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Taxonomic Study of Genus *Cyclosalpa* (Thaliacea: Salpida: Salpidae) from Korea

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ABSTRACT

Aggregate and solitary zooids of salps were collected from April 2001 to June 2009. By the analyses based on the morphological characteristics, four species in the genus *Cyclosalpa* of the subfamily Cyclosalpininae are identified as new records in Korean waters: *Cyclosalpa affinis* (Chamisso, 1819), *Cyclosalpa bakeri* Ritter, 1905, *Cyclosalpa sewelli* Metcalf, 1927, and *Cyclosalpa polae* Sigl, 1912. These species are re-described with illustrations and photographs in this study. In addition, a key to species of the genus *Cyclosalpa* in Korean waters and a key to the life cycles of Salpida are provided. As a result of this study twelve species in the Salpidae have been reported from Korea until now.

Key words: Salpidae, Cyclosalpininae, *Cyclosalpa affinis*, *Cyclosalpa bakeri*, *Cyclosalpa sewelli*, *Cyclosalpa polae*, key, Korean waters

Running title: New Records of Korean *Cyclosalpa*

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INTRODUCTION

The species in the subfamily Cyclosalpinae are mostly free-living marine holoplanktons. They alternate between two quite separate forms in terms of morphology and reproduction, a solitary stage and an aggregate stage as species belonging to other subfamilies in the family Salpidae. Identification for salps is based mainly on the arrangement of the body muscles. For the species of genus *Cyclosalpa*, light organs and dorsal tubercle are also important for their identification. Fourteen species in two genera are currently known in the subfamily Cyclosalpinae worldwide (Chihara and Murano, 1997; Esnal and Daponte, 1999). Four species in the genus *Cyclosalpa* are newly identified from Korean waters during our systematic studies on salps in this paper. Re-descriptions of these species are provided with a key to the species. Including four species reported in this paper twelve different species in the family Salpidae have been recorded in Korean waters (Kim et al., 2010a, 2010b, 2011; Rho, 1967).

MATERIALS AND METHODS

The specimens were collected by using an IKMT net of 417 μm mesh. Materials examined were fixed and stored in 4% buffered formalin and 80% ethyl alcohol, and examined with a stereoscopic microscope (Leica MZ16 with AxioCam HRc). The abbreviation M indicates the muscle band. Body lengths of the most specimens were measured from the terminus of the oral aperture to the atrial aperture by using objective and ocular micrometers. Re-description of each species was provided with a photograph. Illustration of reverse side of the photograph(s) was also provided since the illustration(s) showed morphological characteristics clearer. Specimens examined in this study have been deposited in the Seodaemun Museum of Natural History, Seoul, Korea.

SYSTEMATIC ACCOUNTS

Phylum Chordata Bateson, 1885

Subphylum Tunicata Larmarck, 1816

Class Thaliacea Nielsen, 1995

Order Salpida Uljanin, 1884

Family Salpidae Lahille, 1888

¹*Subfamily Cyclosalpinæ Yount, 1954

Description. Solitary zooid: Test generally soft, smooth, absent echinate and projections. Oral and atrial openings terminal. Seven body muscles symmetrically arranged. Intestine beside the gill anterior, united with it over most of its length. Pairs of light organs generally present, arranged laterally between or on the body muscles.

Aggregate zooid: Test generally soft, smooth, absent echinate and projections. Oral opening terminal and atrial opening dorsal or terminal. Four body muscles fuse or split. Gut straight or wide looped. Intestinal caecum and a blood-forming organ can present. Ovary and embryo between MIII and MIV, on right side. Testis between endostyle and gut, or protruding posteriorly beyond the gut. Aggregate zooids attached by single peduncle.

²*Genus *Cyclosalpa* de Blainville, 1827

Description. Solitary zooid: Body muscles variously continuous or interrupted mid-dorsally, always interrupted mid-ventrally.

Aggregate zooid: Individuals arranged in whorls by means of a prominent attachment organ, peduncle, located on ventral side in anterior. Body muscle continuous dorsally, interrupted ventrally. MI, MII and sometimes a ventral longitudinal muscle continuous into peduncle. Intermediate muscle generally fused with MI muscle. Light organs can be present.

