Thesis for the Degree of Master of Science

A new species of the copepod *Mesocalanus* n. sp. (Calanoida, Calanidae) from the Coastal Waters of Korea

by

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A new species of the copepod *Mesocalanus* n. sp. (Calanoida, Calanidae) from the Coastal Waters of Korea
(한국 근해에서 발견된 요각류 신종 *Mesocalanus* n. sp.)

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by

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주수진

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Abstract

한국 근해에 출현하는 요각류 *Mesocalanus* 속에는 *Mesocalanus tenuicornis* 와 *Mesocalanus lighti* 2 종이 있다. 최근 분자학적 분석을 통해 *Mesocalanus tenuicornis* 로 동정되었던 개체들이 신종이라고 추정되었다. 이러한 신종의 정확한 동정을 위해 형태학적인 분석을 하였다. *Mesocalanus* 시료는 2022 년 4 월, 5 월과 8 월 Bongo net (망구 80 cm, 망목 330 ㎛) 를 이용한 경사채집을 통해 한국 근해에서 채집했다. 형태분석은 몸의 형태, 체장, 두흉부의 길이와 폭의 비율을 측정하고 부속지를 해부했다. 형태는 *M. tenuicornis* 와 유사했으며 뾰족한 형태와 뭉툭한 형태가 있었다. 체장 범위는 1.5 에서 2.1 mm 였고, 전체부 길이의 범위는 1.1 에서 1.65 mm 였다. *Mesocalanus* n. sp.는 *Mesocalanus tenuicornis* 그리고 *Mesocalanus lighti* 와 비교해서 대부분의 부속지는 유사하였으나 수컷의 제 5 흉지에서 차이를 보였다. *Mesocalanus* n. sp.의 제 5 흉지 오른쪽 외지는 가시는 5 개, 강모는 3 개였다. *Mesocalanus tenuicornis* 그리고 *Mesocalanus lighti* 의 제 5 흉지 오른쪽 외지는 가시 5 개에 강모가 없는 형태적 차이를 보였다.

1. Introduction

Copepods are widespread in all aquatic ecosystems as a key link between primary producers and higher predators (Kwok et al. 2015). They also take an important role in the functioning of marine ecosystems by providing half the primary production and contributing to biogeochemical cycling (Richardson and Shoem, 2004).

The species of the genus *Mesocalanus* are marine planktonic copepods that belong to the family Calanidae Dana, 1849. So far, two species of the genus *Mesocalanus* have been reported in the world, *Mesocalanus tenuicornis* (Dana, 1853), and *Mesocalanus lighti* (Bowman, 1955). *Mesocalanus tenuicornis* was first reported by Dana (1853). The species is widely distributed in subtropical regions and found at the depths of at least 200 m (Bradford-Grieve, J. M. 2002). *Mesocalanus tenuicornis* and *Mesocalanus lighti* can be distinguished by the following characteristics: the presence of an elevated postero-dorsal margin of the head; ratio of cephalothorax length to depth; male leg 5 exopod segment 3 terminal spine (Bowman, 1955).

Mesocalanus species found in the coastal waters of Korea are different from those previously reported morphological characteristics

of *Mesocalanus tenuicornis*. As a result of the MtCOI domain analysis, *Mesocalanus* sp. differed more than 94% from *Mesocalanus tenuicornis*. Thus *Mesocalanus* sp. was likely to be a potential new species (Lee, 2020). So, a morphological analysis of the new species is needed to accurate identification of *Mesocalanus* species. In this paper, the morphological characteristics of the *Mesocalanus* n. sp. found in coastal waters of Korea were described and compared with the congeneric species *M. tenuicornis* and *M. lighti*.

This study describes and report a new species of *Mesocalanus* from Korean waters by a defined set of morphological features.

2. Materials and methods

2.1. Sample collection

Mesocalanus species specimens were collected at 13 stations of the coastal waters of Korea in April, May, and August 2022 using a Bongo net (80 cm, 330 μm). Collected specimens were preserved in 90% ethanol and transported to the laboratory (Fig 1).

2.2. Morphological analysis

The body shape, total length, prosomal length, cephalothorax length, and cephalothorax depth of *Mesocalanus* species specimens were measured using a camera (Moticam Pro) attached to a dissecting microscope (Olympus SZX2-ILLK). The selected individuals were softened using a 50% lactic acid solution and Rose Bengal solution was dropped for dyeing. The dyed individuals were placed in 3% glycerin for more than three days. Mouth appendages, a first antenna, a second antenna, and the first leg to the fifth leg of the specimens were dissected and mounted on depression slides. The illustrations were drawn through a microscope with a drawing tube attached.

