

同体長の成熟,未成熟ナンキョクオキアミ(*Euphausia superba* Dana)雄個体の相対成長上の差異

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Allometric Differences Observed on the Same Sized Immature and Mature Males of the Antarctic Krill

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Abstract

Male *Euphausia superba* with developing petasma (IIA3) which have the same body length as more mature ones (IIIB) occurred frequently in the samples collected during the SIBEX II cruise of R. V. Kaiyo Maru. Detailed measurements of several body parts were done because animals of these two stages look quite different in general appearance other than in secondary sexual characteristics. IIIB males were shown to be better developed in exopodite of thoracic leg and pleopod than IIA3 males. These results suggest that IIIB males have better abilities in filtering and swimming as compared with IIA3 males. These morphological changes may occur reversibly if maturity regression as well as progression occurs in natural population.

As a general rule, more mature *Euphausia superba* DANA exhibit greater body size or vice versa (BARGMANN 1945). According to the maturity classification of MAKAROV & DENYS (1980), stage IIA3 males are characterized by developing petasma with wing and IIIB males, by fully formed spermatophores within the ejaculatory ducts. During the SIBEX II cruise of R. V. Kaiyo Maru both IIA3 and IIIB males were found within the same size group. In addition to maturity stages as judged by the morphology of petasma, these equal sized two groups of males were quite different in their appearance. I therefore examined allometry of various body parts of them, and possible causes and ecological implications of this phenomenon are discussed.

Materials and Methods

Samplings were made in the waters northwest of the Antarctic Peninsula, eastern Drake Passage and the Scotia and Weddell Seas during the SIBEX II cruise of R. V. Kaiyo Maru. Krill were collected by a rectangular frame trawl with mouth area of 9 m² and mesh size of 3.4 mm, named Kaiyo Maru Mid-water Trawl (KYMT). KYMT was towed obliquely from ca. 100 m to the surface. Detailed sampling design was given in ENDO et al. (1986).

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Collected specimens were sorted into male and female, maturity stages were determined according to MAKAROV & DENYS (1980), and body lengths were measured. Body length was taken from the anterior tip of the rostrum to the posterior end of the telson to the nearest mm.

Detailed measurements were made on 29 II A3 and 49 III B males collected in the waters west of the South Sandwich Islands, including eye diameter (E), carapace length (C), width (W1) and length (L2) of lobe of exopodite and exopodite length (L1) of first thoracic leg, and length of exopodite (L3) and width (W2) of protopodite (basal segment) of first pleopod (Fig. 1). All these readings were normalized by body length (i. e. divided by body length) prior to statistical tests.

Further observations on the morphology of the filtering basket were made on 7 individuals each for II A3 and III B males. Lengths of ischium and merus segments of third thoracic endopodite and those of primary setae along these segments were measured. Setal distances between the inner margin of the bases of the setae were measured for the primary setae along the ischium and merus segments (at 100 \times magnification), and the secondary setae along the primary setae (at 400 \times).

The significance of the difference in paired means was evaluated by a *t*-test if paired data sets have the same variance, or by an approximate *t*-test if not (SOKAL & ROHLF 1969).

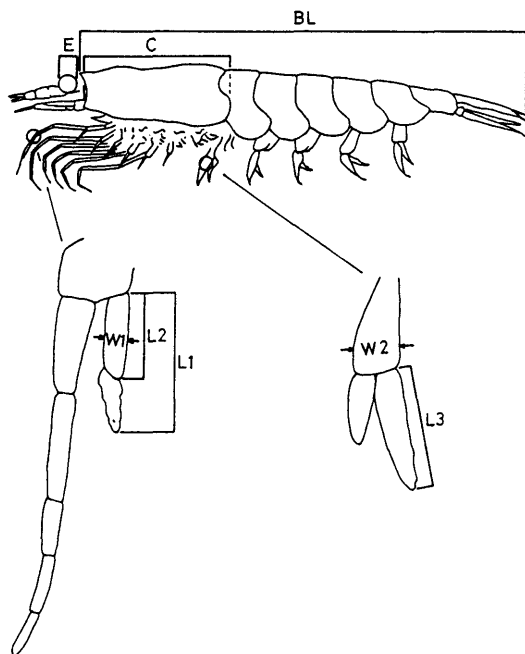


Fig. 1. Body parts of *Euphausia superba* measured. E. eye diameter; C. carapace length; BL. body length; L1. length of exopodite of first thoracic leg; L2. length of exopodite lobe of first thoracic leg; W1. width of exopodite lobe of first thoracic leg; L3. length of exopodite of first pleopod; W2. width of protopodite (basal segment) of exopodite of first pleopod.

