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NAUPLIAR DEVELOPMENT OF *STEPHOS LONGIPES* (COPEPODA: CALANOIDA) FROM THE ANNUAL SEA ICE OF TERRA NOVA BAY, ANTARCTICA

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ABSTRACT

Six naupliar stages are described based on specimens of *Stephos longipes* Giesbrecht, 1902, obtained from sea ice near Terra Nova Bay, Antarctica. Marked differences between nauplii of *Stephos longipes* and *Paralabidocera antarctica* (I. C. Thompson, 1898) were used only to identify the two species in the samples. The copepods *Stephos longipes* and *Harpacticus furcifer* Giesbrecht, 1902, accounted for more than 90% of sympagic communities in the annual sea ice at Terra Nova Bay.

The genus *Stephos* T. Scott, 1892, currently comprises 30 species, all generally of small size. Recently, species of *Stephos* have been described by Riera *et al*., 1991; Bradford-Grieve, 1999; Zagami *et al*., 2000; and Costanzo *et al*., 2000.

Members of the genus *Stephos* range widely throughout the North Atlantic, Indo-West Pacific, and in New Zealand waters. Species occur in temperate, tropical, and polar waters and are typically found living just above the sea floor in shallow coastal waters, anchialine lava pools, the ice/water interface, and in sea ice. Two species of the genus *Stephos* have been recorded in Antarctic waters: *S. longipes* Giesbrecht, 1902, and *S. antarcticum* (I. C. Thompson, 1898) (see Razouls *et al*., 2000).

Stephos longipes has a circumantarctic distribution, and its life cycle is closely associated with the annual cycle of the sea-ice formation, consolidation, and subsequent melt (Schnack-Schiel *et al*., 1995).

In the present paper, we describe the naupliar stages of *S. longipes*. This is the first description of six naupliar stages of a species of *Stephos*. Kurbjeweit (1993) described the egg and first naupliar stage of *S. longipes*.

All specimens of *S. longipes* examined in this study were collected from sea ice. The naupliar stages were easily identified because nauplii of *S. longipes* and *Paralabidocera antarctica* are the only nauplii of calanoid copepods in the sea ice (Schnack-Schiel *et al*., 1995), and naupliar stages of *P. antarctica* have been previously described by Tanimura (1992).

Materials and Methods

The sampling area was located in the offshore annual pack ice of Terra Nova Bay (74°41.72′S, 164°11.63′E), two nautical miles from the Italian Base (Fig. 1). Sea-ice cores (10 cm diameter) were collected, at 3-day intervals, in a 100-m^2 delimited area, from 5 November to 1 December 1997, using an aluminium corer. Sea-ice thickness (about 1.4 m) remained constant during the sampling period.

Immediately after collection, sea-ice cores were sliced, in lighted conditions just sufficient to carry out this operations, into 3-, 6-, and 12-cm-thick sections, according to the parameters to be considered. More details on sea-ice physical, chemical, and biological properties are reported in Guglielmo *et al*. (2000).

All zooplankton in the melted samples were collected and preserved in borax-buffered Formalin (final concentration 1–2%). In the laboratory, copepods were separated by species, sex, and development stage and counted. Differences between *Stephos longipes* and *Paralabidocera antarctica* nauplii, mainly based on the second antennular segment, the maxillule, the maxilliped, and the caudal armature, has been useful for distinguishing the two species. The naupliar stages of *Stephos longipes* were measured, and drawings of the body and appendages were prepared with a Reichert "Visopan" projection microscope.

