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TWO SPECIES OF *BOTRYLLOPHILUS* (COPEPODA: CYCLOPOIDA) LIVING IN COMPOUND ASCIDIANS, AND A REVISION OF FEMALE MORPHOTYPE A OF THE GENUS

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ABSTRACT

This paper is concerned primarily with the taxonomy of two species of the copepod genus *Botryllophilus* (Ascidicolidae: Botryllophilinae) collected from compound ascidian hosts in Golfo di Napoli (= the Gulf of Naples). Both copepods belong to subgroup 2 of female morphotype A of the genus. The female of *B. banyulensis* Brément, 1909, living in the type host *Parascidia areolata* (Delle Chiaie), is redescribed, and the male is described for the first time. In the case of *B. neapolitanus* n. sp., living in *Aplidium* sp., the female is described. In subgroup 2, consisting of four species including the new species, the leg armature formulas are of pattern II, in which additional armature elements (setae, spines, etc.) are found on most legs; this differs from the armature formula of pattern I. Six species of subgroup 1 of morphotype A have pattern I. In this paper, it is shown that the four species of subgroup 2 exhibit four different formulas of pattern II; *B. banyulensis* has pattern II–1, and *B. neapolitanus* has pattern II–3. The original concept of morphotype A is revised in order to accommodate all the species of subgroups 1 and 2.

INTRODUCTION

Two morphotypes (A, B) of the female *Botryllophilus* were established by Ooishi and Illg (1988) on the basis of morphological features of 10 unnamed species of Pacific copepods. In both morphotypes, the number of segments in the urosome has been recognized as a primary character; type A has a 5-segmented urosome, and in type B there are more than 5 segments. Ten valid species (9 from European seas, 1 from the West Indies) of the genus were placed in these two morphotypes. However, these authors emphasized that the two types will not suffice for all species of the genus, because additional characters will have to be considered. Later, Ooishi (1991) suggested that at least type A should perhaps be divided into more types and that redescriptions of old species and descriptions of new species from various coastal waters will have to be dealt with in studies of the genus, which has many taxonomic problems.

For resolving the difficulties, five of the nine European species have been redescribed by Ooishi: type A — (1) *B. norvegicus* Schellenberg, 1921, in 1996, (2) *B. inaequipes* Hansen, 1923, in 2002a, and (3) *B. brevipes* Sars, 1921, as *B. sarsi* n. sp., in 2002b; type B — (4) *B. macropus* Canu, 1891, in 1996, and (5) *B. ruber* Hesse, 1864, in 1999. Four new species have been described as follows: type A (all from the Pacific Ocean) — (1) *B. abbotti* Ooishi and Illg, 1989, (2) *B. koreensis* Seo and Lee, 1995, and (3) *B. bamfieldensis* Ooishi, 2000; type B (from a European sea) — (4) *B. conicus* Conradi et al., 1994. Until now, the genus consisted of 14 valid species (9 of type A, see Ooishi, 2000, 2002b; 5 of type B, see Ooishi, 1999).

In the study (Ooishi, 2000) of *B. bamfieldensis*, it was proposed that the nine species of type A be divided into two subgroups (1, 2) based on leg armature formula patterns I and II. Each pattern was distinguished by the total number of armature elements (setae, spines, etc.) on the endopods and exopods of legs 1–4; six species of subgroup 1 have pattern I, and three species of subgroup 2 have pattern II. The representative formula for pattern I was based on *B. bamfieldensis* and that for pattern II was based on *B. norvegicus*, in which armature elements on most legs have more elements than those of the former species.

The redescriptions of two European species of the genus — *B. inaequipes* and *B. brevipes* Sars (= *B. sarsi*) — made it possible to confirm that six species of subgroup 1 fit pattern I, although one of them has a minute deviation. In the study (Ooishi, 2002b) of *B. sarsi* (= *B. brevipes* Sars), it was mentioned that the morphology of spines on leg 1 exopods can be recognized as a useful character in distinghishing all six species.

In the above-mentioned study (Ooishi, 2000) of *B. bamfieldensis*, *B. brevipes* and *B. banyulensis*, both described by Brément (1909) from Port-Vendres (French coast of the Mediterranean Sea), were designated as members of subgroup 2, because they have additional armature elements, as in *B. norvegicus*. Furthermore, it was stated that redescriptions of *B. brevipes* and *B. banyulensis* (see synonyms of Illg and Dudley, 1980) and descriptions of new species are necessary for obtaining diagnostic features of subgroup 2 with respect not only to the legs but also other appendages.

