make upward migration and perform DVM within the surface layer, then spawn at the surface layer.