Results

Ecological Data

The zooplankton community in the intact sea ice was dominated by copepods. In particular, the calanoid *Stephos longipes* and the harpacticoid *Harpacticus furcifer* accounted for more than 90% of the sympagic fauna. In early spring, these two species were at different stages of their life cycle, for *S. longipes* was largely represented by nauplii, whereas for *H. furcifer*, mainly exuviae and copepodids were observed (Fig. 2). A peak in *S. longipes* abundance was observed about mid-sampling

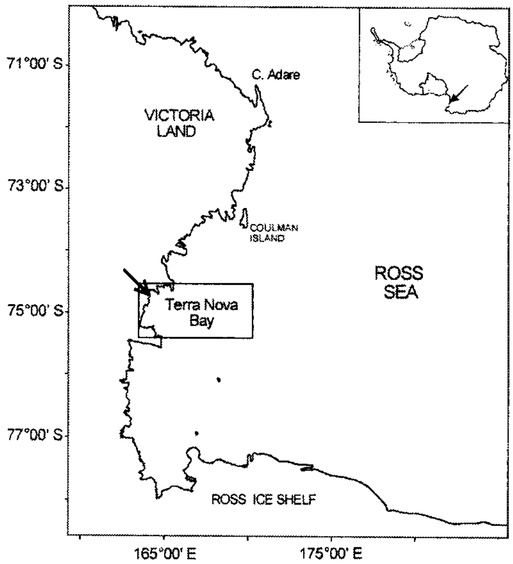


Fig. 1. Location of the ice cores sampling site.

period, whereas *H. furcifer* maintained a low abundance for the entire period of study (Fig. 3).

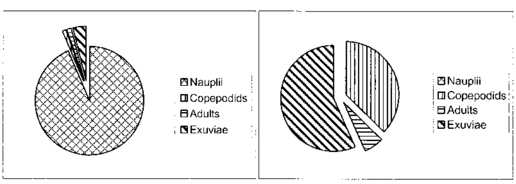
Naupliar Stages

Nauplius I (N I) (Fig. 4A).—One specimen 0.116 mm long. Caudal armature consisting of two spines.

Antennule (Fig. 4B). Three-segmented, with first segment unarmed, second segment with 3 ventral setae, third segment with 3 terminal setae.

Antenna (Fig. 4C). Coxa with 1 spine and 1 small seta; basis with 1 spine, endopod 1-segmented, with 2 medial and 2 terminal setae; exopod 5-segmented, segments 1–4 each with 1 seta, fifth with 2 setae.

Mandible (Fig. 4D). Coxa with 1 small seta; basis with 2 setae; endopod 1-segmented, with 3 medial and 2 terminal setae; exopod 4-segmented, first to third segments each with 1 seta, fourth with 2 setae.



Stephos longipes	MIN	MAX	*Harpacticus furcifer*	MIN	MAX
	Ind L^{-1}			Ind L^{-1}	
Nauplii	0.1	509.5	Nauplii	0.0	0.0
Copepodids	0.0	7.9	Copepodids	0.0	60.1
Adults	0.0	13.1	Adults	0.0	12.0
Exuviae	0.0	21.0	Exuviae	0.0	71.7

Fig. 2. Contribution of different life stages for the two dominant species. The table reports the range of abundance (ind. l^{-1})

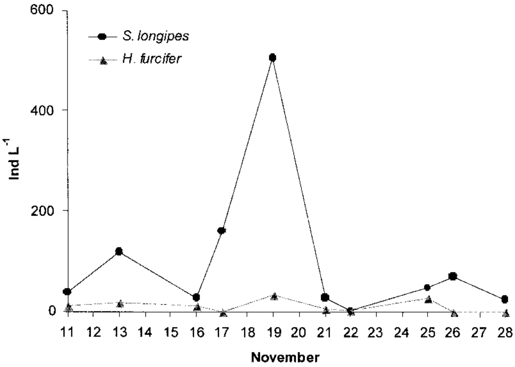


Fig. 3. Variation in time of *Stephos longipes* and *Harpacticus furcifer* (ind. l^{-1}) in the bottom-ice in Terra Nova Bay, November 1997.

