

FEMALE *ASCIDICOLA ROSEA* THORELL (COPEPODA: CYCLOPOIDA)
LIVING IN SOLITARY ASCIDIANS

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A B S T R A C T

This paper deals primarily with a full redescription of the mature female of *Ascidicola rosea* Thorell, 1859, and a young female is described mainly in regard to the urosome. The two species of solitary ascidians containing this copepod, which lacks an eye, were collected at different localities: *Microcosmus sabatieri* Roule at Banyuls-sur-Mer, and *Ascidia mentula* Müller at Strangford Lough. Many systematists have studied this long-known, elongated, pinkish copepod (Ascidicolidae: Ascidicolinae). However, the major articulation between the metasome and urosome has been interpreted differently by authors, and morphological details have not always been consistently described. The intent of the present paper is to resolve such problems. It shows that the ventral transverse spinose pad posterior to the penultimate (second abdominal) segment of the urosome of the mature female is homologous to much of the ventral part of the penultimate (third abdominal) segment of the urosome of the young female.

INTRODUCTION

The female of *Ascidicola rosea* Thorell, 1859 is a relatively large elongated copepod that lives in many species of solitary ascidians of various coastal waters (see Schellenberg, 1922; Gotto, 1957, 2004a; Monniot, 1965, 1981; Illg and Dudley, 1980; Boxshall and Halsey, 2004). *Microcosmus sabatieri* and *Ascidia mentula*, from which the present specimens of *A. rosea* were obtained, have already been reported as hosts by authors listed above.

Gotto (1957) was the first to study the biology of *A. rosea*, including its position, feeding activities, and reproduction, in *Corella parallelogramma* (Müller). He found that this copepod's normal operational base in the ascidian is the esophagus, but on one occasion he observed it in the branchial sac. In Gotto's book (2004b), the relationship of *A. rosea* to its ascidian host was described in detail based mainly on laboratory observations. That *A. rosea* lives in the esophagus of *M. sabatieri* has been shown by Monniot (1961); his specimens were taken at Banyuls-sur-Mer, as mine were.

Thorell (1859) described *A. rosea* from several solitary ascidians: *Ciona intestinalis* (Linnaeus), *Corella parallelogramma*, etc. These ascidians were collected at the Kristineberg (Christineberg) area, on the west coast of Sweden (Bohuslän Province). He divided the copepod body posterior to the cephalosome into a 5-segmented metasome and a 4-segmented urosome. However, the segmental compositions for these body regions given by Thorell are not always the same as those reported by succeeding authors and in this paper.

Sars (1921) described the penultimate segment of the urosome as "having the ventral part of the hind edge remarkably thickened and densely clothed with small pricks." Gotto (1957) found that the pricks observed by Sars are in fact tiny sharply pointed spines. However, these authors did not explain the anatomical derivation of this portion.

Canu (1892) pointed out that the specimen described by Thorell (1859) as a male of *A. rosea* was an immature female. Sars (1921) also stated that Thorell's specimen was an immature female in which the fifth legs were not fully developed. Gotto (1957) observed a very young female, describing its feeding position in the esophagus of the ascidian host. However, no additional morphological studies have been done on these young females. In this paper, a young female that is apparently similar in morphology to the immature females studied by the previous authors has been examined mainly with respect to the urosome.

The results of the present study on the mature and young females of *A. rosea* include some morphological emendations, a different interpretation of the segmental composition of the metasome and urosome, and evidence of the anatomical derivation of the spinose pad of the urosome of the mature female.

This paper is dedicated to the memory of the late Dr. Vivian Gotto who has left a great legacy with respect to the biology and taxonomy of *A. rosea* as well as many other commensal and parasitic copepods associated with marine invertebrates.

MATERIALS AND METHODS

Two species of solitary ascidians, which contained female specimens of *Ascidicola rosea*, were collected at different localities and on different dates: one specimen of *Microcosmus sabatieri* Roule (Stolidobranchia: Pyuridae), which had two females (mature, young), was obtained at Banyuls-sur-Mer (French coast of the Mediterranean Sea) in November 1989; one specimen of *Ascidia mentula* Müller (Phlebobranchia: Ascidiidae), which had one female (mature), at Strangford Lough (the Irish Sea) in August 1995. These copepods were taken from the branchial sac. (Each ascidian host was among several other specimens.) The laboratory work was carried out at two institutions: 1) Observatoire Océanologique de Banyuls, Université P.M. Curie (PARIS 6); 2) the Queen's University of Belfast. Macrophotographs of living mature females were taken at these institutions. The macrophotograph (Fig. 1) presented in this paper is of



Fig. 1. *Ascidicola rosea* Thorell. Macrophotograph of living mature female (ventrolateral) and its egg sacs, from Banyuls.

the mature female from Banyuls. All three females (2 mature, 1 young) were fixed in 95% ethanol and stored in 70% ethanol. The two mature females from the different localities were similar in body shape, size, and coloration.

The three copepods were immersed in lactic acid (with a small amount of methylene blue) for measurements, dissection, drawings, and photomicrographs. Drawings were made with the aid of a camera lucida. The relation of the specimens to drawings is as follows: mature female (intact) from Banyuls for Figs. 2a-f, 3a, g, 4h, 5a-h; mature female (dissected) from Strangford Lough for Figs. 2g, 3b-f, 4a-g; young female (dissected) from Banyuls for Fig. 6a-g. These specimens were also used for photomicrographs: mature female (dissected) from Strangford Lough for Fig. 7a-d; mature female (intact) from Banyuls for Fig. 7e-i; young female (dissected) from Banyuls for Fig. 7j. Photomicrograph Fig. 7j was used for showing the oval area on the fifth urosomal segment illustrated in Fig. 6c.

Dr. Gotto (October 2004) provided me with a file of scanning electron micrographs (SEM) of cuticular ornamentation and receptors of copepod associates of invertebrates from Strangford Lough; this file (unpublished) had been made by his former student, Z. West, in 1977. Some of the micrographs, which are of *A. rosea*, were used for confirming the corresponding elements examined in this paper (small conical spinules, tuberclelike elements, hairlike sensilla, group of ringlike pores, in Fig. 2f; spines on spinose pad, in Fig. 7i). In this paper, *A. rosea* is placed in the family Ascidiolidae Thorell, 1859, sensu Illg and Dudley (1980). Use of the order Cyclopoida Sars, 1886, follows Damkaer (2002).

In the armature formula for legs 1-4, the total number of spines (Roman numerals) is noted first and connected by a dash with the number of setae (Arabic numerals). The total number (T) of these armature elements is given in parentheses for the protopod (coxa, basis), endopod, and exopod. The abbreviations used are: A1 = antennule, A2 = antenna, MD = mandible, MX1 = maxillule, MX2 = maxilla, MXP = maxilliped, PG = paragnath, P1 = leg 1.

SYSTEMATICS

Order Cyclopoida Sars, 1886

Ascidiolidae Thorell, 1859

Ascidiolinae Thorell, 1859

Ascidicola Thorell, 1859

Ascidicola rosea Thorell, 1859

Figs. 1-7

Material Examined.—1 mature ♀ (intact, with 2 egg sacs), MNHN-Cp2294, and 1 young ♀ (mainly urosome), MNHN-Cp2295, both from *Microcosmus sabatieri* Roule, collected at Ile Grosse (42°29'00"N, 3°08'250"E), Banyuls-sur-Mer, France, 7 November 1989, deposited at Muséum National d'Histoire Naturelle, Paris, August 2005; 1 mature ♀ (dissected) from *Ascidia mentula* Müller, collected at Portaferry (54°38'N, 5°54'W), Strangford Lough, N. Ireland, 1 August 1995, in the author's collection.