³****Cyclosalpa affinis* (Chamisso, 1819) (Fig. 1A-D)**

Salpa affinis Chamisso, 1819: 108 (cited from Thompson, 1948); Brooks, 1908: 81, fig. 3.

Salpa (Cyclosalpa) chamissonis Brooks, 1893: 221 (cited from Tokioka, 1937).

Cyclosalpa affinis. Tokioka, 1937: 221; Thompson, 1948: 108, Pls. 32, 35, figs. 1-3, Pl. 41, figs. 1, 2; Yount, 1954: 284, fig. 4; Berill, 1961: 150; Berner, 1964: 250; Gosner, 1971: 611, fig. 24.10; Yamaji, 1984: 444, Pl. 138, fig. 3a, b; Madin, 1991: 108, fig. T-5; Chihara and Murano, 1997: 1373; Van Soest, 1998: 240, fig. 14.4, table 14.4; Esnal and Daponte, 1999: 1430, fig. 3.2a-d.

Material examined. 5 solitary zooids, 61 aggregate zooids, East Sea, 38°29'N 131°30'E, 15 Oct 2001; 2 aggregate zooids, East Sea, 38°30'N 129°49'E, 15 Oct 2001; 1 solitary zooid, 1 aggregate zooid, East Sea, 38°30'N 130°30'E, 15 Oct 2001; 2 solitary zooids, 1 aggregate zooid, East Sea, 36°30'N 130°29'E, 15 Oct 2001.

Description. Solitary zooid: 27-82 mm long, elongate, cylindrical body (Fig. 1A, B). Test thick and relatively stiff. Oral and atrial opening terminal. Dorsal tubercle strongly convoluted and totally

Korean name: ¹*골은장살파아과(신칭), ²*골은장살파속(신칭), ³*무광골은장살파(신칭)

'fan' like shaped. Seven body muscles interrupted ventrally, MI and MII interrupted dorsally, MIII to MVII continuous dorsally. Light organs absent. Endostyle thin, extends from behind oral to MVI ventrally. Branchial septum extend from antero-dorsal surface to esophagus postero-ventrally. Developed stomach absent, straight intestine stretched along dorsal side of whole length of branchial septum. Anal opening just behind ganglion. Stolon arise posterior ventrally, stretch straight forward and break through test MI ventrally.

Aggregate zooid: 23-55 mm long, cylindrical (Fig. 1C, D). Test thick and soft. Peduncle anterior ventrally, not exceed 1/5 body length. Oral and atrial opening terminal. Light organs absent. Dorsal tubercle moderately convoluted. Four body muscles nearly parallel, interrupted ventrally, continuous dorsally. Endostyle thin, extends from behind oral to MIV posterior ventrally. Branchial septum extend from ganglion to gut. Gut wide looped, anal aperture near esophagus. Testis lies along intestine.

Distribution. Pacific Ocean, Atlantic Ocean, Indian Ocean.

^{4*} *Cyclosalpa bakeri* Ritter, 1905 (Fig. 2A-D)

Cyclosalpa bakeri Ritter, 1905: 54 (cited from Yount, 1954); Fraser, 1947: 2; Thompson, 1948: 114, Pls. 32, 36, figs. 3, 4, Pl. 38, figs. 1-4, Pl. 42; Yount, 1954: 286, fig. 6; Yamaji, 1984: 444, Pl. 138, fig. 5a, b; Chihara and Murano, 1997: 1373; Van Soest, 1998: 240, fig. 14.4, table 14.4; Esnal and Daponte, 1999: 1430, fig. 3.5a-f.

Cyclosalpa floridana Apstein, 1906: 114 (cited from Thompson, 1948).

Material examined. 51 aggregate zooids, East Sea, 37°30'N 130°30'E, 18 Apr 2001; 11 solitary zooids, 387 aggregate zooids, East Sea, 38°00'N 130°30'E, 18 Apr 2001; 1 solitary zooid, Korea strait, 32°29'N 127°29'E, 24 Sep 2002; 1 solitary zooid, East Sea, 37°32'N 130°07'E, 30 Sep 2002; 8 aggregate zooids, Jeju, 33°12'N 126°36'E, 22 Jun 2009.