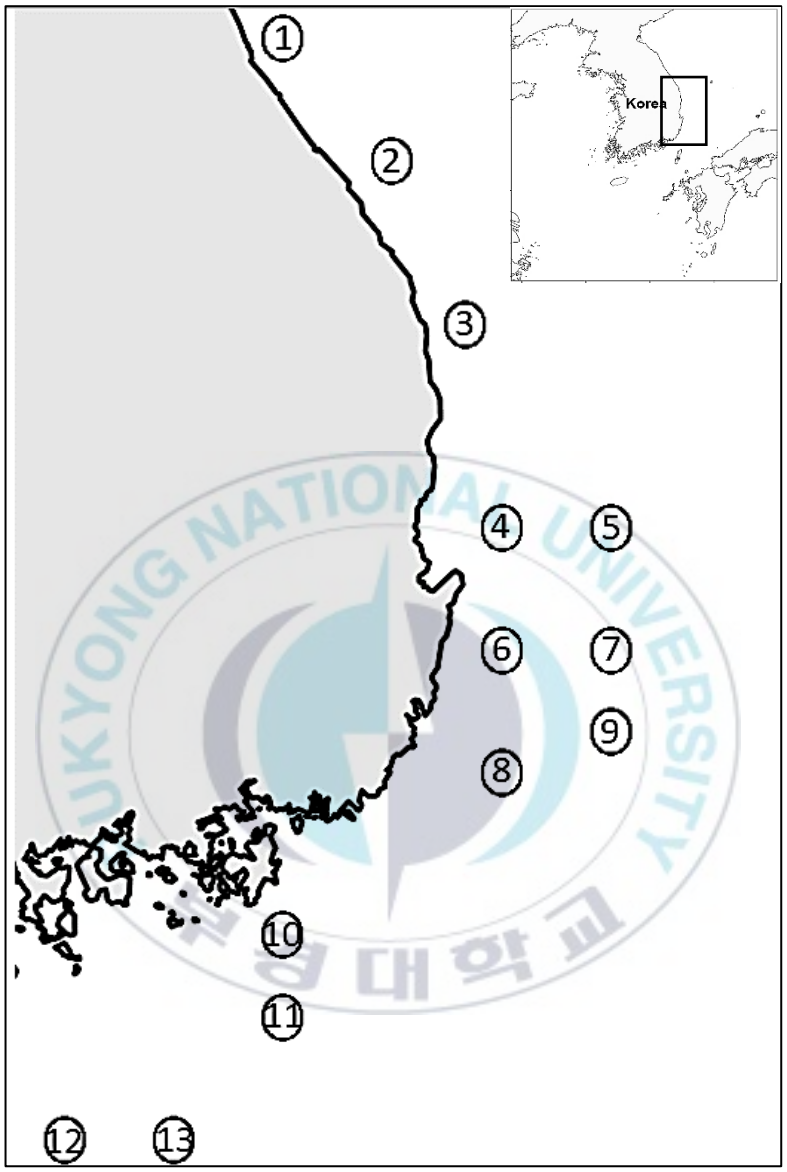

Figure 1. Maps showing 13 sampling stations (as number) of the coastal waters of Korea.

3. Results

TAXONOMY

Order Calanoida Sars, 1903

Family Calanidae Dana, 1849

Genus *Mesocalanus* Bradford & Jillett, 1974

Mesocalanus n. sp.

Material examined

Female Holotype ♀ dissected on one slide. Allotype ♂ dissected on one slide. Paratypes, 2 ♀♀ and 2 ♂♂ were dissected on each slide. All examined specimens were collected from the coastal waters of Korea in April, May, and August 2022 (Fig 1).

Description

Female

Body (Fig. 2A, B)

Size: total length = 1.61 to 2.11 mm (mean = 1.76 ± 0.09 mm)

prosome length = 1.21 to 1.65 mm (mean = 1.4 ± 0.07 mm)

Shape similar to that of *M. tenuicornis*; sharp form with thinner and longer prosome width and stubby form with broader prosome width. Head with a dorsal slope and rounded; posterior border of the head slightly went up; thinner than the thorax. The ratio of cephalothorax length to depth was about 3:1. Body bent in the dorsal midline; ratio of the body to genital somite was 4:1. No distinct patterns or dots. Prosome six somites; first somite longest; second somite 1/4 longer than the third somite; sixth somite overlaps with the genital somite; genital somite round, swollen nucleus downward; anal somite three-segmented; Furcae with 4 long setae.

Antenuule (Fig. 2C). 25 segmented; segments 8 and 9 fused; twice the length of the body; long, slender setae on the 3, 5, 6, 13, 19, and 20 segments; feathery seta on the 23 and 24 segments.

Antenna (Fig. 3A). Coxa with one feathery seta; Basis with 2 setae; Exopod seven segmented with 6 setae on the terminal and 5 setae on subterminal; Endopod two-segmented with 2 setae in the first segment and 15 setae in the second segment; short hairs scattered on the side of the first segment.

Mandible (Fig. 3C). Coxa with short spines in the distal margin; 7 tooth tips in the gnathobase with 3 setae in the center of the basis;

Exopod five segmented with 1,1,1,1,2 setae; Endopod 2 segmented with 4 setae for the first segment and 10 setae for the second segment; 2 out of 10 setae relatively short in the second segment.

Maxillule (Fig. 3D). Praecoxal arthrite with 9 setae; 4 of them spiny; Coxal epipodite with 9 setae; 2 of them relatively short; Coxal endite with 3 setae; Basal endite with 4 setae in the proximal region and 5 setae in the distal region; Endopod three segmented with 13 setae; Exopod undivided segment with 11 setae.

Maxilla (Fig. 3B). Praecoxal with proximal to 5 setae and distal to 3 setae; Coxa with 2 endites with 3 setae on each endite; Basal endite with 4 setae; Endopod four segmented with 8 setae.

Maxilliped (Fig. 3E). Syncoxa with 4 endites with 1, 2, 3, and 4 setae; top 4 setae shorter; Basis distributed with 3 setae; Endopod six segmented with 2, 3, 4, 2, 3, and 3 setae.

Legs 1−4 (Fig. 4A−D). Setal formula of legs 1−4 follows (Table 1).

From leg 1 to leg 4 with a conical projection on the posterior surface first segment of the exopod; Coxa with one feather−shaped seta; Spinules on the ends of the surface of both legs; Leg 3 was the largest.

Leg 5 (Fig. 4E). Smooth inner edge of basipod; Base of coxa with one feather-shaped seta; Exopod three segmented each with 1, 1, and 3 spines and 4 setae; small triangular protrusion next to these spines; the third segment of exopod twice the length of the first segment; Endopod three segmented with seven setae; first and second segment each with one spine.

Male

Body (Fig. 5A, B)

Size: total length = 1.5 to 1.98 mm (mean = 1.67 ± 0.12 mm)

prosome length = 1.1 to 1.58 mm (mean = 1.3 ± 0.1 mm)

Shape similar to the female but slimmer; Head with less pronounced dorsal slops; Prosome with 6 somites; shorter in width and length than females. Genital somite not inflated; Anal somite four segmented; Furcae longer and more divergent than females.

Antenuule (Fig. 5C). 25 segmented; segments 3 to 5, 7 to 9, and 9 and 10 fused; Seta on the 1, 3, 5, 6, 12, 13, 19, and 20 segments.; 23 and 24 segments with one long, feathery seta.

Antenna (Fig. 6A). Basis with no seta; first segment of endopod with

one seta; second segment with 11 setae; Exopod with 10 setae.

Mandible (Fig. 6C). Gnathal lobes smaller than females; First segment of endopod with 3 setae; second segment with 9 setae; Exopod with 6 setae.

Maxillule (Fig. 6D) Coxa epipodite with 8 setae; Endopod with 11 setae.

Maxilla (Fig. 6B). Two endites of coxa each with 2 setae.

Maxilliped (Fig. 6E). Endopod five segmented with 2, 2, 4, 2, and 3 setae.