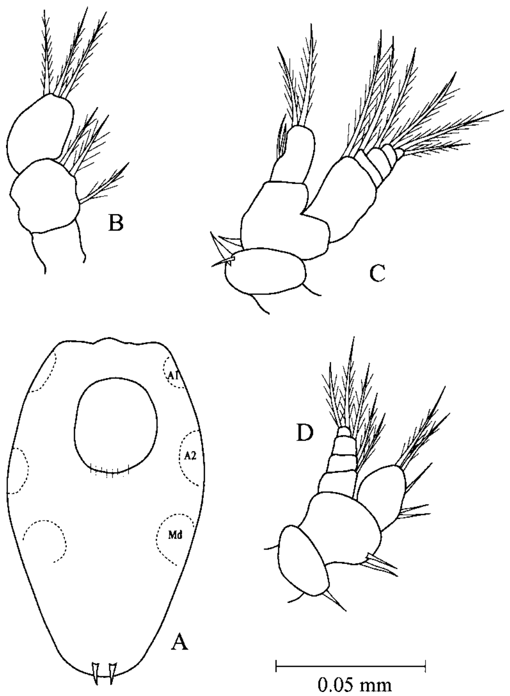


Fig. 4. *Stephos longipes* Giesbrecht, 1902. Nauplius I: (A) ventral view with antennule position (A1), antenna position (A2), mandible position (Md); (B) antennule; (C) antenna; (D) mandible.

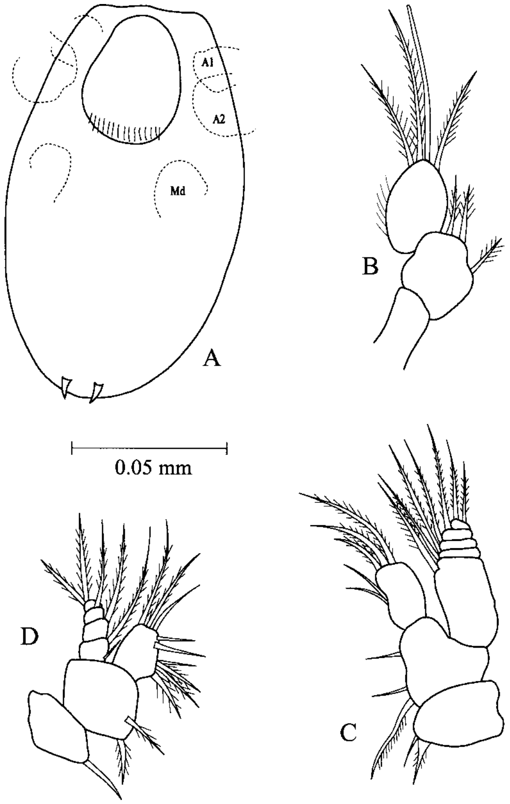


Fig. 5. *Stephos longipes* Giesbrecht, 1902. Nauplius II: (A) ventral view with antennule position (A1), antenna position (A2), mandible position (Md); (B) antennule; (C) antenna; (D) mandible.