Description. Solitary zooid: 12-54 mm long, elongate, cylindrical body (Fig. 2A, B). Test flabby. Oral and atrial opening terminal. Dorsal tubercle 'horseshoe' like shaped. Seven body muscles interrupted ventrally and dorsally. MVI turns forward on each side, forming longitudinal muscle passes MV and MIV. Six pairs light organs well developed, five pairs between MI and MVI, one small pair before MI. Endostyle thin, extends from behind oral to front of gut. Branchial septum slender, extend from ganglion to MVI ventrally. Developed stomach absent, straight intestine along dorsal side of whole length of branchial septum. Two caecum presented posterior. Anal opening just behind MVI.

Aggregate zooid: 8-63 mm long, barrel shaped body (Fig. 2C, D). Test thin, flabby. Peduncle anterior ventrally, not exceed 1/3 body length. Oral and atrial opening terminal. Light organs absent. 4 body muscles continuous dorsally. Intermediate muscle and MI fuse dorsally. MII, MIII and MIV fuse dorsally. MI and MII fuse ventrally. MIV extend ventrally and fuse with MIII.

Korean name: ^{4*}꼬리꼴은장살파(신칭)

Intermediate muscle, MI–MIV muscles continued into peduncle. Intestine muscle extends from MIV to side of alimentary canal. Dorsal tubercle C-like shaped. Endostyle thin, extends from behind oral to MIV posterior ventrally. Branchial septum slender, extends from ganglion to gut. Intestine u-like shaped, mostly lying outside of body, protuberated. One piece of intestine extended and end of this intestine, blood forming organ projected. Testis presented behind intestine. Embryo locates right side, between MIII and MIV.

Distribution. Pacific Ocean, Atlantic Ocean, Indian Ocean.

^{5*} ***Cyclosalpa sewelli* Metcalf, 1927 (Fig. 3A-D)**

Cyclosalpa pinnata sewelli. Metcalf, 1927: 257 (cited from Kott, 2005).

Cyclosalpa sewelli Chihara and Murano, 1997: 1372; Van Soest, 1998: 240, fig. 14.4, table 14.4.

Material examined. 6 aggregate zooids, East Sea, 38°00'N 130°30'E, 18 Sep 2001; 1 aggregate zooid, South Sea, 35°31'N 130°22'E, 15 Oct 2001; 1 solitary zooid, 3 aggregate zooid, Korea strait, 32°29'N 127°29'E, 24 Sep 2002; 1 solitary zooid, Korea strait, 33°59'N 128°17'E, 24 Sep 2002; 4 aggregate zooids, South Sea, 35°11'N 129°53'E, 4 Dec 2002.

Description. Solitary zooid: 10-12 mm long, elongate, cylindrical body (Fig. 3A, B). Test thin, flabby (Fig. 3A, B). Oral and atrial opening terminal. Dorsal tubercle 'triangle' like shaped. Seven body muscles interrupted ventrally and dorsally. Longitudinal muscle absent. Four pairs light organs well developed, placed middle of either side between MII and MVI, spindle shaped. Endostyle thin, extends from behind oral to MVI ventrally. Branchial septum slender, extends from ganglion to MVI ventrally. Developed stomach absent, straight intestine stretched along dorsal side of whole length of branchial septum. Anal opening just behind neural ganglion.

Aggregate zooid: 7-15 mm long, cylindrical or barrel shape body (Fig. 3C, D). Test thin, flabby. Peduncle almost 1.5 times body length. Oral and atrial opening terminal. Elongate light organs on either side, between MII and MIII, almost 1/7–1/8 body length. 4 body muscles continuous dorsally. MI and MII fused dorsally and ventrally. MIII and MIV fused dorsally. Intermediate muscle, MI–MII muscles continued into peduncle. Dorsal tubercle bow-like shaped. Endostyle thin, extends from behind oral to MIV ventrally. Branchial septum slender, extends from ganglion to gut. Developed stomach absent, straight intestine stretched along the ventral side of whole length of endostyle. Anal opening near peduncle.