Redescription of Mature Female.—Body (Fig. 1) of living specimen white, opaque, with pinkish ovarian egg masses on both sides of slightly brownish gut in metasome and urosome; eye lacking. Two egg sacs (Fig. 1) nearly elliptical, flat, clear, containing pinkish eggs (embryos); eggs mostly already hatched. Egg sac with small sections, each holding one egg; egg number approximately 30 in this specimen.

Body (extended fixed specimen, Fig. 2a-c) elongated, almost cylindrical, consisting of cephalosome, longer and wider metasome, and long urosome; proportional lengths 1:3:7.3 for 3 regions. Body without distinct constriction between fourth metasomal (fourth thoracic) and first urosomal (fifth thoracic) segments, but these regions clearly distinguishable structurally. Body length 3.85 mm long, excluding caudal setae. Ratio of length of prosome to that of urosome 0.54:1. Greatest width 0.55 mm in fourth metasomal segment. Cuticular ornamentation and receptors (Fig. 2f) consisting mainly of small conical spinules (directed posteriorly, in rows), minute tuberclelike elements (scattered), hairlike sensilla (each protruded from pit), and groups of ringlike pores.

Cephalosome (Figs. 2a-c, 3a) somewhat squarish dorsally and overlapping anterior portion of first metasomal segment. Cephalic shield (Fig. 2d) sclerotized, with many minute pits for sensilla, and lateral folds developed. Central two-thirds of cephalosome protruded anteriorly, representing rostral area; its distal margin broadly rounded and with low semicircular cuticular line on ventral side. Protruded rostral area, measured on dorsal side, one-third as long as total length of cephalosome and constricted proximally. Cephalosome (including rostral area) slightly shorter than wide (at posterior margin). Large antennules protruding from lateral sides of rostral area, and 5 pairs of appendages (antennae to maxillipeds) on main cephalosome posterior to rostral area.

Metasome (Fig. 2a-c) 4-segmented, gradually increasing in length and width toward fourth segment; in each segment, pleura developed. Proportional lengths, measured along dorsal central axis, 1:1.6:3:3.7, and proportional widths, measured at middle of segments, 1:1.1:1.25:1.32. Each segment mostly sclerotized, but anterior one-third transversely unsclerotized in third and fourth segments. Legs 1-4 (Figs. 2c, 7e) symmetrical in morphology and armature formula; endopods with extremely long setae, and exopods with stout spines.

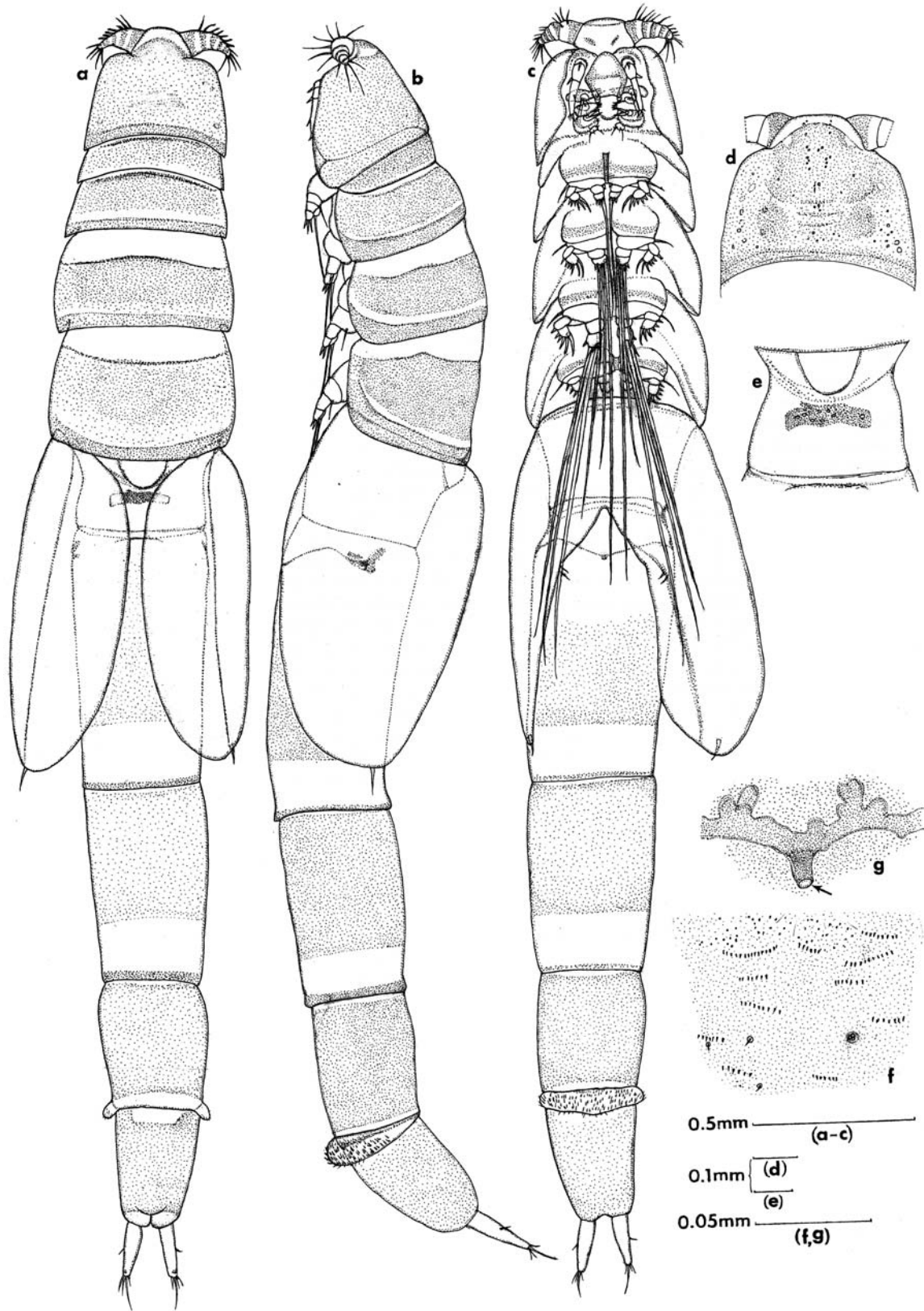


Fig. 2. *Ascidicola rosea* Thorell, female (= mature female). a, body form, dorsal; b, body form, lateral; c, body form, ventral (all setae on leg 4 endopods omitted); d, cephalosome, dorsal; e, first urosomal segment, dorsal, showing semicircular protrusion anteriorly and transverse sclerotization posteriorly; f, cuticular ornamentation and receptors on ventral genital segment (part); g, copulatory organs, anteroventral (arrow indicates copulatory pore).