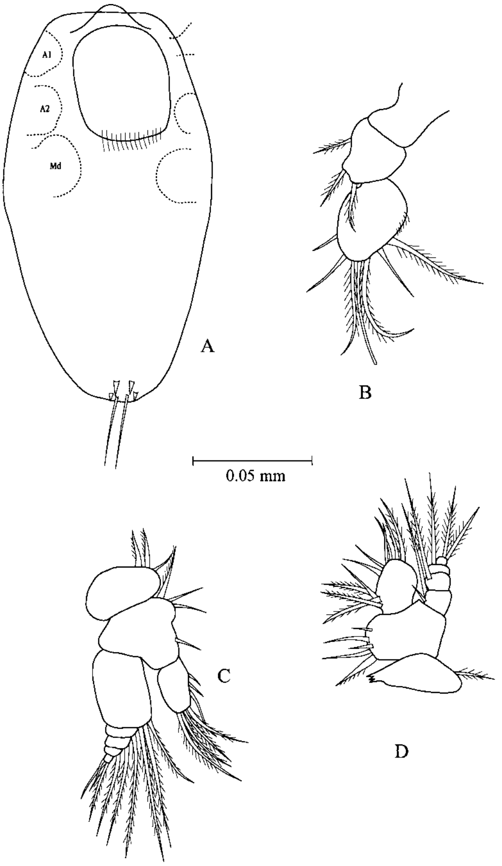


Fig. 6. *Stephos longipes* Giesbrecht, 1902 Nauplius III: (A) ventral view with antennule position (A1), antenna position (A2), mandible position (Md); (B) antennule; (C) antenna; (D) mandible.

Nauplius II (N II) (Fig. 5A).—Five specimens. Body length 0.118–0.135 mm (mean 0.128 mm). Caudal armature as in nauplius I.

Antennule (Fig. 5B). First and second segments as in nauplius I; third segment with 2 dorsal and 1 ventral setae + 1 terminal aesthetasc.

Antenna (Fig. 5C). Coxa with 1 strong spine and small seta; basis with 1 strong spine and 2 small setae; endopod as in nauplius I, but with 3 terminal setae; exopod as in nauplius I, but proximal segment with 2 setae.

Mandible (Fig. 5D). Coxa and basis as in nauplius I; endopod 1-segmented, with 9 setae; exopod as in nauplius I, but proximal segment with 2 setae (1 very small).

Nauplius III (N III) (Fig. 6A).—Seven specimens. Body length 0.156–0.168 mm (mean 0.160 mm). Caudal armature consists of two pairs of spines and one pair of setae.

Antennule (Fig. 6B). First and second segments as in nauplius II; third segment with 3 dorsal and 3 ventral setae + 1 terminal aesthetasc.

Antenna (Fig. 6C). Coxa with 2 strong spines and a small seta; basis with 1 strong spine and 3 small setae; endopod with 3 medial and 4 terminal setae; exopod as in nauplius II, but distal segment and proximal segment with 3 setae.

Mandible (Fig. 6D). Coxa with mandibular blade with 3 teeth and 1 outer seta; basis with strong spine and 4 setae; endopod with 10 setae; exopod as in nauplius II.

Nauplius IV (N IV) (Fig. 7A).—Eleven specimens. Body length 0.175–0.201 mm (mean 0.190 mm). Caudal armature as in nauplius III.

Antennule (Fig. 7B). As in nauplius III, but third segment with 5 dorsal and 5 ventral setae + 1 terminal aesthetasc.

Antenna (Fig. 7C). As in nauplius III, but exopod with 4 setae on proximal segment.

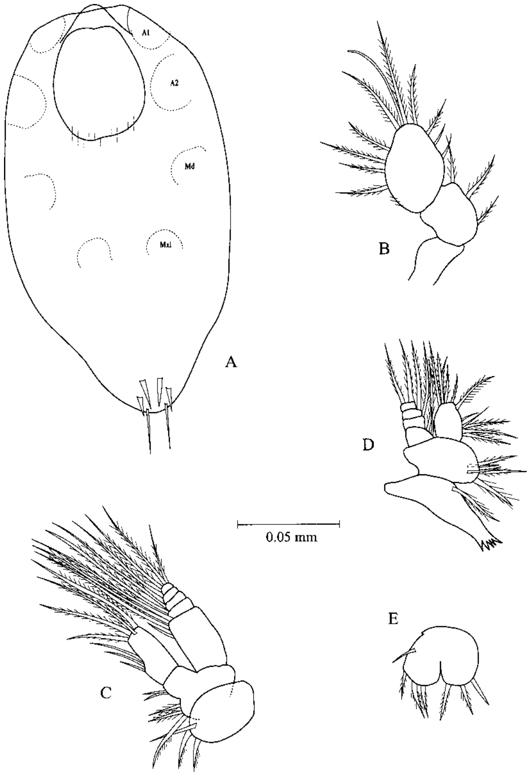


Fig. 7. *Stephos longipes* Giesbrecht, 1902. Nauplius IV: (A) ventral view with antennule position (A1), antenna position (A2), mandible position (Md), maxillule position (Mxl); (B) antennule; (C) antenna; (D) mandible; (E) maxillule.