Results and Discussion

Both II A3 and III B males occurred at 55 out of 65 stations where *E. superba* were collected. Mean body lengths of II A3 and III B stages were not significantly different at 34 out of 55 stations (the MANN-WHITNEY *U*-test, SOKAL & ROHLF 1969). Those stations where similar sized II A3 and III B males occurred were scattered all over the study area. Figure 2 shows two extreme examples of the overlapped length frequency histograms of II A3 and III B males at four stations (pooled data) east of Elephant Island and at six stations (pooled data) west of the South Sandwich Islands. Mean body lengths were 41–42 mm in the waters east of Elephant Island and 49 mm west of the South Sandwich Islands. Body length frequencies of these two stages overlap nearly perfectly in each area.

Table 1 summarizes the results of statistical test of differences between II A3 and III B males in the measures of several body parts normalized by the body length. Eye diameter of III B was slightly larger than those of II A3, although the difference was not significant. The carapace length is significantly shorter in III B than in II A3 males. SIEGEL (1982) observed the same phenomenon in this species, which implies that carapace length becomes shorter as the maturity stage progresses. Width and length of lobe of exopodite and exopodite length of first thoracic leg were significantly greater in III B than in II A3 males. Although relative length of exopodite of first pleopod was not significantly different between these two stages, width of the protopodite

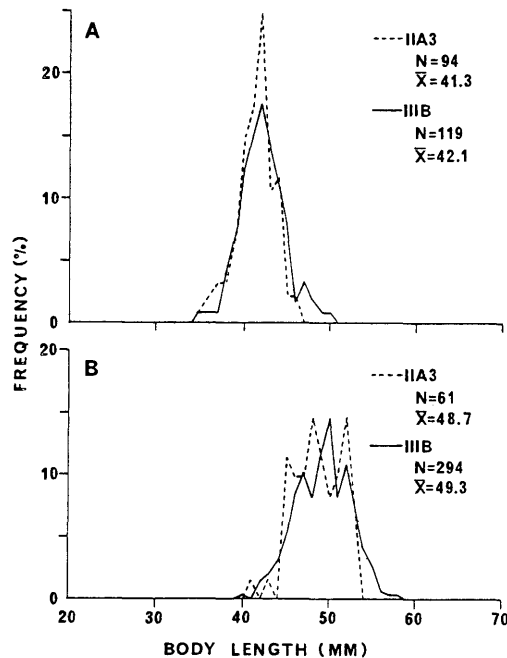


Fig. 2. Length frequency histograms of II A3 and III B males collected in the waters east of Elephant Island (A) and west of the South Sandwich Islands (B).

(basal segment) was significantly larger in III B than in II A3.

Relative lengths and widths of III D females (copulated females with swollen carapace) were also shown for reference in Table 1. All these values were smaller than those of II A3 and III B males except carapace and body lengths.

There were no differences in the dimension and mesh of the feeding basket (Table 2). Primary setal distances were $42.0 \pm 14.4 \mu\text{m}$ (mean ± 1 standard deviation) and $40.3 \pm 16.6 \mu\text{m}$ on ischium and $98.5 \pm 11.5 \mu\text{m}$ and $100.2 \pm 8.9 \mu\text{m}$ on merus for II A3 and III B males respectively. Secondary setal distances were $4.6 \pm 1.0 \mu\text{m}$ and $4.7 \pm 1.4 \mu\text{m}$ on ischium and $15.3 \pm 3.0 \mu\text{m}$ and $13.5 \pm 2.8 \mu\text{m}$ on merus for II A3 and III B males respectively. Primary and secondary setal distances were greater than those given by MCCLATCHIE & BOYD (1983) ($34.5 \pm 8.7 \mu\text{m}$ on ischium and $58.2 \pm 15.9 \mu\text{m}$ on merus for primary seta and $6.5 \pm 2.4 \mu\text{m}$ on ischium and $9.3 \pm 2.8 \mu\text{m}$ on merus for secondary seta) and by SUH & NEMOTO (1987) ($22.1\text{--}33.8 \mu\text{m}$ on ischium and $45.2\text{--}86.2 \mu\text{m}$ on merus for primary seta and $3.9\text{--}5.3 \mu\text{m}$ on ischium and $10.1\text{--}15.7 \mu\text{m}$ on merus for secondary seta) on this species. Since it is known that the larger setal distance and length of primary and secondary setae are associated with the larger specimens (MCCLATCHIE & BOYD 1983; SUH & NEMOTO 1987), these dissimilar results can be explained by the use of larger specimens (44–49 mm for II A3 and 44–53 mm for III B) in this study as compared with those of MCCLATCHIE & BOYD (1983) (23–48 mm) and SUH & NEMOTO (1987) (20–46 mm).