Legs 1−4 (Fig. 7A−D). Setal formula of legs 1−4 follows (Table 2).

Leg 5 (Fig. 7E, F) smooth inner edge of basipod; Smaller left leg; The formula of spine and setal, as well as the shape, showed differences. Endopod with 2 spines and 7 setae; Exopod of the left leg with 5 spines and no setae; Exopod of the right leg with 5 spines and 3 setae.

The forms of the *Mesocalanus* n. sp. and *Mesocalanus* species legs were similar up to 1−4, but there was a difference in the male's fifth leg (Table 3). A more detailed comparison will continue in the discussion.

Morphological damage was found in most specimens. It was difficult to find a sample with fully attached legs, and it was common to have damaged setae.

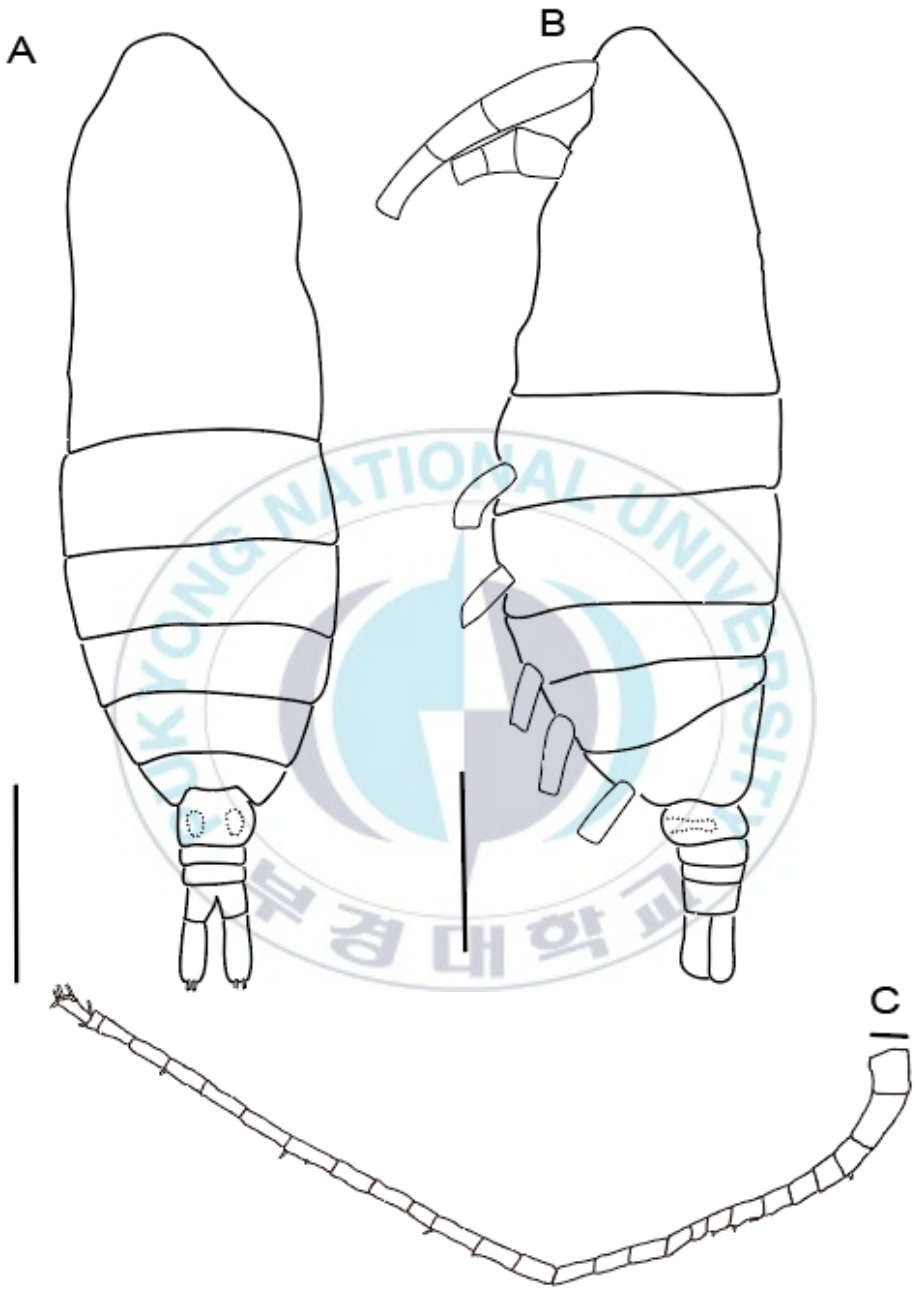

Fig 2. *Mesocalanus* n. sp., female. A, dorsal view; B, lateral view; C, antennule; Scale bars in 1 mm for A and B, and 0.1 mm for C.