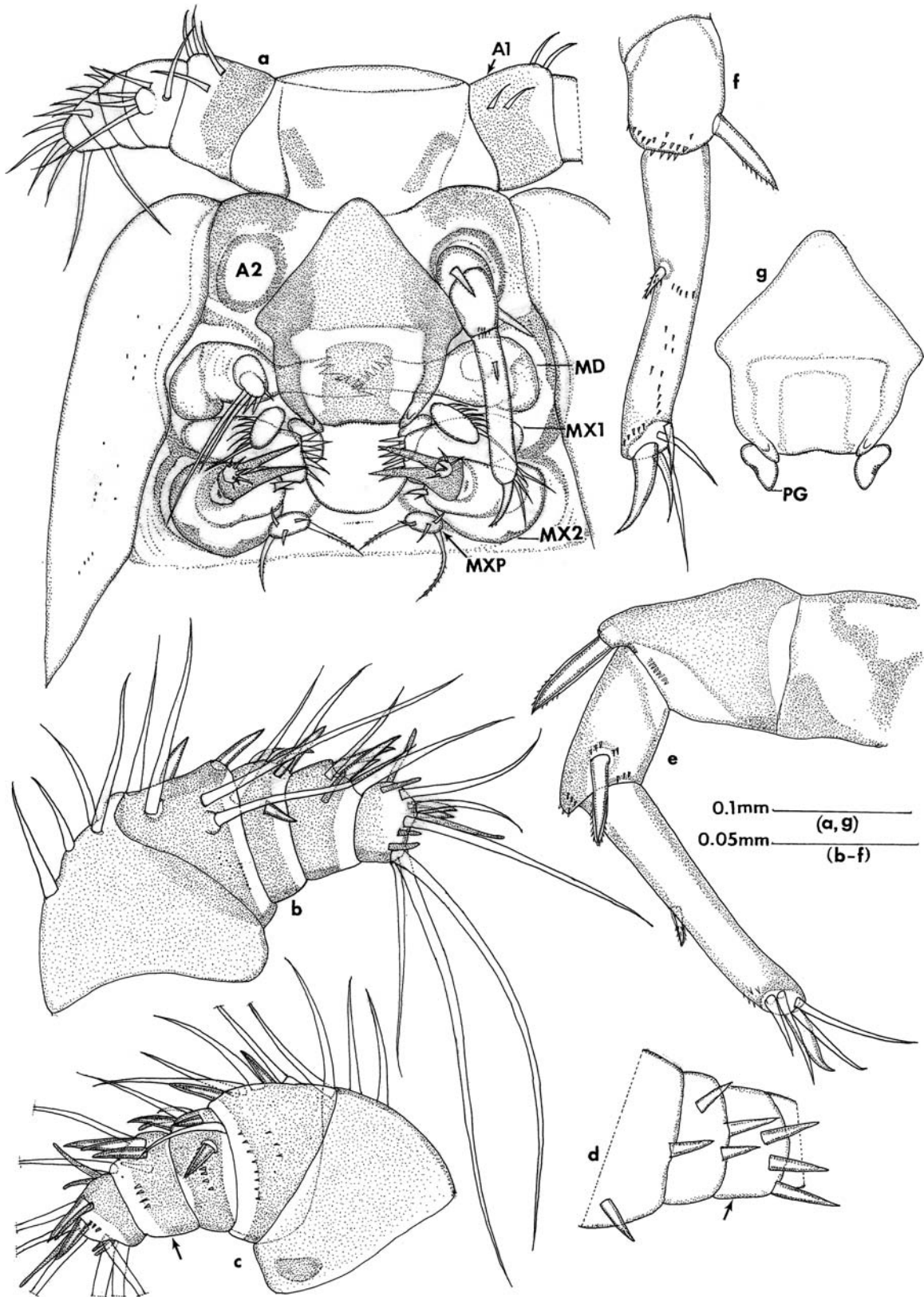


Fig. 3. *Ascidicola rosea* Thorell, female. a, cephalosome, ventral; b, left antennule, ventral; c, left antennule, dorsal (arrow indicates fourth segment); d, left antennule (second to fourth segments shown), anterior (arrow indicates fourth segment), showing only spines on segments; e, left antenna, lateral; f, left antenna (proximal 2 segments omitted), anterior, showing many small conical spinules on third and fourth segments; g, labrum and paragnaths, ventral.

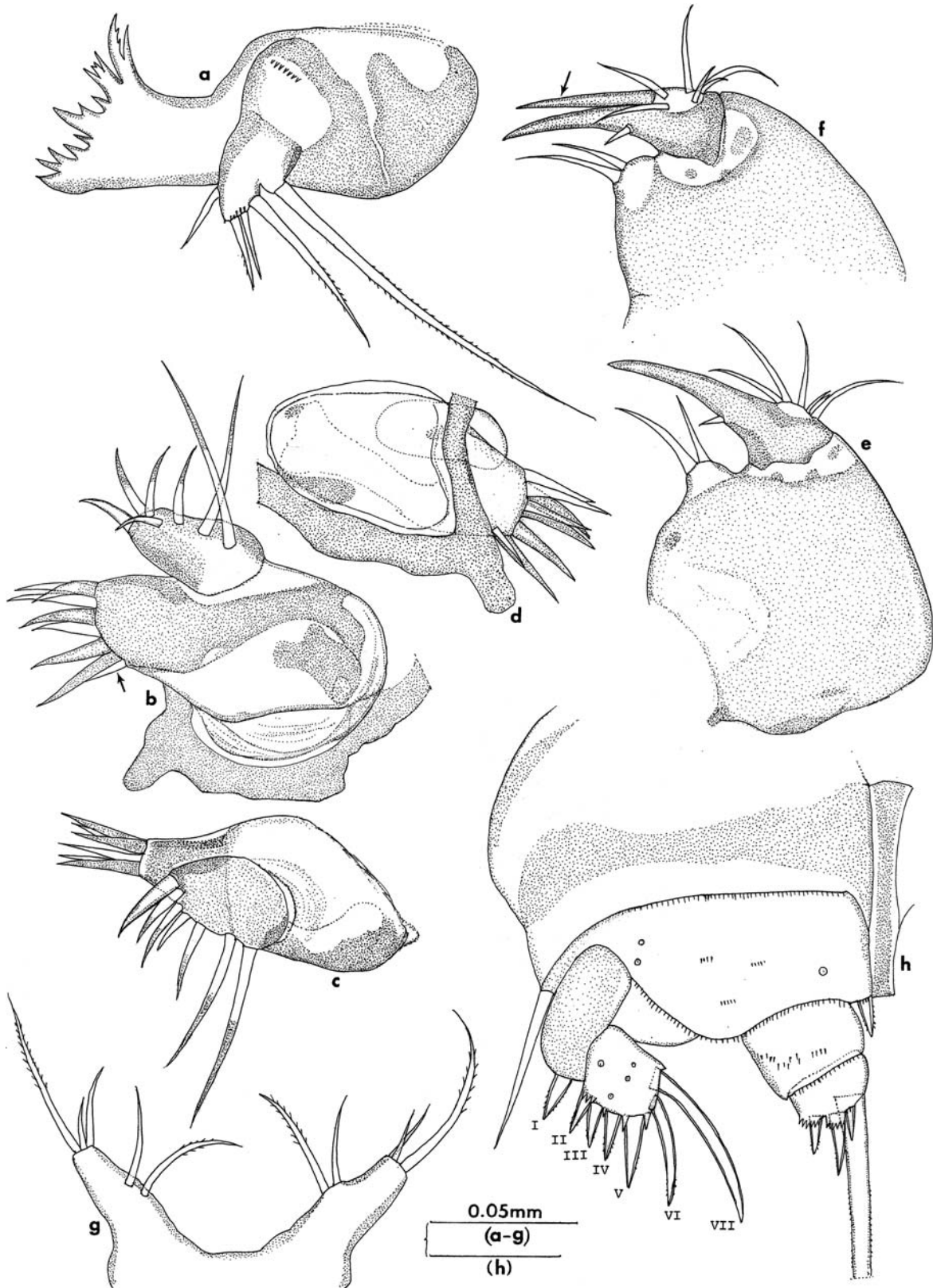


Fig. 4. *Ascidicola rosea* Thorell, female. a, left mandible, anterior; b, left maxillule, posteroventral (arrow indicates 1 short proximalmost seta); c, left maxillule, ventral; d, left maxillule, dorsal; e, left maxilla, posteroventral (1 smaller distal spine of basis not visible); f, left maxilla, anteroventral (arrow indicates 1 smaller distal spine of basis); g, right and left maxillipeds medioproximally connected, posterior; h, right leg 1, anterior (only proximal portion of 1 endopodal seta shown).