Distribution. Pacific Ocean, Atlantic Ocean, Indian Ocean.

^{6*} ***Cyclosalpa polae* Sigl, 1912 (Fig. 4A, B)**

Salpa (Cyclosalpa) polae Sigl, 1912: 220 (cited from Tokioka, 1937).

Cyclosalpa pinnata var. *polae* Tokioka, 1937: 220; Yamaji, 1984: 444, Pl. 138, fig. 2a, b.

Cyclosalpa polae Madin, 1991: 109, fig. T-7; Chihara and Murano, 1997: 1372; Van Soest, 1998:

Korean name: ^{5*}스웰리곶은장살파(신칭),

^{6*}북극곶은장살파(신칭)

240, fig. 14.4, table 14.4; Esnal and Daponte, 1999: 1430, fig. 3.1a–d.

Material examined. 2 aggregate zooids, South Sea, 35°11'N 129°53'E, 4 Dec 2002.

Description. Aggregate zooid. 14–27 mm long, cylindrical or barrel shape body (Fig. 4A, B). Test thin, flabby. Peduncle almost body length. Oral and atrial opening terminal. Elongate light organs on either side, between MII and MIII, almost 1/4 body length. 4 body muscles continuous dorsally. MI, MII fused dorsally and ventrally. MIII, MIV fused dorsally. Intermediate muscle, MI–MII muscles continued into peduncle. Dorsal tubercle w-like shaped. Endostyle thin, extends from behind oral to MIV ventrally. Branchial septum slender, extends from ganglion to gut. Developed stomach absent, straight intestine stretched along ventral side of whole length of endostyle. Anal opening near peduncle.

Distribution. Pacific Ocean, Atlantic Ocean.

Remarks. Aggregate zooid of the species is the almost same as that of *C. sewelli*, except morphology of dorsal tubercle, length of attachment organ (peduncle) and light organs. Solitary zooids of this species were not collected during this study.

Key to the life cycles of Salpida

1. Stolon present at ventral or posterior, egg and embryo absent; attachment organ absent solitary zooid
- Stolon absent, eggs or embryo present at right (if mirror image - sinistral individuals: left posterior); attachment organ (peduncle) present aggregate zooid

Key to species of the genus *Cyclosalpa* from Korea

Solitary zooid

1. Longitudinal muscles present *Cyclosalpa bakeri*
- Longitudinal muscle absent 2
2. Light organs present on either side *Cyclosalpa sewelli*
- Light organs absent *Cyclosalpa affinis*

Aggregate zooid

1. Gut u-like shape *Cyclosalpa bakeri*
- Gut wide looped or straight 2
2. Light organs absent *Cyclosalpa affinis*
- Light organs present on either side 3
3. Dorsal tubercle w-like shaped *Cyclosalpa polae*