This paper includes a redescription of the female of *B. banyulensis*, a description of its male, and also a description of the female of *B. neapolitanus* n. sp. Both species belong to subgroup 2 and are from the Italian coast of the Mediterranean Sea. The results lead to the conclusion that females of four species (3 known, 1 new) of subgroup 2 are distinguished from the members of subgroup 1 in regard to leg armature formulas as well as most of the cephalosomal appendages and genitalia. These differences will be shown in the revised diagnosis of morphotype A, which has two subgroups. This genus now consists of 15 species (females) including the new species; the male of *B. banyulensis* is here added to three males that have already been described.

MATERIALS AND METHODS

Sampling of copepods from ascidian hosts (Aplousobranchia: Polyclinidae) was carried out at Stazione Zoologica Anton Dohrn Napoli, Italy, from

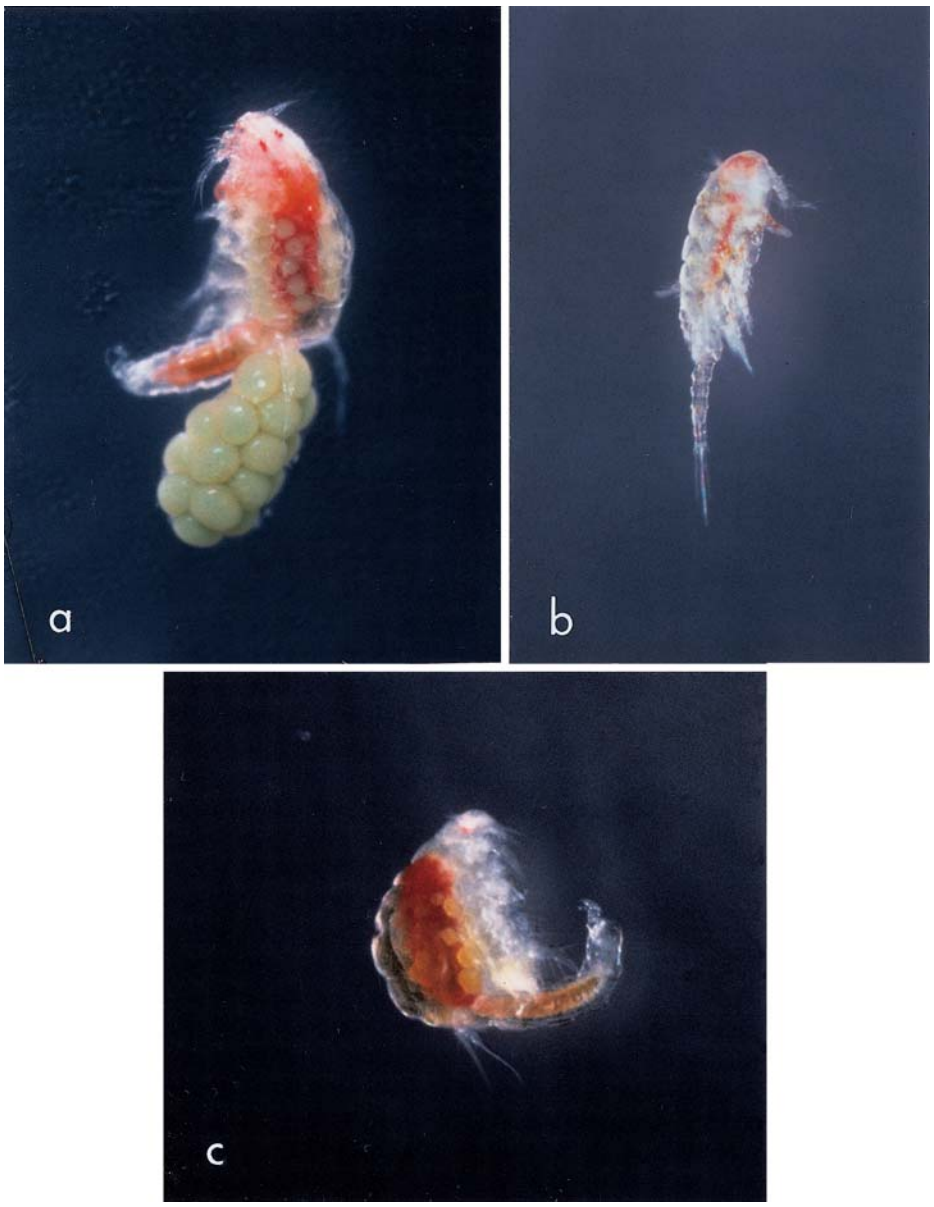

Fig. 1. Macrophotographs of two species of *Botryllophilus*, based on living specimens. a, *B. banyulensis* Brément, female, lateral; b, *B. banyulensis* Brément, male, ventrolateral; c, *B. neapolitanus* n. sp., female, lateral.

24 September to 21 November 1989 (see Ooishi and Illg, 1977, for detailed sampling methods). The institution provided me with the ascidians collected by diving, depth between 6–12 m, at a coastal station (st. MC, 40°48.5′N, 14°15′E) in The Gulf of Naples.

The ascidian host for *B. banyulensis* from Naples has been designated as *Parascidia areolata* (Delle Chiaie) for the following reasons: (1) the ascidian containing the copepod is apparently the same as *P. areolata* reported by Salfi (1931) from Naples because it has a similar color (reddish) and morphology (globular, 1–2 cm diameter, 8 branchial lobes); (2) Dr. M. Nakauchi (personal communication) has confirmed that specimens of *P. areolata* collected at Naples for his paper (1980) are comparable to mine in having similar external morphological features; and (3) *P. areolata* is the type host for *B. banyulensis* described by Brément (1909) from Port-Vendres. The ascidian host (red, in thick colonies more than 5 cm wide) for *B. neapolitanus* n. sp. has been designated as *Aplidium* sp., according to Dr. R. Brunetti (personal communication).