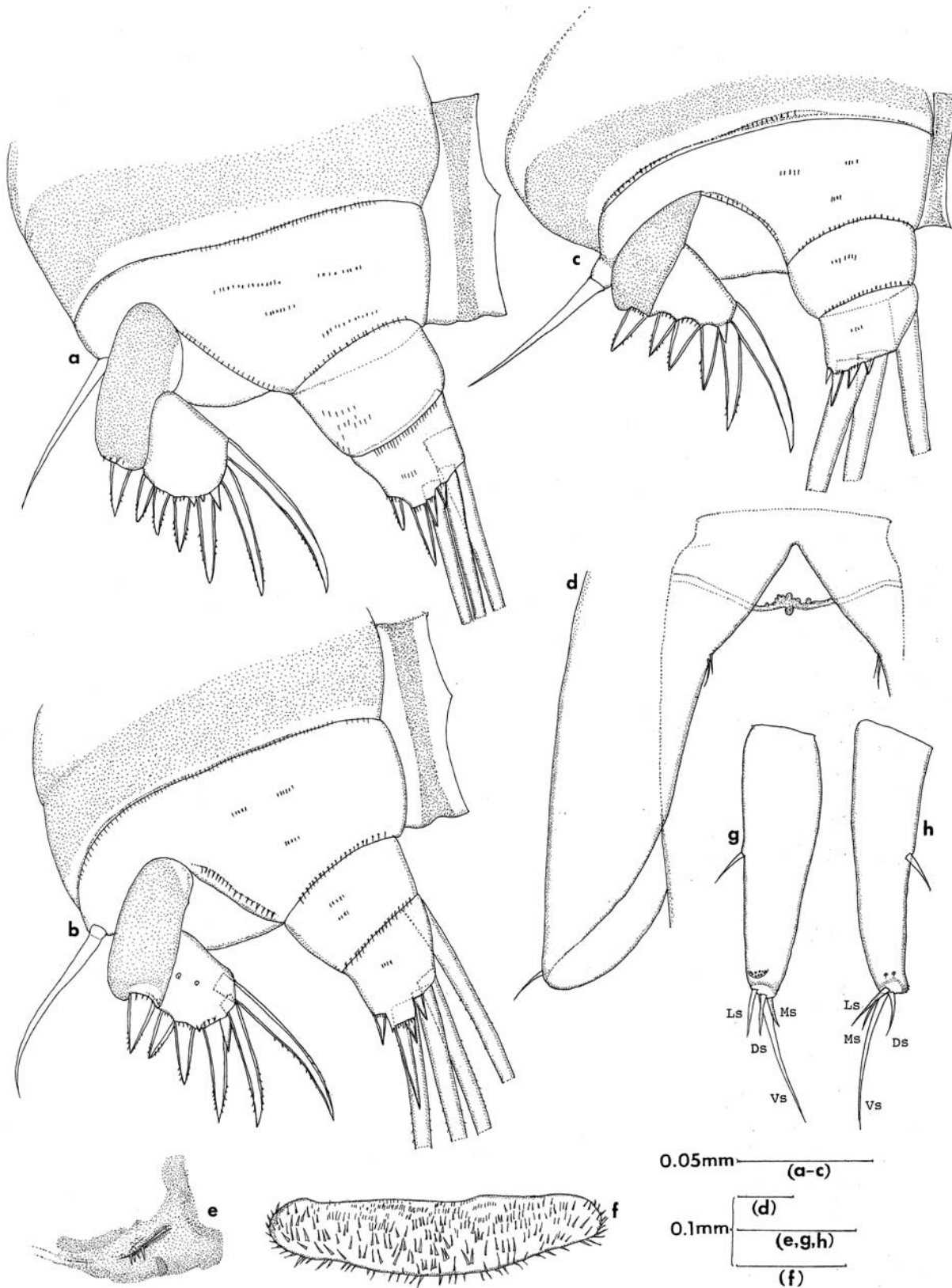


Fig. 5. *Ascidicola rosea* Thorell, female. a, right leg 2, anterior (only proximal portions of 3 endopodal setae shown); b, right leg 3, anterior (only proximal portions of 4 endopodal setae shown); c, right leg 4, anterior (only proximal portions of 3 endopodal setae shown); d, lamellate fifth legs connected medioproximally and anterior genital segment with copulatory organs, ventral (for left leg 5, only ventromedial margin with pair of setae shown); e, left gonoporal area with gonopore armed with several small spines on its medial margin, lateral; f, spinose pad ornamented with sharply pointed spines (single and paired), ventral; g, left caudal ramus, dorsal, showing 5 setae and spinulose posterolateral projection; h, left caudal ramus, lateral.

