Spawning Behaviour and Early Development of the Antarctic Krill, *Euphausia superba* DANA, Observed on Board R. V. KAIYO MARU in 1979/80

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船上飼育による南極オキアミ *Euphausia superba* DANA の産卵行動と初期発生

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要旨：1979-80年開洋丸第1次南極海調査航海中，1980年1月24日，64°45.'5S, 110°04.'0E において，KOC-A ネットの 0-36 m 傾斜引採集により得られた南極オキアミ *Euphausia superba* DANA 成熟雌20個体を船上で飼育し，産卵行動と初期発生を観察した．水温約 0.4°C において採集後 3-9 日に産卵が行われ，産卵行動を写真撮影した．産卵には約50分間を要し，成熟雌 6 個体について各々の総産卵数を計数して 1140-1688 個の値を得た．産卵後 7 日目から一部の幼生の孵化がみられ，孵化率は飼育密度により大きく変動した．その後25日間メタノウプリウス期に至る初期発育過程を観察した．

Abstract: During the cruise of the Antarctic Expedition R. V. KAIYO MARU in 1979-80, the rearing of the Antarctic krill, *Euphausia superba* DANA, was conducted in order to observe the spawning behaviour and the early development. The krills which were collected by a 0-36 m oblique tow using the KOC-A net at the position of 64°-45.5'S, 114°-04.0'E on January 24, 1980 were reared at 0.4°C. The time needed for completion of spawning was about 50 minutes. Spawning behaviour was photographed and sketched. The total numbers of spawned eggs counted soon after the spawning in six females were in a range of 1140-1688. Nauplii began to hatch out after seven days of spawning. The hatchability varied with the rearing density. Twenty five nauplii developed to the metanauplius stage after 25 days of spawning.

1. Introduction

The maintenance of the Antarctic krill, *Euphausia superba*, for the study

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of its biology has been made by MACKINTOSH (1967), MCWHINNIE and DENYS (1978), MCWHINNIE *et al.* (1979) and DENYS *et al.* (1980). However, the information in relation to the reproduction and early developmental course was only reported by MCWHINNIE and DENYS (1978). This paper deals with the observations on the spawning behaviour and the subsequent development by rearing *E. superba* on board during the R. V. KAIYO MARU cruise to the Antarctic Ocean.

2. Materials and Methods

The rearing was conducted during the cruise of the Antarctic Expedition R. V. KAIYO MARU for a period between January 24 and February 25, 1980. The krills were collected by a 0–36 m oblique tow using the KOC-A net (KAIYO MARU Opening and Closing Acoustic, mesh aperture 5.6 mm, size $3\times3\times16$ m) at the position of 64°-45.5′S, 114°-04.0′E, between 1212-1237 (local time) on January 24. Immediately after the sampling, 20 mature females were sorted out from the composite sample and were kept in a plastic container ($40\times50\times30$ cm) filled with 30 litres of surface sea water together with young krills.

In order to acclimatize the krills under an artificial condition on board, the container was placed in a chilled fish hold under the dark condition. The rearing water temperature was controlled to be about +0.4°C constantly. After 24 hours, each of the 20 mature females was transferred to each of 20 vessels with the capacity of 0.2–3.0 *l* in order to make the observations of individual spawning behaviour easy. The fish hold was lighted for 2–3 hours by an electric bulb of 60 watts once or twice a day for observations. Throughout the rearings, at intervals of one or two days, the rearing water was changed using surface sea water and phytoplankton was given them as a food which was obtained by towing a net of 0.99 mm mesh apertures. The spawning behaviour of 20 females was photographed and sketched. Soon after the spawning, 14 females out of 20 individuals were fixed for the later histological examination of their ovaries. The released eggs from six females were subsequently kept without food to observe the early developmental course.

3. Results and Discussion

In the present rearings, six mature females (denoted as A1–A6 in the text

Table 1. Rearing conditions and hatchability observed on six mature females of *E. superba*, collected on January 24, 1980. Rearing temperature was kept about 0.4°C.

Animal No.	Date of spawning	Rearing condition			Number of egg		Hatchability (%)
		Number of vessel	Volume of vessel (*l*)	Density of egg (eggs/*l*)	Spawned	Hatched	
A1	1980 January 31	1	0.5	2436	1218	0	0
A2	February 1	1	0.5	2472	1236	0	0
A3	January 29	1	0.5	2640	1320	0	0
A4	January 28	2	3.0	190	1140	723**	63.4
A5	January 29	2	0.5	1251	1251	35***	2.8
A6	January 27	19 ↓* 25	0.2 ↓* 0.02	440 ↓* 750	1688	858**	50.8

* : Eight days after spawning the eggs and larvae were transferred to small vessels.
** : Hatched during seven and 18 days after spawning.
*** : Hatched during seven and 14 days after spawning.

and Table 1) released eggs on January 27, 28, 29, 31, and February 1, 1980. A pair of chains of eggs was released intermittently from a genital pore as shown in Figs. 1 and 2. The spawning behaviour was also observed during the next KAIYO MARU cruise to the Antarctic in 1980/81 and the photographs successfully taken in this cruise are illustrated here. During the course of spawning, the krills were lying of the bottom of the rearing vessels or occasionally swimming in the vessels, while their expodites of thoracic and swimming legs were in active motions. Egg chains of about 1.0–1.2 cm long having about 15 eggs were released intermittently. Since eggs were connected very loosely, they were separated from one another and carried posteriorly by the water current caused by the movements of swimming legs (Fig. 3). The released eggs sank to the bottom of the vessels. The time needed for completion of spawning was about 50 minutes.