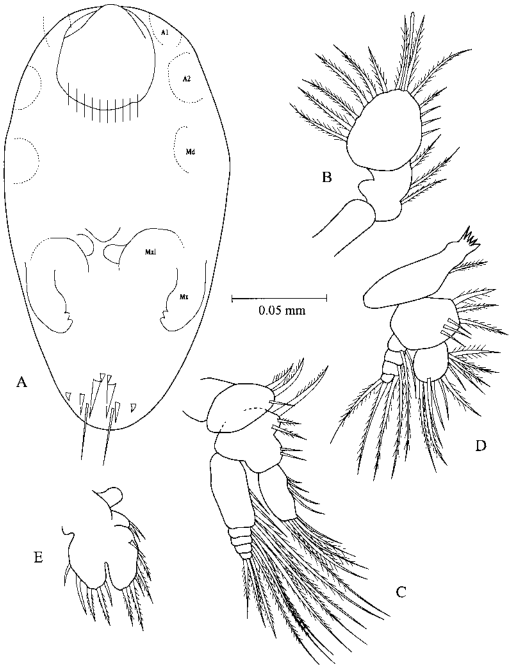


Fig. 8. *Stephos longipes* Giesbrecht, 1902. Nauplius V: (A) ventral view with antennule position (A1), antenna position (A2), mandible position (Md), maxillule position (Mxl), maxilla position (Mx); (B) antennule; (C) antenna; (D) mandible; (E) maxillule.

Mandible (Fig. 7D). As in nauplius III, but mandibular blade with 5 teeth; endopod with 11 setae.

Maxillule (Fig. 7E). Well defined, bilobed, with 3 distal setae on each lobe and 1 ventral, proximal seta.

Nauplius V (N V) (Fig. 8A).—Ten specimens. Body length 0.210–0.244 mm (mean 0.229 mm). Caudal armature with 4 pairs of spines and one pair of setae.

Antennule (Fig. 8B). As in nauplius IV, but third segment with 7 dorsal and 6 ventral setae + 1 terminal aesthetasc.

Antenna (Fig. 8C). As in nauplius IV, but endopod with 4 medial and 5 terminal setae and exopod with 5 setae on proximal segment.

Mandible (Fig. 8D). As in nauplius IV, but basis with strong spine and 5 setae.

Maxillule (Fig. 8E). Distinctly bilobed distally, with outer lobe bearing 5 setae and inner lobe bearing 6 setae, proximal lobe unarmed, middle lobe with 2 setae.

Maxilla (Fig. 8A). A sac-like fold of sternal cuticle just behind maxillule.

Nauplius VI (N VI) (Fig. 9A).—Seven specimens. Body length 0.269–0.282 mm (mean 0.274 mm). Caudal armature as in nauplius V.

Antennule (Fig. 9B). As in nauplius V, but third segment with 8 dorsal and 8 ventral setae + 1 terminal aesthetasc.

Antenna (Fig. 9C). As in nauplius V, but exopod with 6 setae on proximal segment.

Mandible (Fig. 9D). As in nauplius V.

Maxillule (Fig. 9A). Well defined, with 7 setae on outer lobe. Inner lobe already differentiated into areas suggestive of copepodid condition. Praecoxal arthrite with 3 spines, two basal endites and coxal endite with 2 setae on each lobe.

Maxilla (Fig. 9E). A single bud, with setose endites, suggestive of copepodid condition.

Maxilliped (Fig. 9A). Elongate lobe, with 2 terminal setae.