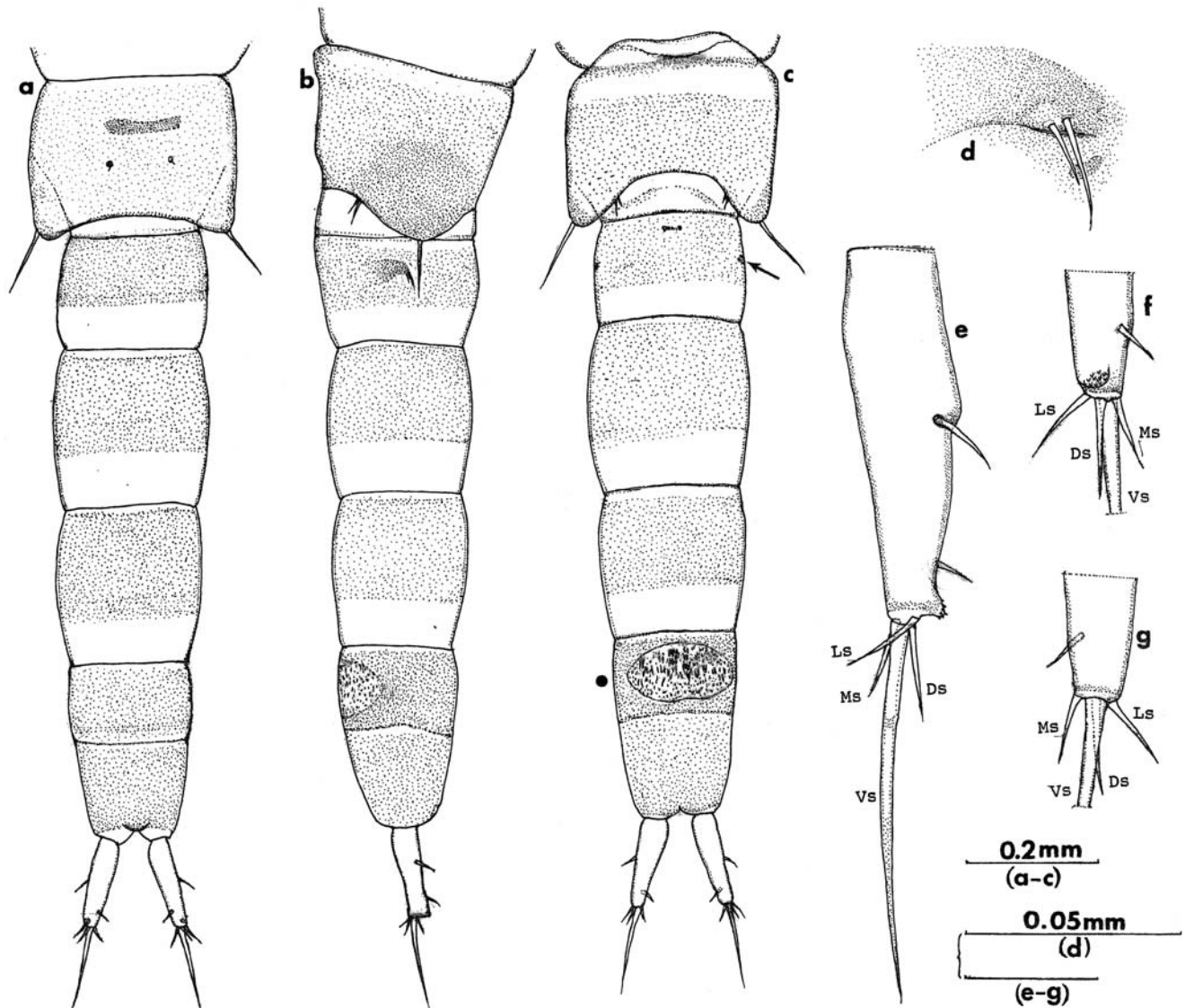


Fig. 6. *Ascidicola rosea* Thorell, young female (prosome omitted). a, 6-segmented urosome (articulation between last 2 segments indistinct) with caudal rami, dorsal, showing first segment with transverse sclerotization, 2 hairlike sensilla, and rudimentary fifth legs (each with 1 distal seta); b, urosome, left side, showing first segment with rudimentary leg 5 with 3 setae, second segment with rudimentary gonoporal area bearing 2 setae (leg 6), and penultimate segment with ventral oval area (lateral side) ornamented by rudimentary spines; c, urosome, ventral, showing first segment with rudimentary fifth legs (each with 3 setae), second segment with transverse sclerotization anteriorly and 2 rudimentary gonoporal areas (arrow indicates left one) laterally, and penultimate segment (indicated by dot) with oval area ornamented by rudimentary spines; d, left rudimentary gonoporal area with 2 setae, lateral; e, left caudal ramus, lateral, showing 6 setae and spinulose projection; f, left caudal ramus (only distal portion shown), dorsal, showing 5 setae (only proximal portion of ventral seta shown) and spinulose projection; g, same specimen, ventral.

Urosome (Fig. 2a-c) consisting of 5 segments (leg 5-bearing, genital, 2 abdominal, anal). Proportional lengths, measured along dorsal central axis, 1:2.7:2:1.3:1.3, and proportional widths, measured at middle of segments, 1:1:0.9:0.8:0.6. First (fifth thoracic) segment articulating with posterior margin of fourth metasomal segment, slightly narrowed posteriorly and depressed on dorsal and lateral sides; dorsal side (Fig. 2e) with semicircular cuticular protrusion proximally and transverse sclerotization at middle of segment. Longest genital (sixth thoracic) segment with genitalia on anterior portion; 2 gonopores lateral, copulatory organs midventral.

Two lamellate fifth thoracic legs (Fig. 2a) protruding from anterior edge of first urosomal (fifth thoracic)

segment and articulating with posterior edge of metasome except on dorsal side. Right and left legs, each with broadly rounded medial margin, separated entirely on dorsal side, but their dorsal medial margins often overlapping. On ventral side (Fig. 2c), proximal one-third of both lamellate legs connected medially. Remaining portions of these legs separated posterodistally, their obliquely separated ventral medial margins making triangle on anterior portion of genital segment; copulatory organs therefore not covered by legs. In lateral view (Fig. 2b), each lamellate leg 1.6 times as long as wide (at middle). These lamellate legs encompassing all of first and most of second urosomal segments, making space to hold 2 nearly elliptical egg sacs under them;

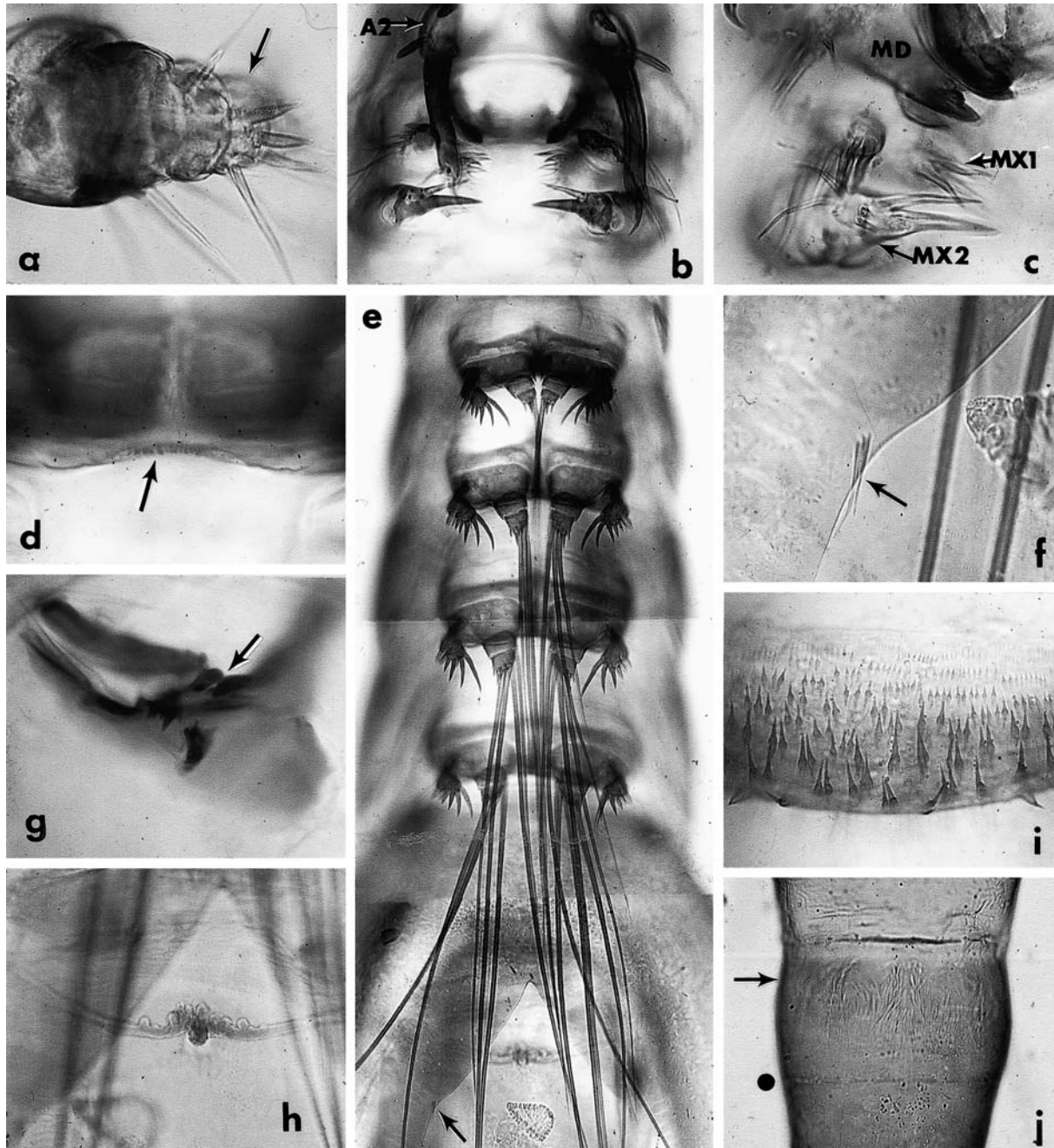


Fig. 7. *Ascidicola rosea* Thorell, photomicrographs of mature female (a-i) and young female (j). a, left antennule, anterior (arrow indicates fourth segment with 3 spines); b, cephalosome, ventral, showing antennae and mouthparts; c, right mouthparts, ventral; d, labrum, ventral (arrow indicates centrodistal margin with minute denticlelike elements); e, biramous first to fourth legs and lamellate fifth legs (proximal portions), ventral (arrow indicates location of setae on ventromedial margin of right leg 5); f, medioproximal portion of right leg 5, ventral (arrow indicates pair of unequal setae); g, left gonoporal area, lateral (arrow indicates gonopore); h, copulatory organs not covered by fifth legs, ventral; i, spinose pad (mid-portion) ornamented with sharply pointed spines, ventral; j, urosome (part) of young female, ventral (arrow indicates penultimate segment with large oval area ornamented by rudimentary spines; dot indicates indistinct articulation with anal segment).

each egg sac probably attached to gonoporal area (Figs. 2b, 5e) by its anterior tip.