The rearing condition and the hatchability of eggs from A1–A6 are given in Table 1. All eggs from A1–A3 died before hatching. The minimum time required for hatching after spawning was seven days (A4–A6). The hatchability after 14 days was very low for A5 and it was 51–63% after 18 days for A4 and A6. As shown in Table 1, hatchabilities for high rearing densities

Fig. 1. Spawning of *Euphausia superba* and a chain of eggs (lateral view).

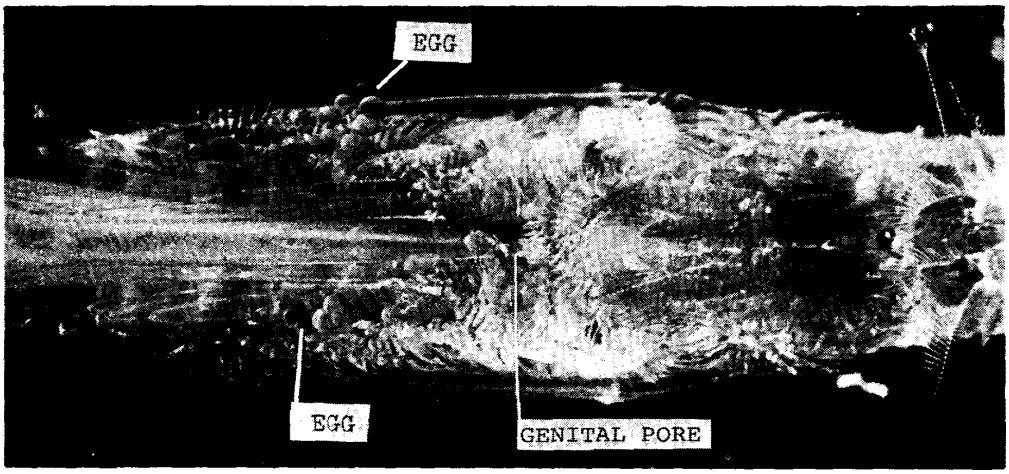

Fig. 2. Spawning of *Euphausia superba*. A pair of chains of eggs is observed (ventral view).

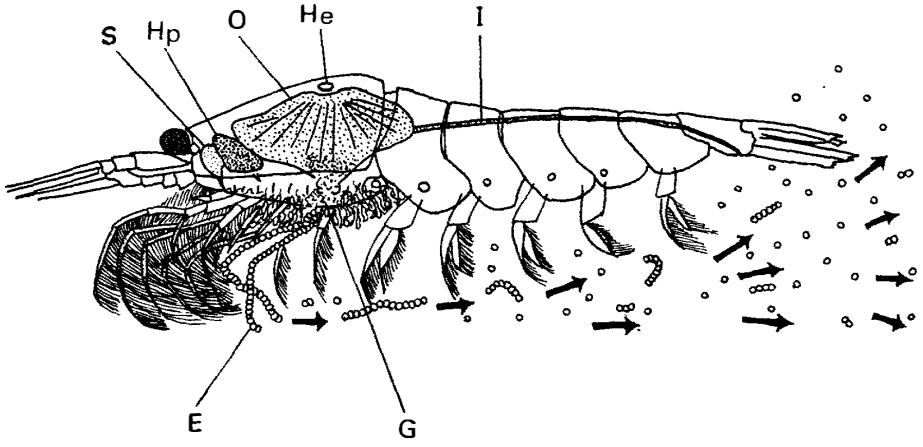

Fig. 3. Schematic representation of spawning behaviour of *Euphausia superba*. Arrows indicate the direction of water currents. E: Egg; He: Heart; Hp: Hepatopancreas; I: Intestine; O: Ovary; S: Stomach; G: Genital pore.

Table 2. Early development from egg to metanauplius stage of *E. superba* (A6 in Table 1).

Developmental stage *	Egg	Egg **	Nauplius I	Nauplius II	Metanauplius
Days after spawning	0 (Soon after spawning)	5	7	21	25
Diameter of egg or body length of larva (mm)	0.52	—	0.62	0.90	0.90

* : After the definition by FRASER (1936).

** : Formation of 1st and 2nd antennae.

(A1–A3) were 0 %, while those for low densities (A4–A6) were 3–63 %. Therefore, the rearing density might have some effects on the hatchability. MAKAROV (1975) and MAUCHLINE and FISHER (1969) calculated the number of eggs on the assumption of weight-volume conversion and reported 2110–6240 eggs and 310–800 eggs, respectively. On the other hand, MAUMOV (1962) directly counted the number of ripening eggs in the ovary and reported 2362–3480 eggs per female. Total numbers of spawned eggs counted soon after the spawning for A1–A6 were in a range of 1140–1688 with an average of 1309 per female as summarized in Table 1. According to the above-mentioned results, the number of eggs per female might vary considerably. However, four females out of 20 individuals seemed to keep some eggs still in the ovary after spawning in the present observations. It is still unknown whether the remaining eggs are to be spawned later during the same spawning season.

Although most of the hatched larvae floated at the surface of the vessel water soon after hatching, they settled on the bottom thereafter. The development of the released eggs to metanauplius was observed successfully in A6 as summarized in Table 2. Among 858 hatched larvae, only 25 nauplii (about 3 %) developed to the metanauplius stage.

The cleavage began soon after spawning and an egg developed morula within several hours. After five days, the first and second antennae became recognizable and the rotation of embryo was observed. The diameter of spawned egg is about 0.52 mm, and the body length of nauplius I stage just after hatching is 0.62 mm, while it grows to the metanauplius stage of 0.90 mm.

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