First and second legs (Fig. 9A). Rudimentary lobes, with acute terminal processes.

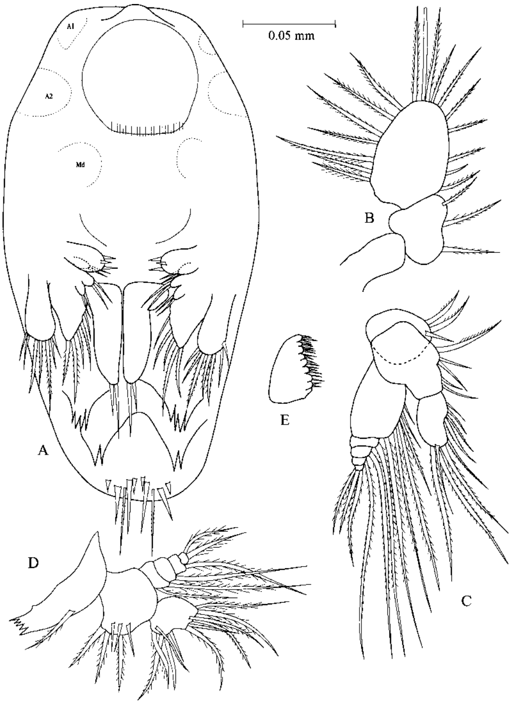


Fig. 9. *Stephos longipes* Giesbrecht, 1902. Nauplius VI: (A) ventral view with antennule position (A1), antenna position (A2), mandible position (Md); (B) antennule; (C) antenna; (D) mandible; (E) maxilla.

Discussion

The body of all stages of *Stephos longipes* is symmetrically oval in outline, without particular differentiation posteriorly.

For all six naupliar stages, the antennule shows the typical aspect of the calanoid nauplius, with the distal segment rather wide. It always remains three-segmented; the number of setae of the third segment varies from three in NI to 16 in NVI. The terminal setiform aesthetasc, typical of calanoid nauplii, appears at NII.

The caudal armature is composed of a pair of short spines in NI and NII, two pairs of spines and a pair of setae in NIII and NIV, four pairs of spines and a pair of setae in NV and NVI. Although the caudal armature is asymmetrical in many calanoid nauplii, as reported by Izawa (1987), it is symmetrical in *Stephos longipes* and *Paralabidocera antarctica*, another calanoid whose postembryonic development has been studied by Tanimura (1992) in specimens obtained from ice cores withdrawn at Syowa Station in Antarctica. The caudal armature of another calanoid belonging to the family Pseudocyclopidae, *Pseudocyclops umbraticus* Giesbrecht, 1893, whose naupliar development we are studying, is also symmetrical. Because the family Pseudocyclopidae is generally believed to be rather primitive, the asymmetrical condition of the caudal armature of the nauplii of Calanoida seems to support Izawa's (1987) hypothesis of an autapomorphy.

Among Calanoida, many species have symmetrical caudal armature during their naupliar development, e.g., *Paracalanus parvus* (Olgivie, 1953); *Paracalanus crassirostris* (Lawson and Grice, 1973); *Paracalanus aculeatus*, *Rhincalanus cornutus*, and *Euchaeta marina* (Björnberg, 1972, 1986). In agreement with Björnberg (1972), we believe that it is important to consider the form of the nauplii in the creation of any taxonomic classification of the Calanoida.

Our results confirm previous studies on the life-cycle strategy of the Antarctic calanoid copepod *Stephos longipes* (see Schnack-Schiel *et al*., 1995). In the early spring, nauplii dominate in the sea-ice. Knowledge of naupliar development advances our understanding of the life history of *Stephos longipes*, the most abundant calanoid copepod in spring-summer sea ice in the Weddell (Schnack-Schiel *et al*., 2001) and Ross Seas (L. Guglielmo, personal communication).

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