On ventral side of urosome, wide transverse spinose pad (Fig. 2b, c) present posterior to penultimate (second abdominal) segment. This small ventral projection originating on ventral part of third abdominal segment of young female (see Description of Young Female). According to SEM image

(of Z. West, unpublished), this structure not connected with either penultimate or anal segment. Anal segment (Fig. 2a) slightly branched posteriorly and bearing narrow setiferous caudal rami terminally. Anus opening posterodorsally.

Antennule (Fig. 3b-d) 5-segmented, each segment wider than long, gradually tapered distally. Armature consisting of 37 elements; 18 simple setae (se), 9 aesthetes (ae), and 10

spines (sp). Armature formula for 5 segments: 4 (4 se), 7 (5 se, 2 sp), 6 (1 se, 2 ae, 3 sp), 6 (2 se, 1 ae, 3 sp), and 14 (6 se, 6 ae, 2 sp). Two long setae on fifth segment longer than appendage. Spines (Figs. 3d, 7a) stout, minute marginal serrations visible. Second to fifth segments with rows of small conical spinules on dorsal side (Fig. 3c).

Antenna (Fig. 3e) 4-segmented; proportional lengths, measured along central axis (lateral side), 1:1.25:1:2.4. First and second segments (coxa, basis) wider and directed ventrally, third and fourth segments (endopod) narrower and directed posteriorly, thus distinctly bent between second and third segments. First segment without armature; second segment anterodistally with 1 large stout spine with marginal serrations; third segment laterodistally with 1 similar large stout spine; fourth segment with 1 much smaller but similar spine midway on anterior (or anteromedial) side and 5 elements (4 simple setae, 1 weak clawlike spine) terminally. Second to fourth segments with many small conical spinules essentially on anterior (or anteromedial) side (Fig. 3e, f).

Labrum with anterior half triangular, posterior half nearly rectangular; these 2 portions characteristically sclerotized, as illustrated (Fig. 3a, g). In nearly rectangular portion, each thickly sclerotized lateral margin directed posteromedially and ending in bilobed tip; slightly concave centrodistal margin with minute denticlelike elements (Fig. 7d).

Paragnath (Fig. 3g) kidneybean-shaped, mid-portion of lateral margin concave and sclerotized, and located near posterior end of posteromedially directed lateral margin of labrum.

Mandible (Fig. 4a) consisting of coxa and palp (basis, exopod, and endopod fused). Gnathobasic medial margin of coxa with variously shaped toothlike elements; 2 bipartite, 2 tripartite, and 3 sharp, conical. Small palp longer than wide, weakly divisible into 2 portions. Proximal portion basally with transverse row of small conical spinules. Distal portion with 5 unequal setae; 1 long lateral (serrated, more than twice as long as palp), 1 distolateral (serrated, half as long as lateral seta), 2 short apical (1 simple, 1 serrated), and 1 short simple medial (near apex). Distal margin, close to 2 short apical setae, with small conical spinules.

Maxillule (Fig. 4b-d) consisting of large precoxa and small palp (coxa, basis, exopod, and endopod fused). Precoxa wider than long, with 8 simple setae on medial margin; 1 short proximalmost seta inserted on posterior side of margin. Palp wider than long, bearing 7 simple setae (5 short, 2 long, from medial to lateral) along distal margin.

Maxilla (Fig. 4e, f) comprising massive syncoxa and mostly sclerotized basis fused with reduced endopod distally. Syncoxa as long as wide, with 2 simple setae on mammiform endite protruded from medial margin. Basis consisting of 2 unequal long, clawlike spines (larger proximal, smaller distal); proximal spine with 1 small simple seta on posterior margin; distal spine inserted at base of proximal one-third on anterior margin of proximal spine. When viewed from posteroventral side, only larger proximal spine may be visible (Fig. 4e). Endopod represented by 6 simple setae (2 short, 4 long) inserted on unsclerotized anteroproximal margin of proximal spine of basis.

Maxilliped (Fig. 4g) consisting of 1-segmented narrowed lobe, 1.3 times as long as proximal width. Right and left maxillipeds connected medioproximally. Armature comprising 5 setae; subequal 2 setae midway on medial margin, and unequal 3 setae (2 short, 1 long) on truncated terminal margin. Proximalmost and distalmost (longest) setae with marginal serrations.

Legs 1-4 (Figs. 4h, 5a-c, 7e) consisting of 2-segmented protopod and rami; intercoxal sclerites extremely narrow. Coxa twice as wide as long, unarticulated at base; distal margin armed with small conical spinules. In legs 1-4, basis with 1 long simple seta on lateral margin; leg 1 basis also with 1 short spine (with minute serrations) on mediiodistal margin. Endopod articulating with medial half of distal margin of basis. Exopod modified. Sclerotized first segment twice as wide as long; medial half directed medioproximally and articulating with basis. Second segment as long as wide, articulating with lateral half of first segment. Basis between lateroproximal corner of first endopodal segment and mediiodistal corner of first exopodal segment making oblique cuticular ridge, thus small part of basis distinguished laterally. In basis, small conical spinules present on surface, distal margin close to endopod, and oblique ridge; distal margin of small part lacking them.

Endopods of legs 1-4 (Figs. 4h, 5a-c, 7e) longer than wide; each segment wider than long. Endopod of leg 1 slightly shorter than its exopod, and endopods of legs 2-4 nearly as long as respective exopods. Main armature consisting of extremely long, flexible setae beset with minute spinules directed posteriorly. Medialmost seta on leg 2 endopod originating on posterior side of second segment, and that on endopods of legs 3 and 4 originating on distal margin of posterior side of first segment. Remaining setae (1 on leg 1; 2 on legs 2 and 4; 3 on leg 3) originating near distal margin of posterior side of second segment. Mediiodistal seta on leg 1 endopod shortest, but reaching to middle of leg 3. Three setae on second endopodal segment of leg 3 extending beyond middle of second urosomal segment. In legs 1-4, second segment additionally with unequal short stout spines on distal margin; 3 spines (1 longer, 2 shorter) on leg 1 endopod, and 4 spines (1 longer, 3 shorter) on endopods of legs 2-4. Distal margin of first and second (close to spines) segments and surface of these segments armed with small conical spinules.

In exopods of legs 1-4 (Figs. 4h, 5a-c, 7e), main armature consisting of stout spines with minute marginal serrations. First segment of these exopods with 1 lateral spine, this slightly longer than proximal lateral spine on second segment. Second segment with 6 graduated spines on legs 1 and 2, and 5 graduated spines on legs 3 and 4. In each second segment, 2 spines distal, others lateral, and mediiodistal spine longest and distinctly curved laterally. Proportional lengths 1:0.9:1:1:1.5:2.7:3.7 for 7 spines (I-VII) in case of leg 1 exopod (Fig. 4h); longest mediiodistal spine (VII) twice as long as second exopodal segment. In exopods of legs 1-4, lateral margin of first and second segments, close to each spine, with small conical spinules. Small spines additionally present on distolateral margin of second segment; 2 spines on leg 1, and 1 spine on legs 2-4.