Macrophotographs (Fig. 1a–c) of *B. banyulensis* (♀, ♂) from *P. areolata* and of *B. neapolitanus* n. sp. (♀) from *Aplidium* sp. were of living specimens. Some of the female specimens of *B. banyulensis* were used for the study by a scanning electron microscopy at the Station. All other copepod specimens collected were fixed in 95% ethanol and stored in 70% ethanol; some of them were immersed in lactic acid (with a slight amount of methylene blue) for dissecting, drawings, measurements, and photomicrographs. Drawings were made with the aid of a camera lucida.

In this paper, *Botryllophilus* is placed in the family Ascidicolidae Thorell, 1859, sensu Illg and Dudley (1980). The taxonomic status of the genus used in this paper is comparable to that used by Gotto (2004). The order Cyclopoida Sars, 1886, is based on Damkaer (2002).

In the armature formula for legs 1–4, the total number of spines or spiniform elements (Roman numerals) is indicated first and connected by a dash with the number of setae (Arabic numerals). The total number (T) of these elements is given in parentheses for protopod (coxa, basis), endopod, and exopod. The total number denoted by an asterisk (*) means that one mediodistal element (reduced or feeble, from the posterior side) is included.

The abbreviations used are: A1 = antennule, A2 = antenna, MD = mandible, MX1 = maxillule, MX2 = maxilla, MXP = maxilliped, PG = paragnath, P_1 = leg 1, R = rostrum, I = first armature element of antenna or leg 1 exopod and also first major seta of maxilla, I_1 = first major seta on first

segment of antennule, 1 = 1 independent seta (generally short) of antennule or 1 long seta proximal to major seta I of maxilla, +1 = subordinate seta associated with a major seta of antennule or maxilla.

SYSTEMATICS

Order Cyclopoida Sars, 1886
Family Ascidicolidae Thorell, 1859
Subfamily Botryllophilinae Sars, 1921
Genus *Botryllophilus* Hesse, 1864
Botryllophilus banyulensis Brément, 1909
Figs. 1–12

Material Examined.—6 ♀♀ (BMNH2005.198-203) and 1 ♂ (BMNH2005.204), living in *Parascidia areolata* (Delle Chiaie), collected on 23 October 1989, from The Gulf of Naples, deposited in the Natural History Museum, London, March 2005.