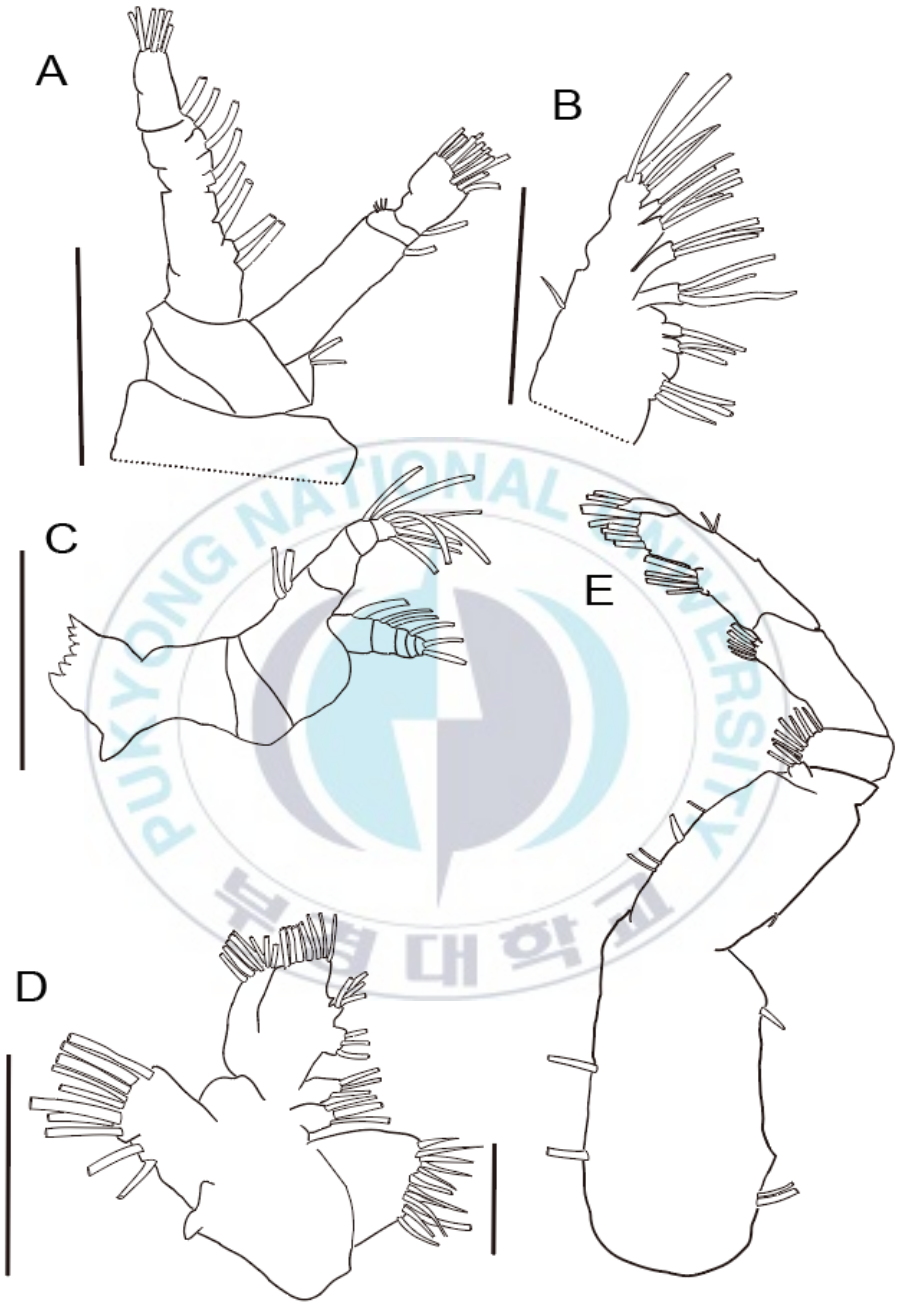

Fig 3. *Mesocalanus* n. sp., female. A, antenna; B, maxilla; C, mandible; D, maxillule; E, maxilliped; Scale bars in 1 mm for A, B, C, and D, and 0.1 mm for E.

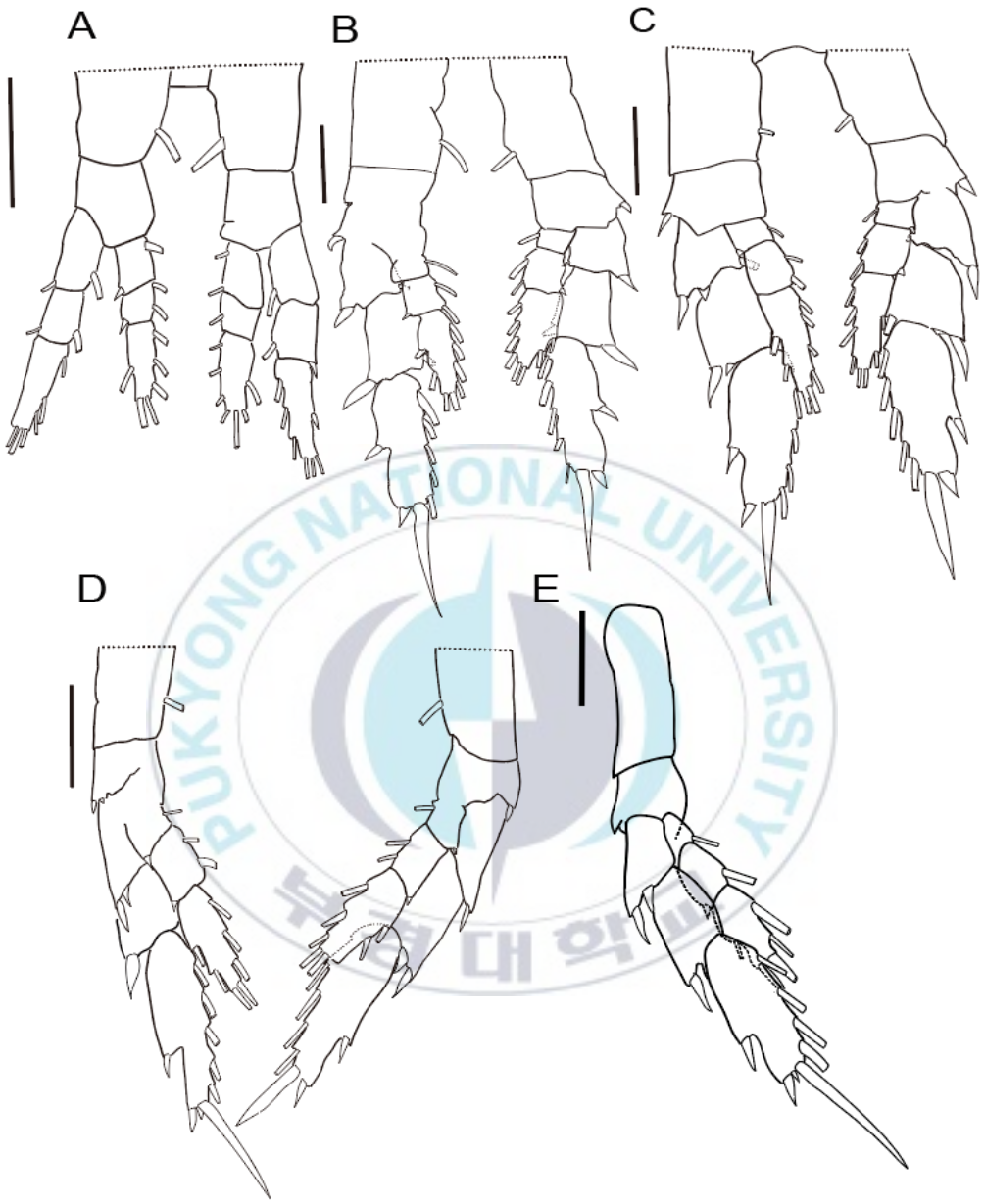

Fig 4. *Mesocalanus* n. sp., female. A, leg 1; B, leg 2; C, leg 3; D, leg 4; E, leg 5; Scale bats in 0.1 mm for A, B, C, D and E.