Armature formula for legs 1-4, based on main elements (setae on endopods; spines on exopods), given below.

Additional elements (small spines on both rami) not included.

	Coxa; Basis (T)	Endopod (T)	Exopod (T)
P1	0-0; I-1.....(2)	0-0; 0-1.....(1)	I-0; VI-0.....(7)
P2	0-0; 0-1.....(1)	0-0; 0-3.....(3)	I-0; VI-0.....(7)
P3	0-0; 0-1.....(1)	0-1; 0-3.....(4)	I-0; V-0.....(6)
P4	0-0; 0-1.....(1)	0-1; 0-2.....(3)	I-0; V-0.....(6)

Leg 5 (Figs. 2a-c, 5d, 7e, f) lamellate, characteristically shaped, as previously mentioned. Armature consisting of 3 simple small setae; pair of unequal setae (shorter anterior, longer posterior) at base of proximal one-third of ventromedial margin, and 1 seta on distal margin.

Gonoporal area (Figs. 2b, 5e, 7g) recognizable as subtriangular sclerotization on both lateral sides of genital segment; small slitlike gonopore opening at middle of area. Medial margin of gonopore armed with several small sharp conical spines.

Copulatory organs (Fig. 2g), when viewed anteroventrally on ventral side of genital segment of dissected specimen, consisting of circular copulatory pore opening internally into probable single seminal receptacle, this longer than wide and darkly stained. Probable seminal receptacle proximally joined to receptacle ducts extending laterally toward gonoporal areas. Each lateral receptacle duct on ventral side with several rounded protrusions. When viewed vertically on intact specimen, darkly stained portion visible as midventral structure (Figs. 2c, 7h).

Spinose pad (Figs. 2c, 5f), measured on ventral side, 4.5 times as wide as long (at middle). Its surface entirely ornamented with many sharply pointed small spines (single and paired); when viewed from ventral side, these spines directed anteriorly and gradually decreasing in size from posterior to anterior (Fig. 7i).

Caudal ramus (Figs. 2a-c, 5g, h) 4 times as long as wide, half as long as anal segment, with 5 simple setae; 1 short seta midway on lateral margin and 4 setae (Ms, Ls, Ds, Vs) terminally. Ventral seta (Vs) half as long as ramus and 3 times as long as medial (Ms), lateral (Ls), and dorsal (Ds) setae. Posterolateral corner protruded and armed with patch of conical spinules; 2 small hairlike sensilla present laterally near apex.

Description of Young Female.—In living specimen, body colorless; eye absent. Body (of fixed specimen) consisting of cephalosome, 4-segmented metasome, and 6-segmented urosome, representing cyclopoid form. Appendages basically comparable in armature formulas to those of mature female, but differing somewhat in morphology (shape, lengths). In legs 1-4, exopods less-modified, subequally divided into 2 segments. First segment slightly widened but not protruded medioproximally, thus most of its distal margin articulating with proximal margin of second segment; oblique ridge of basis (present in mature female) therefore not formed. Distal and lateral margins of basis ornamented with small conical spinules.

Urosome (Fig. 6a-c) almost cylindrical, consisting of fifth thoracic, genital, 3 abdominal, and anal segments. Proportional lengths (measured along dorsal central axis) 1:0.7:1:1:0.5:0.6; proportional widths (measured at middle of dorsal segments) 1:0.6:0.6:0.6:0.5:0.4. First (fifth thoracic)

segment distinctly longer than second (genital) segment and constricted anteriorly; on ventral side, centroanterior margin protruded toward fourth metasomal segment (Fig. 6b, c).

In first segment (Fig. 6a-c), rudimentary fifth legs developed on both sides as posteriorly prolonged, sclerotized semicircular lobes; these fused medially on both dorsal and ventral sides. Dorsally, posterior margin of medial fused portion slightly hollowed anteriorly; this margin on ventral side more deeply hollowed. Each lobe (Fig. 6c) with 3 short simple setae; pair of unequal setae (shorter anterior, longer posterior) midway on ventromedial margin and 1 seta on distal margin. Mid-dorsal surface of segment (Fig. 6a) with small transverse sclerotization at base of proximal one-third, and 2 hairlike sensilla posterior to it. Setation (3 setae) and transverse sclerotization similar to those of mature female.

Second (genital) segment with small sclerotized area at base of proximal one-third of each lateral side (Fig. 6b, c); sclerotized area (Fig. 6d) with 2 unequal simple setae (shorter inner, longer outer), representing sixth thoracic leg and indicating rudimentary gonoporal area. On ventral side (Fig. 6c), short narrow transverse sclerotization present anteriorly, near posterior margin of first segment, as rudiment of copulatory organ complex.

Third to fifth (first to third abdominal) segments clearly articulated with one another, but fifth (penultimate or third abdominal) segment only indistinctly articulated with anal segment (Figs. 6a-c, 7j). Ventral part of penultimate segment distinguished by large oval area (Figs. 6c, 7j); this twice as wide as long, with broadly rounded anterior margin and slightly concave posterior margin. Surface of area ornamented with many rudimentary spines, most of them slender, pointed, directed anteriorly (but some directed anteromedially), and arranged on anterior two-thirds of area; small and minute elements present mainly in posterior portion. This oval area distinctly corresponding to ventral spinose pad posterior to penultimate (second abdominal) segment of urosome of mature female.

Anal segment slightly branched terminally (Fig. 6a, c). Caudal ramus (Fig. 6a-c, e) approximately 4 times as long as wide (at base), as long as anal segment; posterolateral corner protruded and armed with patch of conical spinules, as in mature female. Setation consisting of 6 simple setae (Fig. 6e-g): 1 seta midway on lateral margin, 1 seta near apex on dorsal margin, and 4 setae (Ms, Ls, Ds, Vs) terminally. Ventral seta (Vs) as long as caudal ramus, and 4 times as long as other 3 (Ms, Ls, Ds).

DISCUSSION

Morphology and Armature Formulas

Sars (1921: 65) stated that in *Ascidicola rosea* the eye is inconspicuous, and his illustrations of female body form (pl. XXXI, ♀, 4.10) shows a small dot that apparently indicates an eye. In this paper, however, the fact that this copepod is lacking an eye has been confirmed on living mature and young females collected from two different seas (Mediterranean, Irish); thus Sars' observation has been emended here. According to Lützen (1968: 97), the female *Styelicola bahusia*, another member of the subfamily Ascidiolinae living in the esophageal region of the solitary ascidians *Styela atlantica* (Van Name) and *S. gelatinosa* Traustedt

from the Skagerrak, also lacks an eye. It is interesting that the absence of an eye is characteristic of two species of the subfamily. Monniot (1981: 431) recorded *S. bahusia* in *Ciona gelatinosa* Bonnevie and *A. rosea* in *Ascidia celtica* Monniot, both from Golfe de Gascogne (Atlantic Ocean).

Although armature formulas for appendages given in previous papers vary, it is possible to identify among them the same formulas as those given in the present paper (see Table 1). That the antennule bears spines in addition to setae and aesthetes, as described in this paper, has not been reported for *A. rosea*. However, similarly shaped spinelike elements on the antennules illustrated by Monniot (1965, fig. 43D) and also by Illg and Dudley (1980, fig. 1b) apparently correspond to the spines mentioned above. In *Mytilicola fimbriatus* (Cyclopoida: Mytilicolidae), as described by Humes and Ho (1970: 584, fig. 7), the antennule is ornamented with similar spiniform elements.