Redescription of Female.—Body of living specimen (Fig. 1a) overall reddish. In cephalosome, eye absent but a pair of small red pigment spots present internally near anterior margin. Metasome with large red gut and small light green eggs on both sides of gut, and urosome with similarly red gut. Single large egg sac ellipsoidal, nearly as long as prosome, enclosing light green eggs (embryos).

Body (Figs. 2a–c) stout, compact, consisting of small cephalosome, barrel-shaped metasome, and relatively short cylindrical urosome directed posteroventrally. Proportional lengths 1:4:2.5 for 3 regions. Ratio of length of prosome to that of urosome 2:1; prosome rather straight. Body length (excluding caudal spines) 1.49 mm. Range of lengths 1.36–1.58 mm, based on 5 mature females (with egg sac). Body surface with sparsely scattered hairlike sensilla.

Cephalosome (Fig. 2a–c) subtriangular, wider than long, with rounded distal margin. Rostrum (Figs. 2d, 7a) nearly V-shaped, longer than wide, slightly expanded ventrally. Both lateral margins and narrow distal apex thickly sclerotized; unsclerotized central portion with several minute hairlike sensilla. Each lateral sclerotized portion, close to anterior base, with 1 laterally curved small sclerite protruded from surface. Appendages (Fig. 2d, e) consisting of 6 pairs including maxillipeds.

Metasome (Fig. 2a–c) unsegmented on dorsal side, divided into 5 segments on ventral side. Right and left legs 1–4 modified, asymmetrical; intercoxal sclerite absent. In first to third pairs, right and left legs widely separated; in fourth pair, right leg closer to left leg. Greatest width (0.44 mm) and thickness (0.5 mm) in third pedigerous segment. Fifth pedigerous segment narrowed posteriorly, bearing relatively long uniramous fifth legs anterolaterally; these directed posterolaterally. Ventrally, semicircular middistal margin of this segment (Fig. 6d) prolonged posteriorly, covering midventral genital segment of urosome.

Urosome (Fig. 2a–c) 5-segmented, with proportional lengths 1:0.8:0.8:0.8:1. Genital segment indistinctly demarcated from metasome, with 2 gonopores dorsolaterally and copulatory organs midventrally; 3 abdominal segments each much wider than long; and anal segment with short caudal rami terminally. Anus opening posterodorsally.

Antennule (Figs. 3a, 7a) 4-segmented. First segment weakly articulated with second segment, shorter than total length of narrowed second to fourth segments. Armature comprising 28 simple setae including 1 aesthete-like seta on fourth segment. First segment with 9 setae ($I_1 + 2$, $II_1 + 2$, $III_1 + 1$, 1); second segment with 4 setae (I_2, $II_2 + 2$); third segment with 3 setae ($I_3 + 2$); and fourth segment with 12 setae ($I_4 + 11$). In first segment, each of 3 major setae inserted on long prominence (endite); 1 independent seta at anterodistal corner longer than subordinate setae. In third segment, distal subordinate seta (on I_3) extremely small.

Antenna 4-segmented, armature elements on right and left sides asymmetrical in shape. In right antenna (Fig. 3b), proportional lengths, measured along central axis on anterior side, 1:3:0.8:2.6 for 4 segments. Fourth segment with 6 armature elements (I–VI); 1 seta (I) and 1 spine (II) on medial margin, and 2 spines (III, IV) and 2 setae (V, VI), from medial to lateral, on terminal margin. These elements with minute serrations on distal half (in setae) or distal tip (in spines). Proportional lengths 1:0.4:0.4:0.7:1.2:1.7 for 6 elements; first element (I, seta) longer than second one (II, spine), and sixth element (VI, seta) longer than fourth segment. In left antenna (Fig. 3c), 6 elements all replaced by setae, but first seta not longer than second seta.

Labrum (Fig. 2d) protruded posteriorly; truncated distal margin with minute setules on both sides.

Mandible (Fig. 3d) consisting of coxa and palp (basis, exopod, and endopod fused). Medial margin of coxa with comblike spinules (major portion in double rows) and single row of 2 modified conical spines (each with 1 fused smaller spine anteriorly) and 2 sharp conical spines on common base (first spine with serrations anteriorly), from anterior to posterior. Palp with 9 setae: exopodal region with 3 setae (1 shorter proximal, 2 longer distal on common base); endopodal region with 6 setae (2 unequal short medial; 2 subequal long distolateral; 2 subequal long terminal). Except for shorter medial seta, all setae plumose.

