Euphausia superba: Fecundity and physiological ecology of its eggs and larvae

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During USARP 82 we measured spawning frequency in schools of krill near Elephant Island and the South Shetland Islands, Antarctic Peninsula, on two cruises of the R/V *Hero*. At Palmer Station we began to gather the data necessary to determine the depth at which eggs hatch and the rate at which energy reserves in early nonfeeding stages are depleted.

There are a number of conflicting views about the spawning behavior of *Euphausia superba*. El-Sayed and McWhinnie (1979) support the view that krill spawn possibly twice a year for a period of 2 years; they also suggest that each brood contains 1,000–2,000 eggs. We used a modification of the method developed by Ross, Daly, and English (1982) to measure the spawning frequency of live *Euphausia superba* on board the *Hero*. The inverse of the daily spawning frequency is the interval between broods. We calculated the brood interval for four schools of krill sampled near Elephant Island in January and for three schools found on the outside of the South Shetland Islands in February (table 1). The average brood intervals calculated for days 2 and 3 and for days 2, 3, and 4 were about the same. For all but school 8, the average brood interval for days 2, 3, and 4 was 5–7 days, in both January and February. We are not sure whether the longer brood interval of 11.4 days for school 8 was significantly longer or within the range of variability, and we intend to investigate this question during the 1982–83 season. Brood size varied greatly and was not closely linked to size of the female. It appeared that each female released 1,000 to 6,000 eggs with each brood; the median brood size (from the data analyzed thus far) was 2,000 eggs.

Table 1. Brood interval (in days) of schools of *Euphausia superba* in the Antarctic Peninsula, USARP 82

Location/ School number	Date	Average brood interval: Days 2–3	Days 2–4
Elephant Island			
4	8 Jan	6.0	6.5
6	9 Jan	10.7	7.2
8	9 Jan	11.4	—[a]
14	12 Jan	7.4	6.4
South Shetland Islands			
23	13 Feb	8.0	7.1
25	13 Feb	4.9	5.6
26	14 Feb	5.2	—[a]

[a]Females were observed for only 3 days, so the average brood interval for days 2, 3, and 4 could not be calculated.

Although we were not able to determine spawning frequency in December and March, we did find reproducing females in late December, indicating that the spawning season of *Euphausia superba* lasts at least 2 months. Assuming a brood interval of 6 days, a spawning season of 2 months, and a brood size of 2,000 eggs, a single *Euphausia superba* will release about 20,000 eggs in a season. This estimate of the fecundity of individual females is 5–10 times greater than previous estimates made by investigators who worked primarily with frozen or preserved animals.

We used eggs released from female krill brought back to Palmer Station to measure the sinking rate of the eggs during their development and to determine hatching and developmental times of the eggs and early larvae. The average sinking rate of eggs from an individual female varied with age or developmental stage of the egg (figure 1). For the first 24 hours the sinking rate was about 195 meters per day; between 36 and 72 hours after release the sinking rate decreased to a minimum of 95 meters per day and then increased again prior to hatching. The individual observations of sinking rates were not always distributed normally. After the blastula stage (24–36 hours) the distribution was either skewed or bimodal; at limb bud stage (78–123 hours) the point distribution was again normal. Using rough averages of egg sinking rates calculated every 24 hours for 135 hours, we estimated that with no, or low, vertical water velocities the eggs should hatch above 700 meters.

Despite inadequate temperature control (0.5°C ± 0.5°C), eggs in about 44 percent of the broods released in February and