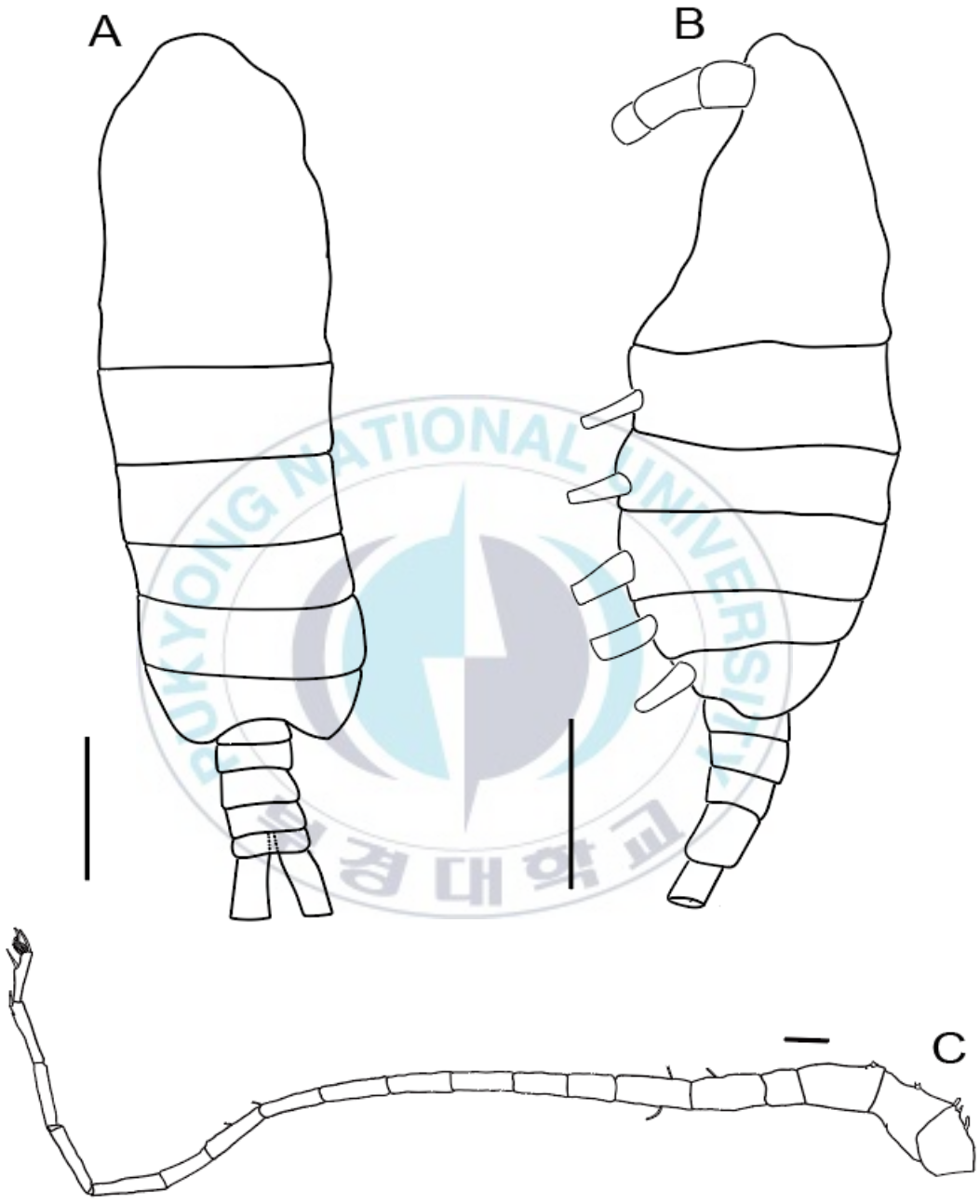

Fig 5. *Mesocalanus* n. sp., male. A, dorsal view; B, lateral view; C, antennule; Scale bars in 1 mm for A and B, and 0.1 mm for C.