Paragnath (Fig. 3e) bean-shaped, attached to medial margin of oral sclerite surrounding mandible and maxillule.

Maxillule (Fig. 3f) comprising precoxa and palp (coxa, basis, and exopod fused; endopod distal), and bearing 15 setae. Precoxa with 6 medial plumose setae. Epipodite of coxa represented by small lobe with 1 short simple apical seta. Basis represented by 2 long plumose setae directed distally and setules posterior to them. Exopodal region with 3 relatively short plumose setae (1 directed proximally, 2 directed distally) and 1 small mammiform projection next to endopod, this with 3 plumose apical setae.

Maxilla (Fig. 3g) consisting of precoxa, coxa, and fused basis and endopod, and bearing 11 setae. Precoxa with 4 setae (1, I, II + 1), coxa with 4 setae (III + 2, IV), and fused distal portion with 3 setae (V – VII). These setae plumose, except for 1 distal subordinate (on III) and 2 major (V, VI) setae.

In maxilliped (Fig. 3h, i), coxa twice as long as basis; medial surface with 2 simple setae proximally and patch of spinules midway on surface. Basis with 2 small simple setae (anterior, posterior) on medial margin. Endopod 3-segmented; second segment longest, with 2 minute setae on posterior side, and third segment claw-shaped, with tridentate apex.