- Dorsal tubercle bow-like shaped *Cyclosalpa sewelli*

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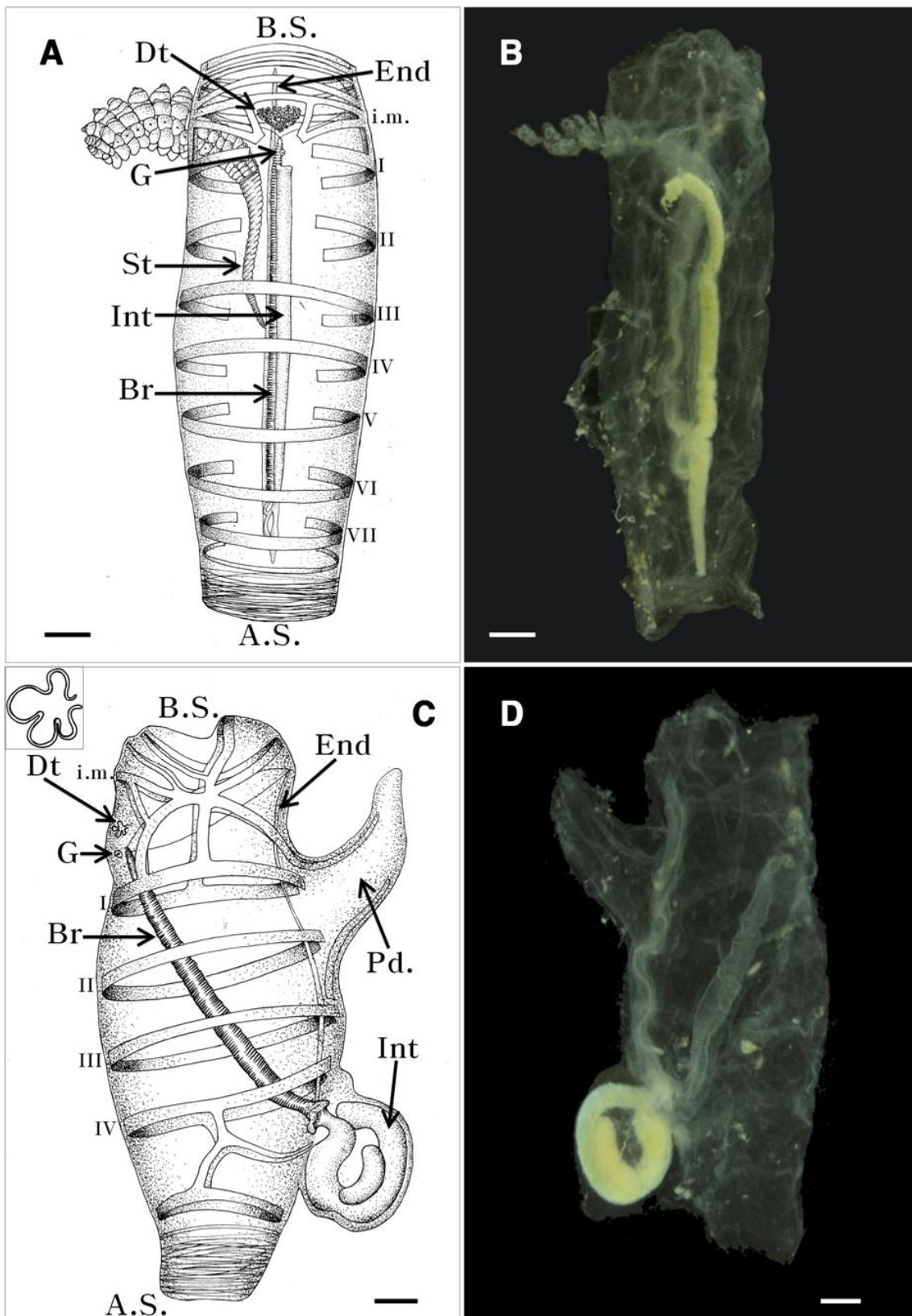


Fig. 1. *Cyclosalpa affinis* (Chamisso, 1819). A, B, Solitary zooid, dorsal view; C, D, Aggregate zooid; C, Right side view; D, Left side view. A.S., atrial siphon; Br, branchial septum; B.S., buccal siphon; Dt, dorsal turbercle; End, endostyle; G, ganglion; i.m., intermediate muscle; Int, Intestine; I-VI, body muscles; Pd., peduncle; St, stolon. Scale bars: A, B=6 mm, C, D=3 mm.