The lamellate fifth leg of the mature female, which bears a pair of unequal setae on the ventromedial margin, was illustrated for the first time by Huys and Boxshall (1991, fig. 2.8.32F); this setation has been confirmed in the present paper (Fig. 5d). Their illustration, however, did not show another seta that is present on the distal margin. The young female illustrated by Thorell (1859, Tafl. IX, 13.C, 13.F, as male) resembles the young female studied in this paper in having similarly shaped rudimentary fifth legs. However, Thorell's interpretation of two setae (1 ventromedial, 1 distal) on each leg has been emended to three (2 ventromedial, 1 distal). The pattern of setation is characteristic for the female *A. rosea*.

Segmentation of Metasome and Urosome

According to Thorell (1859: Tafl. IX, 13.A), the metasome (thorax) of the mature female of *A. rosea* consists of five segments, thus including the lamellate fifth thoracic legs, and the urosome (abdomen) consists of four segments (genital, 2 abdominal, anal). Sars (1921: 64, pl. XXXI, ♀, 4.10) had a similar interpretation as to the segmental composition of these body regions, stating that the metasome (trunk) consists of five segments and the urosome (tail) consists of four segments, and that the last metasomal segment is not clearly distinct from the first urosomal segment. Illg and Dudley (1980: 22, fig. 1a) mentioned that the usual major body articulation is not formed in this species, and interpreted the metasome to consist of five segments (4 leg-bearing, plus a long, complex region bearing lamellate fifth legs and genital apertures) and the urosome to consist of three segments (2 abdominal, anal).

In the present paper, which offers a different interpretation, the metasome and urosome are stated to consist, respectively, of four and five segments. Therefore, the segment that bears the lamellate fifth legs is not included in the metasome but in the urosome, representing a cyclopoid form. The recognition of the metasome-urosome boundary is based on the following reasons: (1) the first urosomal (fifth thoracic) segment is clearly articulated with the fourth metasomal (fourth thoracic) segment as in the young female, in which the articulation is also indicated by a constriction; (2) the first urosomal segment is basically similar in morphology to the remaining urosomal segments, which are cylindrical and narrower than the widened metasome;

Table 1. Comparison of appendages in female specimens of *A. rosea* Thorell, as given in the present paper (Ooishi) and previous papers (Thorell, 1859; Brady, 1878; Aurivillius, 1882; Sars, 1921; Monniot, 1965; Illg and Dudley, 1980, see fig. 3c, for legs 1-4 by Chatton; Huys and Boxshall, 1991). The formulas in previous papers were based mainly on the illustrations given by their authors. ae = aesthete, en = endopod, ex = exopod, se = seta, seg = segment, sp = spine.

Appendages	Present paper	Previous papers
Antennule		
(5 seg)	37 (18 se, 9 ae, 10 sp)	30 (se): Thorell, Sars 31 (se): Monniot 35 (31 se, 4 ae): Illg and Dudley
(7 seg)		21 (se): Brady 23 (se): Aurivillius
Antenna		
(3 seg)		4 (3 sp, 1 se): Brady 7 (4 sp, 3 se): Aurivillius 8 (4 sp, 4 se): Thorell, Sars, Monniot, Illg and Dudley
(4 seg)	8 (4 sp, 4 se)	8 (4 sp, 4 se): Huys and Boxshall
Mandible		
coxa	toothlike elements	toothlike elements: Thorell, Brady, Aurivillius, Sars, Monniot, Illg and Dudley
palp	5 se	3 se: Thorell 4 se: Sars, Illg and Dudley 5 se: Aurivillius, Monniot 6 se: Brady
Maxillule		
precoxa	8 se	4 se: Brady 6 se: Thorell 7 se: Aurivillius, Sars, Illg and Dudley 8 se: Monniot
palp	7 se	7 se: Thorell, Brady, Aurivillius, Sars, Monniot, Illg and Dudley
Maxilla		
syncoxa	2 se	2 se: Thorell, Brady, Aurivillius, Sars, Monniot, Illg and Dudley
basis; en	9 (2 sp, 1 se; 6 se)	6 (2 sp; 4 se): Thorell, Brady, Sars 7 (2 sp; 5 se): Aurivillius, Monniot, Illg and Dudley
Maxilliped	5 se	4 se: Brady 5 se: Thorell, Aurivillius, Sars, Monniot 6 se: Illg and Dudley
Legs 1-4		
en (se)	1,3,4,3	en = 1,3,3,3: Illg and Dudley en = 1,3,4,3: Chatton
ex (sp)	7,7,6,6	ex = 7,7,7,6: Illg and Dudley ex = 7,7,6,5: Chatton
Leg 5	3 se (1 distal, 2 ventromedial)	1 se (distal): Thorell, Aurivillius, Sars, Monniot, Illg and Dudley 2 se (ventromedial): Huys and Boxshall
Caudal ramus	5 se	5 se: Thorell, Brady, Aurivillius, Monniot, Illg and Dudley 6 se: Sars

(3) probably, the first two urosomal segments (leg 5-bearing, genital) together function to hold the nearly elliptical egg sacs under the lamellate large fifth legs. Thus, the major body articulation of *A. rosea* is interpreted to be between the fourth and fifth thoracic segments.

In the young female studied by Thorell and mentioned above, the urosome (abdomen, posterior to fifth thoracic

segment) was shown as consisting of five segments. However, when the fifth thoracic segment is included in the urosome, its 6-segmented urosome corresponds to that of the young female examined in this paper (Fig. 6b).

The male of *A. rosea* was dealt with by Sars (1921: pl. XXXI, ♂, 1.20) and Monniot (1965, fig. 43C), respectively. In their specimens, the urosome was illustrated as consisting of five segments (leg 5-bearing, genital, 2 abdominal, anal). However, the urosome of the male *A. rosea* is probably 6-segmented, as in the young female described here and in males of *Botryllophilus* (see Ooishi, 2000, fig. 7a, b) and other ascidicolous copepods examined. Gage (1966: 231) pointed out that the male studied by Sars appears to be a copepodid stage before metamorphosis to the adult form. The present paper supports this.

Homology of Spinose Pad

It is obvious that the ventral transverse spinose pad posterior to the penultimate (second abdominal) segment of the urosome of the mature female is homologous to the large oval area, with rudimentary spines, of the ventral part of the penultimate (third abdominal) segment of the urosome of the young female. It is almost certain that all of the dorsal side of the third abdominal segment of the young female, and also part of the ventral side of this segment, becomes greatly reduced, and that the ventral oval area with rudimentary spines persists in the mature female as a ventral spinose pad. That the third abdominal segment has only an indistinct articulation with the anal segment strongly suggests the segmental reduction mentioned above. The formation of the spinose pad could be one of the adaptations for the characteristic feeding mode in *A. rosea*. The spinose pad is clearly not a part of the penultimate segment. The 5-segmented urosome (leg 5-bearing, genital, first and second abdominal, anal) of the mature female thus does not have a genital double somite (fused genital and first abdominal), which Huys and Boxshall (1991: 231, fig. 2.8.32.F and its legend) thought it did.

The spinose pad was not observed in the mature female examined by Illg and Dudley (1980: 22, fig. 1a); it was not shown in a similar female (ventral view) illustrated by Monniot (1965: 159, fig. A). It is likely that in these females this small projected structure separated from the urosome. The spinose pad may not be indispensable for feeding activity of this copepod. However, Gotto (1957: 285, 286) observed that it functions effectively as a crampon for clinging to a mucus cord in the host esophagus; on occasion, he also saw a young female (without spinose pad) with a mature female on the same food string. In any case, a comparative study of the urosomes of mature and young females of *A. rosea*, as reported in this paper, makes it possible to recognize the homology of the spinose pad.

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