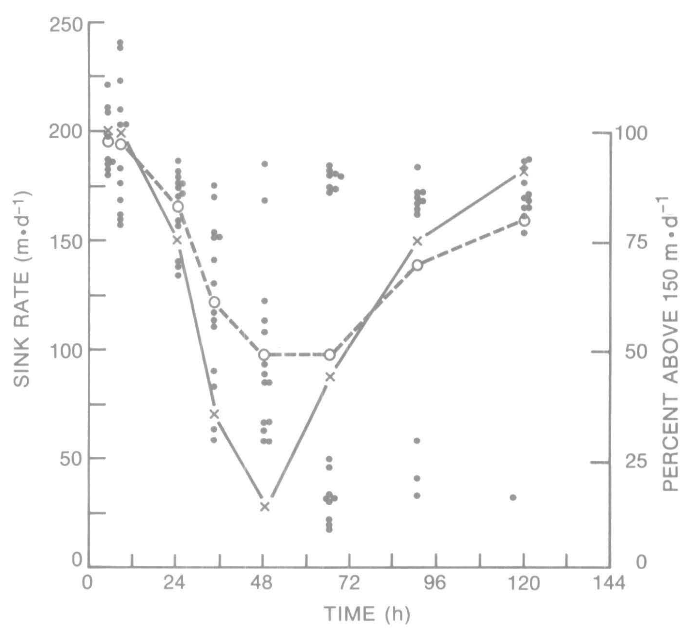

Figure 1. Sinking rates (in meters per day) of individual eggs from a single brood of *Euphausia superba*, from release to hatching, at a temperature of 2.0°C and a salinity of 36.2‰ (equivalent to a water density of 1.029 grams per cubic centimeter). Each sinking rate measurement is represented by a closed circle; the average sinking rate at each age is represented by an open circle; and the average rates are connected by a dotted line. The percentage of measurements above 150 meters per day ($m \cdot d^{-1}$) at each age (x) is on the right y-axis; the points are connected by a solid line.

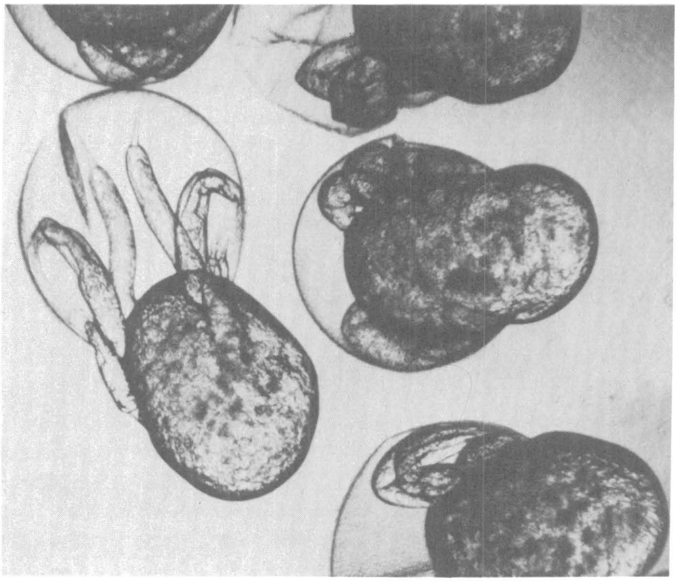

Figure 2. Nauplii hatching from eggs released by *Euphausia superba* at Palmer Station during USARP 82. (Photo by L. B. Quetin)

Table 2. Developmental times (in days) for larvae of *Euphausia superba*

	Investigators		
Stage	McWhinnie & Denys (1978)	Witek et al. (1980)	Present study (USARP 82)
Egg to nauplius I	3–4	N.D.[a]	5–6
Egg to nauplius II	7–8	N.D.	8–10
Egg to metanauplius	10–18	N.D.	15–18
Egg to calyptopis I	N.D.	30	21–25
Egg to calyptopis II	N.D.	45, 50, 60[b]	32–37

[a]N.D. = no data.

[b]Field estimates based on first, middle, and last time of spawning to first, middle, and last appearance of calyptopis II in the plankton.

March went on to hatch (figure 2). Usually, either all the eggs hatched or none hatched. We found developmental times for the naupliar stages comparable to those that McWhinnie and Denys (1978) found. Laboratory estimates of developmental times for the calyptopis stages, however, appear to be shorter than field estimates (Witek, Koronkiewicz, and Soszka 1980) (table 2). Newly hatched larvae must reach the surface in 21–25 days, if surface food sources are vital to their development at the first feeding stage (calyptopis 1).

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Diatoms from brittle star stomach contents: Implications for sediment reworking

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Pre-Recent Ross Sea sediments are distinguished by a diatom flora of mixed age whose frustules have undergone considerable chemical dissolution and severe mechanical breakage (Kellogg and Kellogg 1981; Kellogg, Truesdale, and Osterman 1979). We consider the discrepancy in ages of species present in these older sediments and their poor preservation to be hallmarks of reworking. Considering the regional distribution of these sediments, such reworking must have occurred on a very large scale.

Reworked sediments can be produced by the action of bottom currents, former grounded ice sheets, and bottom-dwelling organisms. All three mechanisms might result in some degree of breakage and transport of frustules. Current action can be discounted as the dominant mechanism in most reworked sediment because it would result in obvious size sorting, such as occurs in the relatively rare sediments of the late Glacial-Recent–aged Ross Sea Transition Zone (Kellogg, Osterman, and Stuiver 1979; Kellogg and Truesdale 1979) but not at other levels in Ross Sea cores (Anderson et al. 1980; Kellogg, Truesdale, and Osterman 1979).