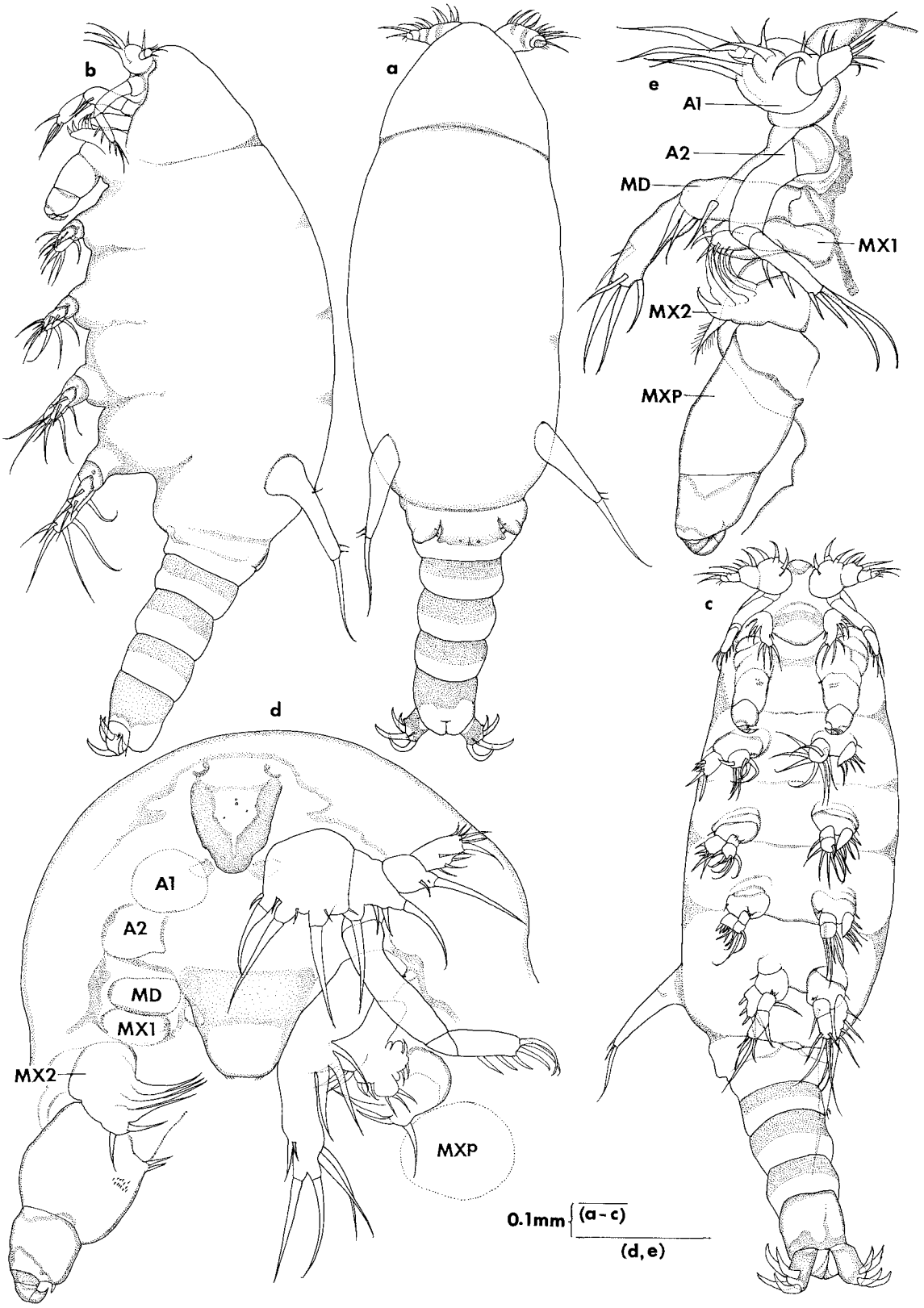

Fig. 2. *Botryllophilus banyulensis* Brément, female. a, body form, dorsal; b, body form, lateral; c, body form, ventral; d, cephalosome, anteroventral; e, cephalosome, lateral.

Fig. 3. *Botryllophilus banyulensis* Brément, female. a, right antennule, anterior (arrow indicates aesthete-like seta); b, right antenna, anterior; c, left antenna (mainly fourth segment), anterior; d, right mandible, anterior; e, right paragnath, ventral; f, right maxillule, posterior; g, right maxilla, posterior; h, left maxilliped, anterior; i, left maxilliped (endopod), posterior.

In right and left legs 1–4 (Figs. 4a–f, 5a–f), coxa unarticulated at base, without armature. Basis with 1 simple seta on lateral margin and patch of conical spinules on sclerotized mediodistal margin. Spinular formulas on basis: 8,5,4,3 for right legs 1–4; 6,3,3,3 for left legs 1–4. In right leg 4 (Fig. 5d) and left legs 2–4 (Figs. 4e, 5b, e), 3 spinules on basis fused at base; those enlarged in left leg 4 (Fig. 7b).

Endopods of right and left legs 1–4 (Figs. 4a, b, d, e, 5a, b, d, e) consisting of 2 segments, but segmentation weak in leg 1 pair. In legs 1–3, endopods longer than wide and nearly as long as respective exopods. In leg 4 pair, endopods much longer than exopods; right leg 4 endopod 1.6 times as long as its exopod. Armature formulas (8,8,6,6) for endopods of legs 1–4 on both sides symmetrical; first segment with 1 seta. In endopods of right legs 1–4 (Figs. 4a, d, 5a, d, 7c, d), second segment with 1 spiniform element with minute serrations in addition to setae; this element represented by one short slender or rigid seta in all left endopods.

Exopods of right legs 1–4 (Figs. 4a, d, 5a, d, 7c) 1-segmented. In legs 1–3, exopods approximately trapezoidal, but exopod of leg 4 elongated (not trapezoidal); armature consisting of stout spines. Exopods of right legs 1–3 with 6 spines (I–VI, in cases of legs 1 and 2) on uneven truncated distal margin, but short fourth spine (IV) protruded from anterior side and longest sixth spine (VI) from posterior side. In right leg 1 exopod, 3 spines (I, V, VI) remarkably long; proximalmost spine (I) twice as long as lateral margin of ramus, and longest spine (VI) from posterior side 3 times as long as ramus. These 3 long spines (I, V, VI) somewhat reduced in length in exopods of legs 2 and 3. Proportional lengths 1:0.6:0.4:0.4:1.3:1.5 for 6 spines (I–VI) of leg 1 exopod. In elongate right leg 4 exopod, lateral and terminal margins corresponding to broad truncated distal margin in right legs 1–3 exopods. Armature comprising 5 spines (1 spine fewer than in legs 1–3); fifth spine on medial margin (posterior side) homologous to sixth spine (VI) on exopods of right legs 1–3.