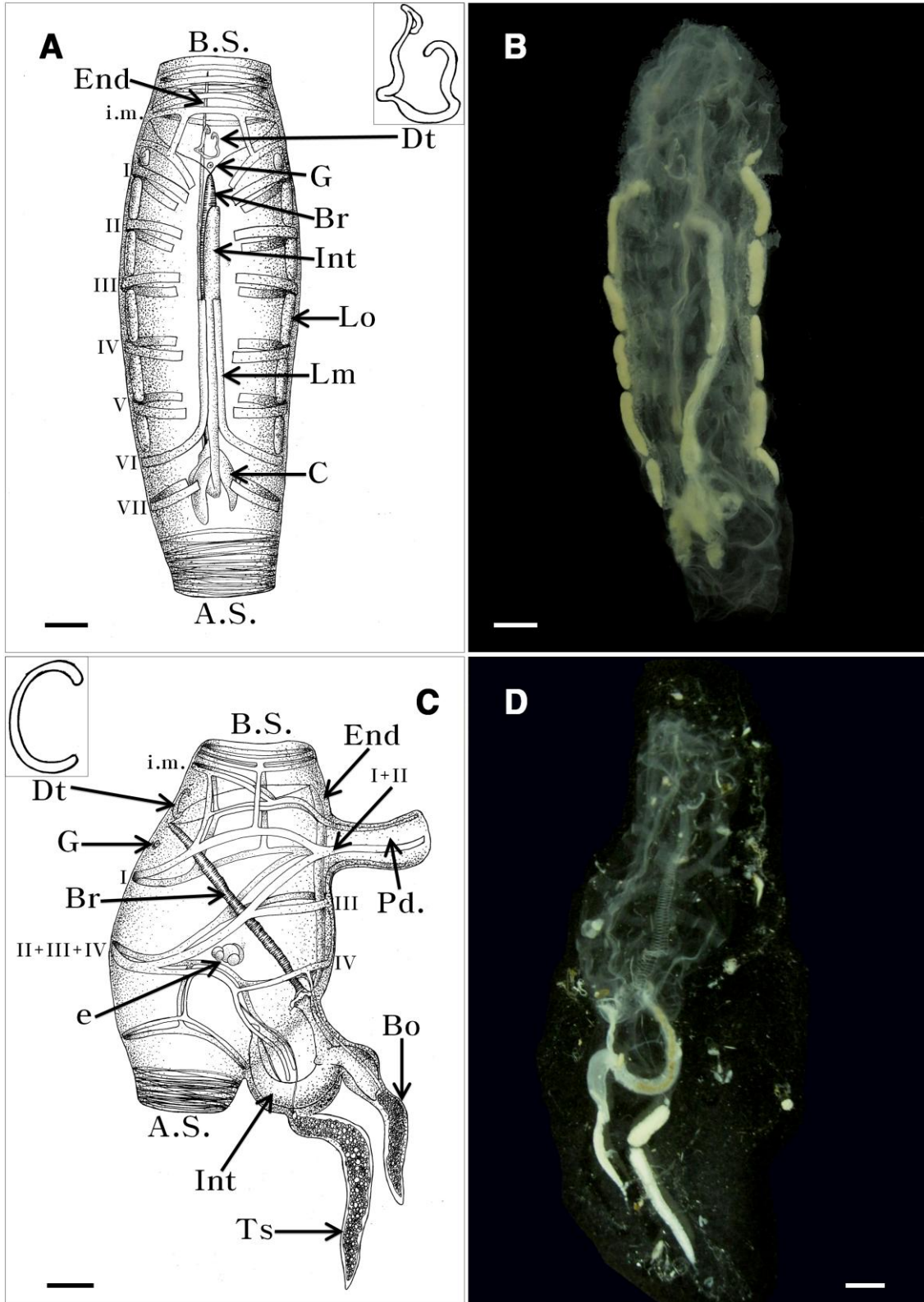


Fig. 2. *Cyclosalpa bakeri* Ritter, 1905. A, B, Solitary zooid, dorsal view; C, D, Aggregate zooid; C, Right side view; D, Left side view. A.S., atrial siphon; Bo, blood forming organ; Br, branchial septum; B.S., buccal siphon; C, caecum; Dt, dorsal turbercle; e, embryo; End, endostyle; G, ganglion; i.m., intermediate muscle; Int, Intestine; I-VI, body muscles; Lo, light organs; Lm, longitubinal muscle; Pd., peduncle; Ts, testis. Scale bars: A, B=3 mm, C, D=5 mm.