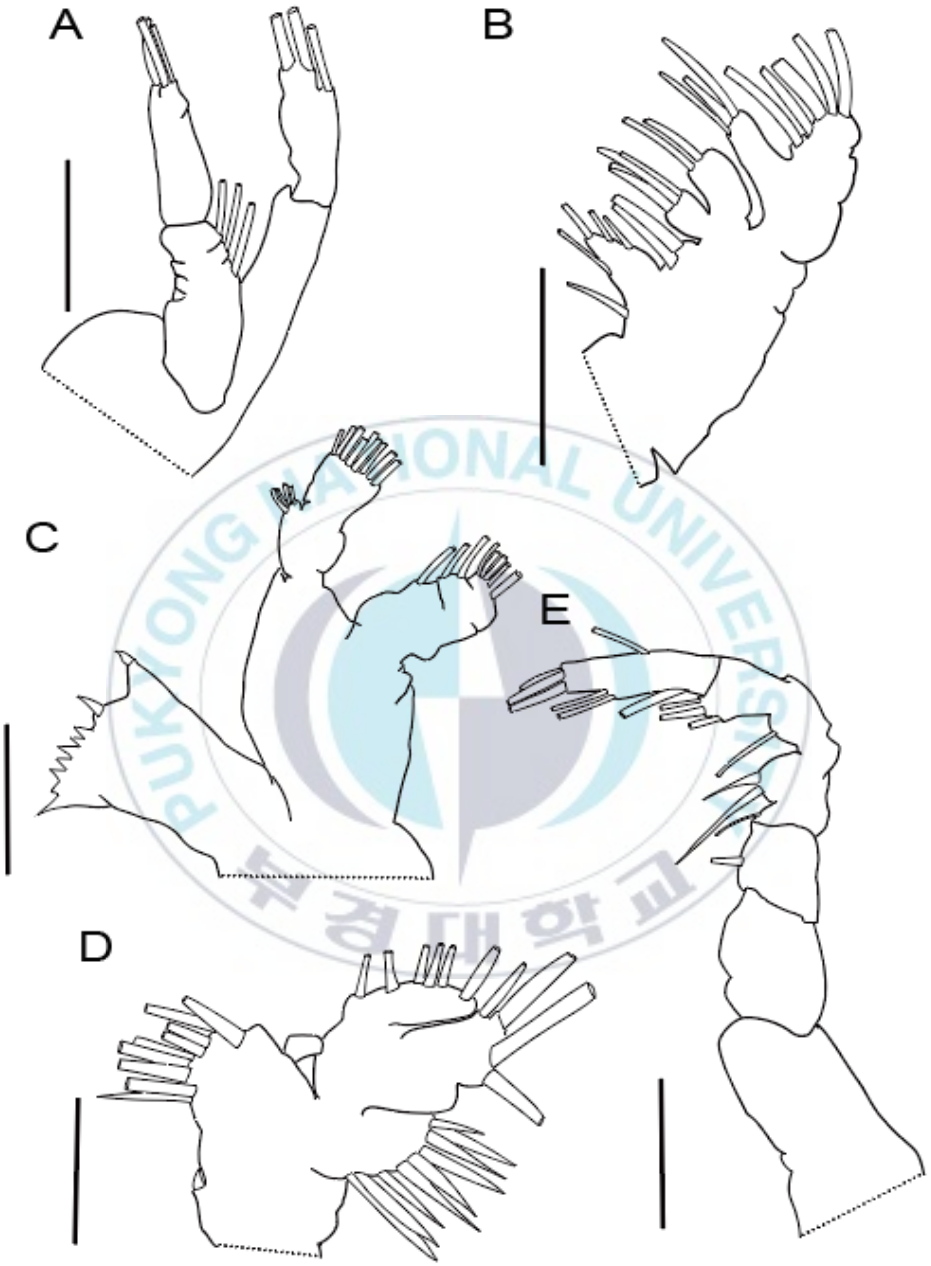

Fig 6. *Mesocalanus* n. sp., male. A, antenna; B, maxilla; C, mandible; D, maxillule; E, maxilliped; Scale bars in 0.1 mm for A, B, C, D and E.

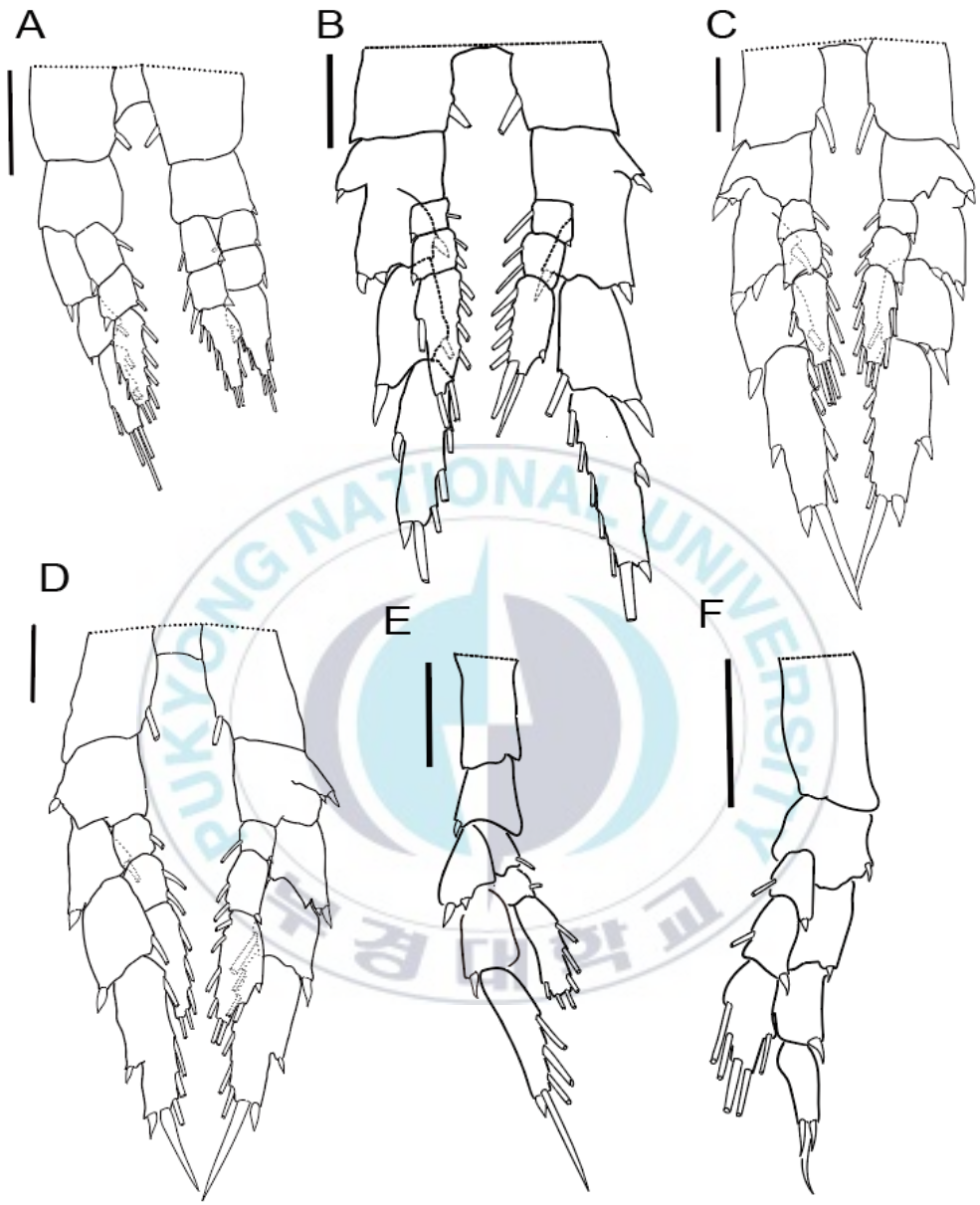

Fig 7. *Mesocalanus* n. sp., male. A, leg 1; B, leg 2; C, leg 3; D, leg 4; E, right leg 5; F, left leg 5; Scale bats in 0.1 mm for A, B, C, D, E, and F.