HAMNER (1988) made an excellent observation on the morphology and filtering mechanism of the thoracic endopodites and exopodites of *E. superba* and renewed the previous conflicting explanations on the filtering mechanism of euphausiids (see BERKES 1975). As the feeding basket expands laterally a pressure gradient is created which sucks water and food particles into the basket from the front. Particles are retained on the filter and water is squeezed out laterally between the setae of endopodite when the feeding basket compresses. During expansion of the basket the exopodites act as flapper valves which inhibit lateral entry of water, but during the compression stroke the exopodites lift for approximately 100 ms and permit expulsion of water.

TABLE 1. RELATIVE LENGTHS AND WIDTHS OF SEVERAL BODY PARTS TO BODY LENGTH OF II A3 AND III B MALES (MEAN ± 1 STANDARD DEVIATION). THOSE VALUES OF III D FEMALES ARE ALSO SHOWN. RESULTS OF THE *t*-TEST FOR THE DIFFERENCE IN MEANS BETWEEN II A3 AND III B MALES ARE SHOWN. NS= $P>0.05$; *= $P<0.05$; **= $P<0.01$

		II A3	III B	(♀ III D)	<i>t</i> -value
N		29	49	21	
Eye	E	0.047 ± 0.003	0.052 ± 0.002	0.043 ± 0.003	1.30 ^{NS}
Carapace	C	0.323 ± 0.017	0.281 ± 0.008	0.368 ± 0.013	2.47 *
Thoracic leg	L1	0.092 ± 0.005	0.112 ± 0.004	0.080 ± 0.004	2.95 **
	L2	0.052 ± 0.004	0.064 ± 0.003	0.043 ± 0.002	2.57 *
	W1	0.019 ± 0.001	0.026 ± 0.002	0.015 ± 0.001	2.79 **
Pleopod	L3	0.087 ± 0.005	0.097 ± 0.003	0.077 ± 0.004	1.89 ^{NS}
	W2	0.038 ± 0.002	0.046 ± 0.003	0.033 ± 0.002	2.10 *
BL(mm)		47.1 ± 2.6	47.7 ± 2.8	51.0 ± 2.9	0.13 ^{NS}

TABLE 2. COMPARISON OF LENGTHS OF ISCHIUM AND MERUS SEGMENTS OF THIRD THORACIC LEG, LENGTHS OF PRIMARY SETAE (PS) ALONG THESE SEGMENTS, AND DISTANCES BETWEEN THE BASES OF PRIMARY SETAE AND SECONDARY SETAE (SS) OF II A3 AND III B MALES (MEAN \pm 1 STANDARD DEVIATION). NO SIGNIFICANT DIFFERENCES WERE FOUND IN ANY PAIR OF MEANS.

	II A3	III B
Ischium		
Length(mm)	6.56 \pm 0.21	6.14 \pm 0.36
Length of PS(mm)	2.25 \pm 0.07	2.29 \pm 0.19
Distance between PSs (μ m)	42.00 \pm 14.37	40.30 \pm 16.63
Distance between SSs (μ m)	4.55 \pm 0.98	4.72 \pm 1.40
Merus		
Length(mm)	3.40 \pm 0.12	3.36 \pm 0.15
Length of PS(mm)	2.79 \pm 0.13	2.85 \pm 0.21
Distance between PSs (μ m)	98.50 \pm 11.51	100.17 \pm 8.86
Distance between SSs (μ m)	15.25 \pm 2.98	13.51 \pm 2.78

Pleopods are believed to be responsible for locomotion as well as creating feeding and respiratory currents (e. g. MAUCLINE & FISHER 1969, MAUCLINE 1980). Exopodite of thoracic leg and protopodite of pleopod proved to be better developed in III B than in II A3 males (Table 1).

These results suggest that III B males are superior to II A3 males in filtering and swimming abilities. Moreover shorter carapace in III B males may indicate better development in abdomen and hence better swimming ability as compared with II A3 males.

It has been observed that maturity stage of *E. superba* is reversible in the laboratory experiment (MCWHINNIE et al. 1979, POLECK & DENYS 1982, IKEDA & THOMAS 1987). MAKAROV (1976) deduced that maturity regression occurs in natural population, especially males, from the examination of samples collected in summer, winter and spring of 1965, 1967 and 1968-1971. MCWHINNIE et al. (1979) and IKEDA & THOMAS (1987) showed experimentally that maturity regression and progression is not always accompanied by body length reduction and increment respectively. Borne in mind this flexible maturation process in *E. superba*, II A3 males observed in this study may be the specimens progressed from less mature ones or regressed from matured ones (III B). These maturity progression and regression were shown to be accompanied by increase and decrease of filtering and swimming abilities in males in this study. These morphological changes may be related to the food availability in their habitats. Alternatively, males may require powerful swimming ability to capture females to copulate and therefore need more energy, considering that females do not show apparent morphological changes except in gonad and secondary sexual characteristics in the process of maturation.

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