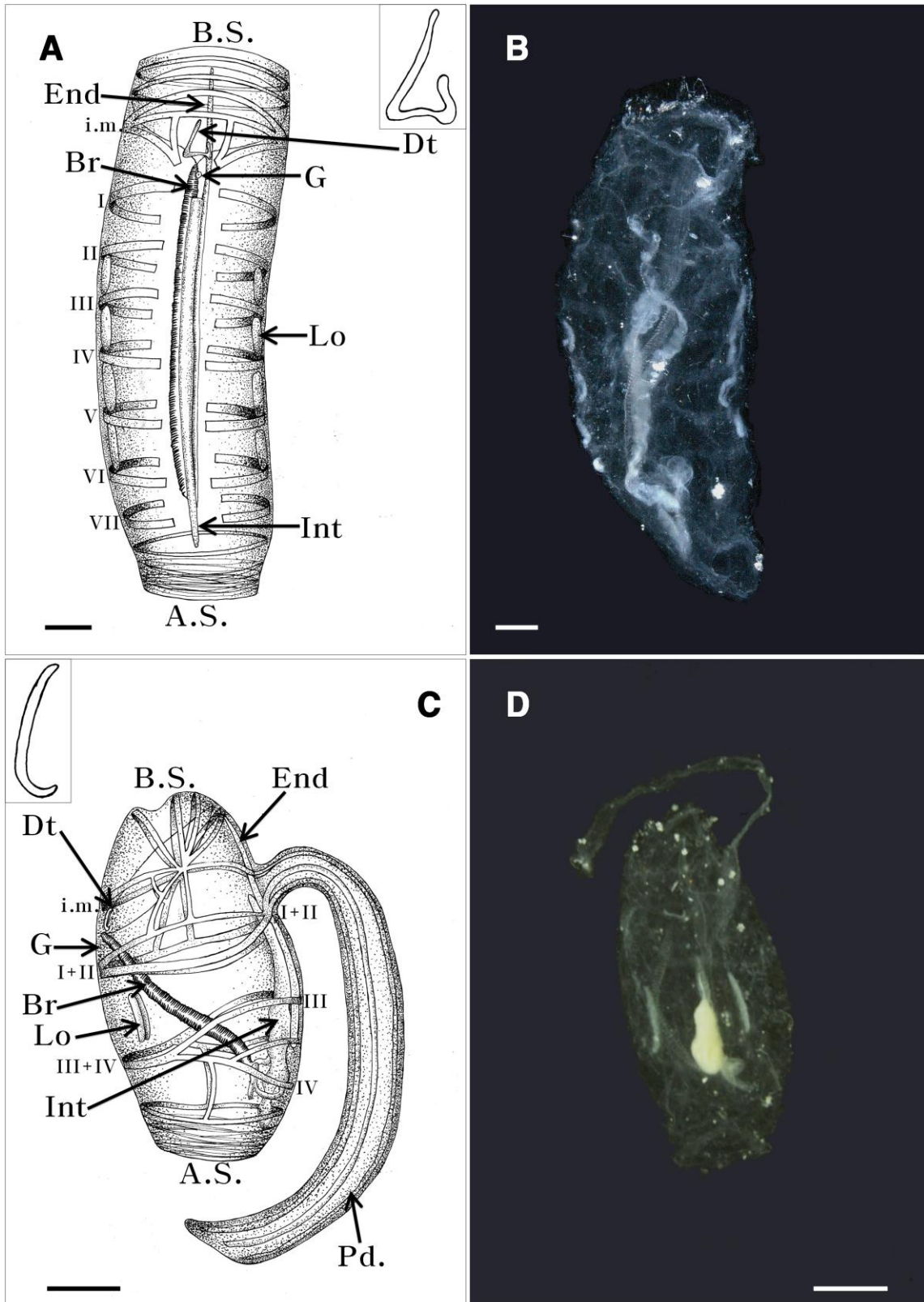


Fig. 3. *Cyclosalpa sewelli* Metcalf, 1927. A, B, Solitary zooid, dorsal view; C, D, Aggregate zooid; C, Right side view; D, Dorsal view. A.S., atrial siphon; Br, branchial septum; B.S., buccal siphon; Dt, dorsal turbercle; End, endostyle; G, ganglion; i.m., intermediate muscle; Int, Intestine; I-VI, body muscles; Lo, light organs; Pd., peduncle. Scale bars: A, B=1 mm, C, D=2 mm.