Table 1. Spine and setal formula of swimming legs 1−4 of *Mesocalanus* n. sp. female

	Coxa	Basis	Endopod	Exopod
Leg 1	;0−1	0−1;	1,1 ; 8	3 ; 7
Leg 2	;1	1;	1,1 ; 1,2,8	1,1,2 ; 1,1,6
Leg 3	;1	1;	1,1 ; 1,2,8	1,1,2 ; 1,1,6
Leg 4	;1	1;	1,1 ; 2,7	1,1,3 ; 1,1,5

Spine;Setae

Table 2. Spine and setal formula of swimming legs 1−4 of *Mesocalanus* n. sp. male

	Coxa	Basis	Endopod	Exopod
Leg 1	;1	0−1;	1,1 ; 7	3 ; 6
Leg 2	;1	1;	1,1 ; 1,2,8	1,1,3 ; 1,1,5
Leg 3	;1	1;	1,1 ; 1,2,8	1,1,3 ; 1,1,5
Leg 4	;1	1;	1,1 ;1,2,7	1,1,3 ; 1,1,5

Spine;Setae

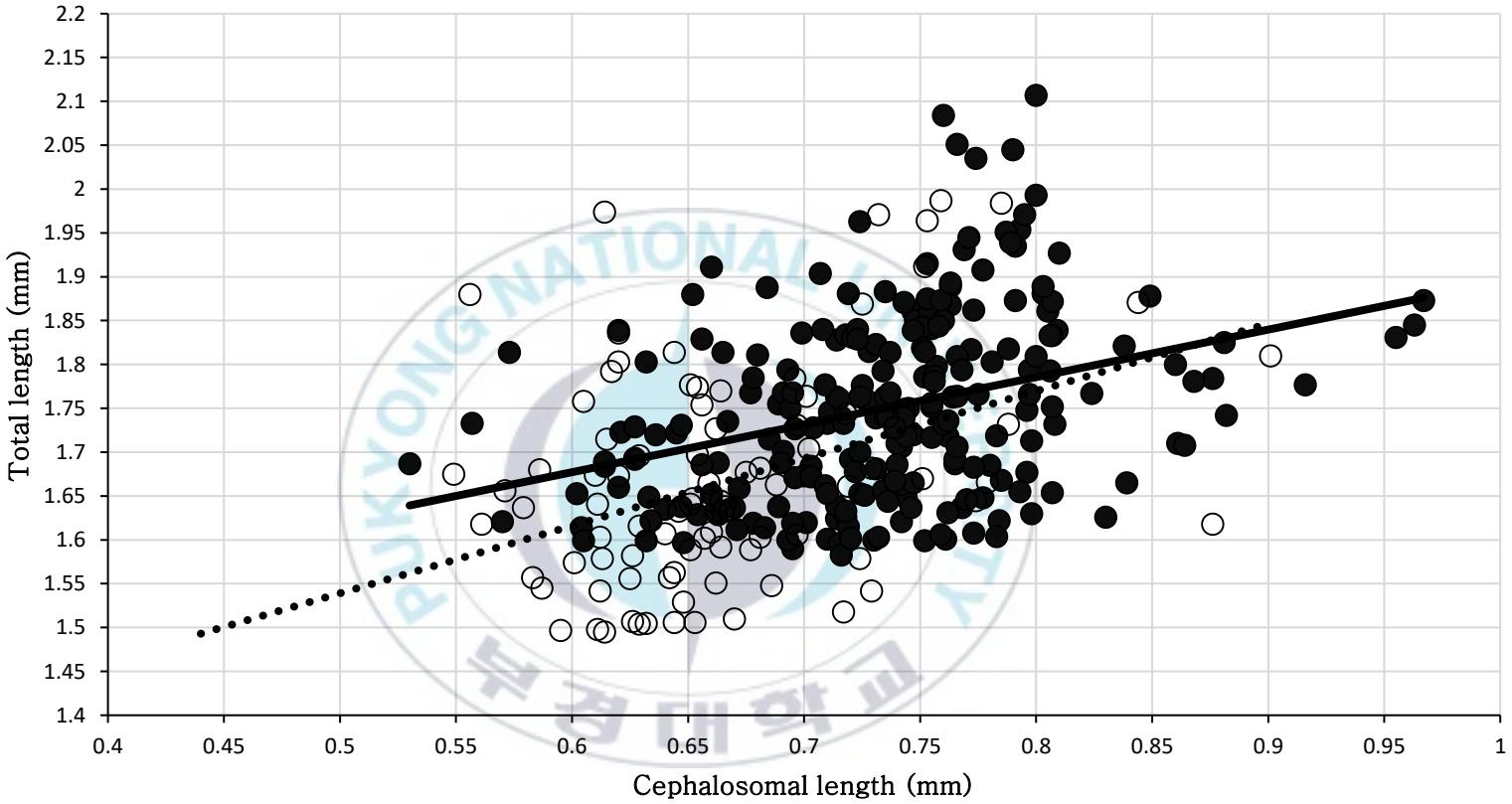

Figure 8. Total length of *Mesocalanus* n. sp. plotted against cephalosomal length (solid dots and solid line for females; open circles and dotted line for males).