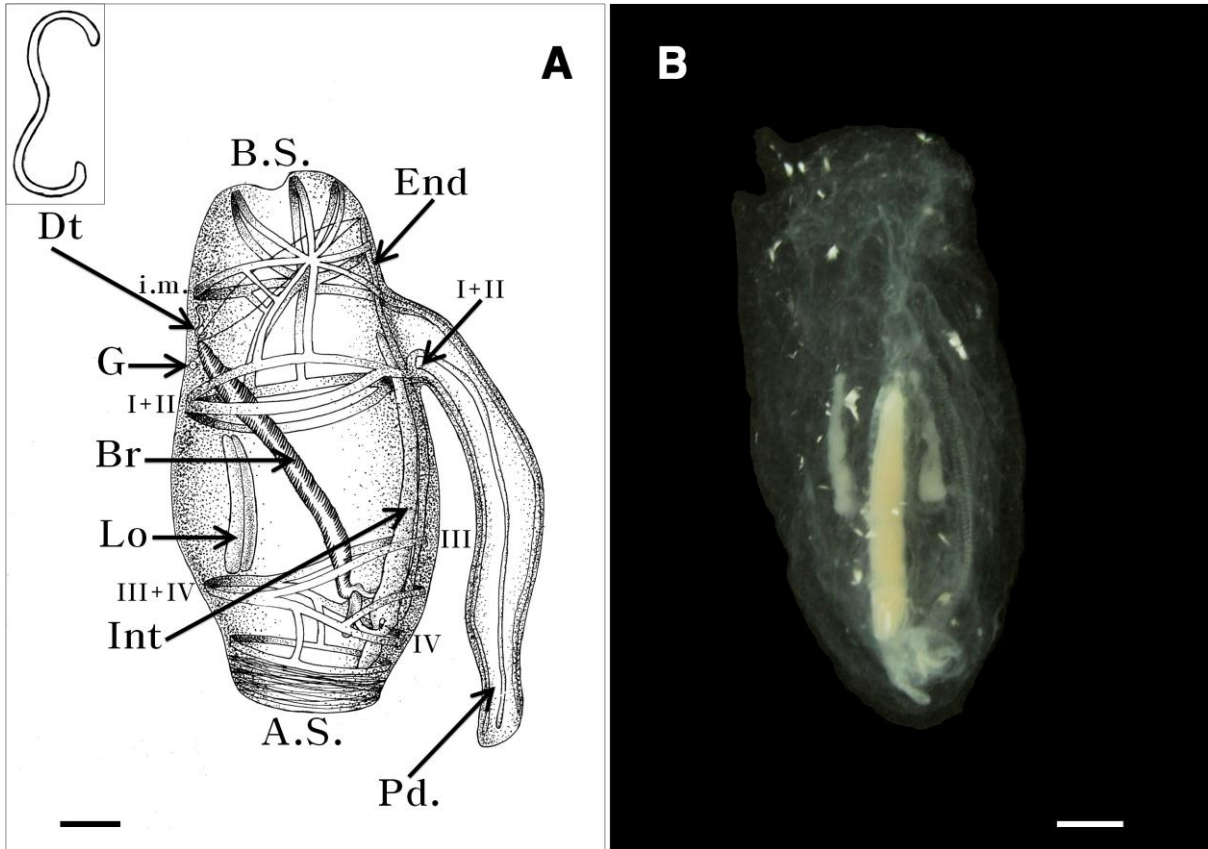


Fig. 4. *Cyclosalpa polae* Sigl, 1912. A, B, Aggregate zooid; A, Right side view; B, Dorsal view. A.S., atrial siphon; Br, branchial septum; B.S., buccal siphon; Dt, dorsal turbercle; End, endostyle; G, ganglion; i.m., intermediate muscle; Int, Intestine; I-VI, body muscles; Lo, light organs; Pd., peduncle. Scale bars: A, B=3 mm.