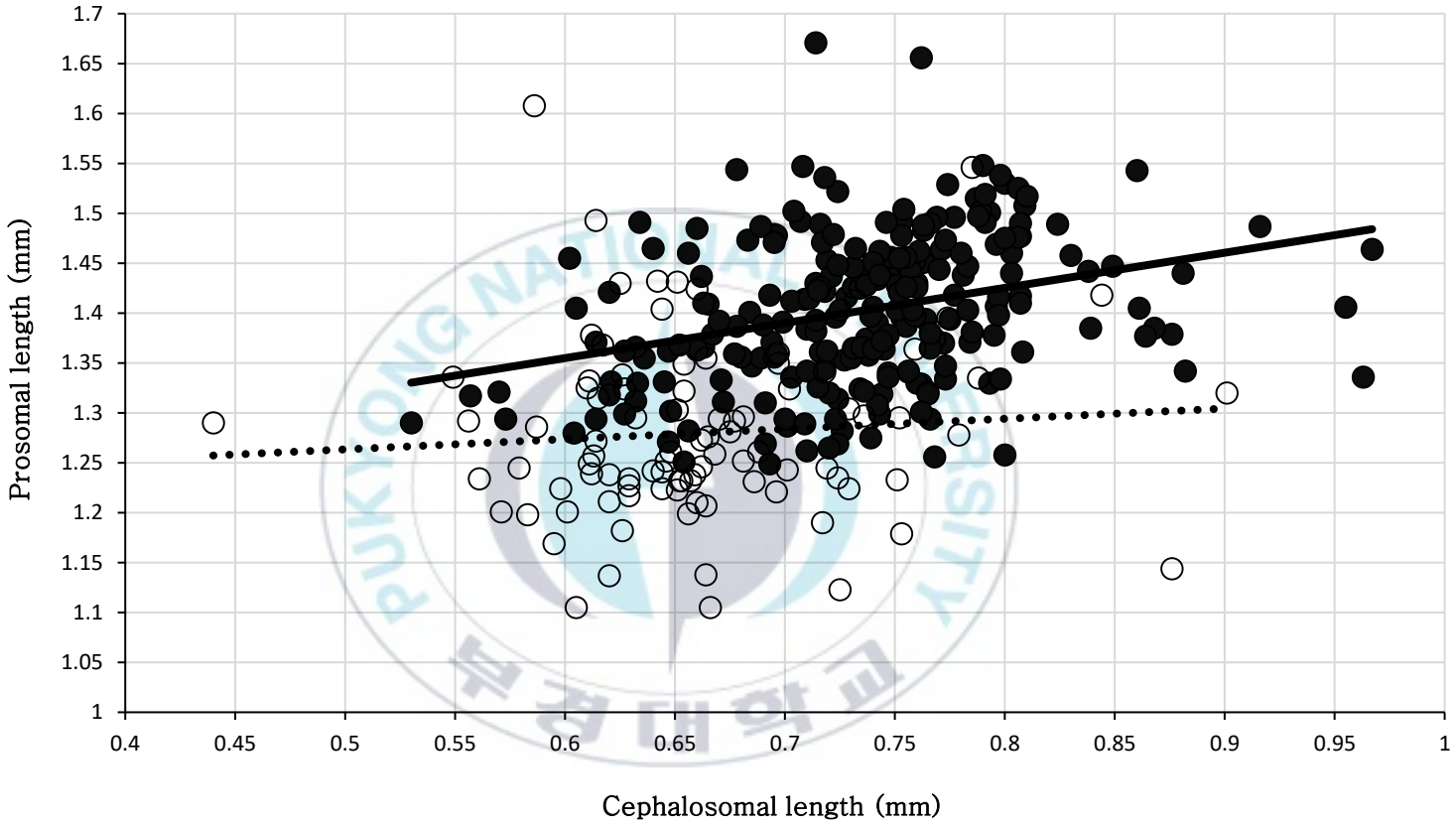

Figure 9. Prosomal length of *Mesocalanus* n. sp. plotted against cephalosomal length (solid dots and solid line for females; open circles and dotted line for males).

Table 3. Comparisons of the fifth swimming leg between *Mesocalanus* species

Characters	*Mesocalanus* n. sp.				*Mesocalanus tenuicornis*				*Mesocalanus lighti*			
	Female		Male		Female		Male		Female		Male	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Exopod segment	3	3	3	3	3	3	3	3	3	3	3	3
Endopod segment	3	3	3	3	3	3	3	3	3	3	3	3
Exopod setation	4	4	3	0	4	4	0	0	4	4	0	0
Endopod setation	7	7	7	7	7	7	7	7	7	7	7	7
Exopod spine	1,1,3	1,1,3	1,1,3	1,1,3	1,1,3	1,1,3	1,1,3	1,1,3	1,1,3	1,1,3	1,1,3	1,1,3

4. Discussion

Mesocalanus genus currently includes two species, *Mesocalanus lighti* (Bowman, 1955) and *M. tenuicornis* (Dana, 1849). Mullin (1969) has reported a subantarctic calanid called "Intermediated Form" which probably belongs to this genus, but was not definite about its taxonomic status. The present specimens do have similar characteristics to *M. tenuicornis*. The new species body shape was similar to that of *M. tenuicornis* in a sharp form and stubby form species. The sharp form was generally thinner and longer, and the stubby form had a broader prosome than the sharp form. The Head of *M. lighti* has a more flattened dorsal slope than *M. tenuicornis*, and *Mesocalanus* n. sp. has quite a projected dorsal slope. *Mesocalanus* n. sp. and *Mesocalanus* species legs were similar up to 1−4, but there was a difference in the male's fifth leg (Table 3). The right exopodite of the fifth leg of *Mesocalanus* n. sp. consists of three segments and has five spines and three setae. The right exopodite of *M. tenuicornis* and *M. lighti* fifth leg showed a morphological difference with three segments, five spines, and no setae. There was also a difference in the distribution and morphology of spines. The new species had three spines placed in a row at the end of the third segment. But in *M. tenuicornis* and *M. lighti* along the outer

border, there was one spine in the center and two at the end of the third segment. *M. tenuicornis* had the most terminal spine on the third segment exopodite of the fifth leg. It was as long as the segment when measured along the outer border. And the spine of *M. lighti* was slightly shorter and slenderer than that of *M. tenuicornis* (Bradford-Grieve, 2002). But the new species had a spine shorter than the segment.

The new species showed a difference in the range of male and female total length. Studies on *M. tenuicornis* showed that the total length was 1.6 to 2.39 mm for females and 1.71 to 2.02 mm for males. And for females of *M. light* total length was 2.32 to 3.08 mm, and for males was 1.9 to 2.68 mm (Bowman, 1955). In this study, the total length of *Mesocalanus* n. sp. females was 1.61 to 2.1 mm, and for males was 1.49 to 1.98 mm. The ratio of length to depth of cephalothorax was all different in *Mesocalanus* species (Bowman, 1955). In *M. tenuicornis* was 4.5:1, *M. light* was 6:1 and *Mesocalanus* n. sp. was 3:1.

This paper described a morphological study of *Mesocalanus* n. sp. The new species can be separated from *Mesocalanus* species by the exopodite of the male's leg 5 (i.e., *Mesocalanus* n. sp. has five spines and four setae, but *M. tenuicornis* and *M. lighti* had five spines, and no setae) and the ratio of length to depth of cephalothorax (i.e., 3:1 in *Mesocalanus* n. sp. but 4.5:1 in *M. tenuicornis* and 6:1 in *M. light*).

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