Distal margin of exopods of right legs 1–3 (Figs. 4a, d, 5a), close to each of first 5 spines, slightly protruded and with 2 or 3 small conical spinules fused at base; these spinules absent near sixth spine (VI). In exopod of right leg 4 (Fig. 5d), 2 spinules present near first and second spines and 1 spinule near third and fourth spines; spinules lacking around fifth spine.

Exopods of left legs 1–4 (Figs. 4b, e, 5b, e) 1-segmented, approximately rhomboidal; exopod of leg 4 much longer and narrower than exopods of legs 1–3. Ratio of length to width 2.5:1 for legs 1–3, and 3:1 for leg 4. Distal three-fifths of lateral margin with long simple setae: 5 setae (I–V, in cases of legs 1 and 2) in legs 1–3; 4 setae in leg 4. Single vestigial element (Figs. 4c, f, 5c, f) on posterior side near distalmost seta; vestigial element homologous to sixth long spine on exopods of right legs 1–3 and fifth spine on exopod of right leg 4. Thus, one element lacking on exopods of left legs 1–4. Ratio of lengths 1:1.7:1.5:1.5:2.2 for 5 setae (I–V) on exopod of left leg 1. In all left exopods, distalmost seta distinctly long. Spinules on lateral margin of left exopods basically comparable in arrangement to those on distal margin of right exopods. Armature formula for right and left legs 1–4 given below, this showing pattern II–1.

(Right)	Coxa; Basis (T)	Endopod (T)	Exopod (T)
P_1	0–0; 0–1. . .(1)	0–1; I–6. . .(8)	VI–0. . .(6)
P_2	0–0; 0–1. . .(1)	0–1; I–6. . .(8)	VI–0. . .(6)
P_3	0–0; 0–1. . .(1)	0–1; I–4. . .(6)	VI–0. . .(6)
P_4	0–0; 0–1. . .(1)	0–1; I–4. . .(6)	V–0. . . .(5)
(Left)			
P_1	0–0; 0–1. . .(1)	0–1; 0–7. . .(8)	0–5. . .(5)
P_2	0–0; 0–1. . .(1)	0–1; 0–7. . .(8)	0–5. . .(5)
P_3	0–0; 0–1. . .(1)	0–1; 0–5. . .(6)	0–5. . .(5)
P_4	0–0; 0–1. . .(1)	0–1; 0–5. . .(6)	0–4. . .(4)

Leg 5 pair almost symmetrical. Left leg 5 (Fig. 6a) narrowed distally, 3 times as long as proximal width, and 50% as long as urosome. Armature: 3 short simple setae on dorsal margin (1 at base of proximal two-fifths, 1 subterminal, 1 almost terminal), and 1 long simple seta terminally. Two short distal setae with noticeable space between them, and terminal seta shorter than appendage.

In genital segment (Fig. 6b), dorsal cuticle between gonopores with 2 hairlike sensilla posteriorly. Apparatus at gonopore (Figs. 6c, 7e, f): pair of unequal blunt long conical spines (1 smaller proximal, articulated; 1 larger distal, unarticulated) and 1 sharp conical spine (lateroproximal) externally, and 7 conical spines (stout, most in 2 rows) internally. Ventrally, genital atrium not present. Two small seminal receptacles (Figs. 6d, 7g) in subcuticular elliptical copulatory organ complex. Two tubular copulatory pores externally protruded from these receptacles; each pore with circular opening (Fig. 7h). Receptacle ducts extending from seminal receptacles toward lateral antra internally.

Anal segment (Figs. 6e–g, 7i) longer than wide on dorsal side, wider than long on ventral side; hairlike sensilla apparently present, but not easily distinguished. Sclerotization of posterior half of centroventral surface shaped as an inverted T.

Caudal ramus (Fig. 6e–g) sclerotized, longer than wide, with 2 simple setae (longer lateral, shorter dorsal) and 4 ventrally curved spines terminally. Lateral margin of ramus, close to anterior base of lateral seta, with 5 spinules (Fig. 7j). Four caudal spines claw-shaped, sharply pointed and without marginal serrations (confirmed by scanning electron microscopy); lateral spine (LS) less-sclerotized (Fig. 7i), but medial (MS), dorsal (DS), and ventral (VS) spines sclerotized.

Description of Male.—Body of living specimen (Fig. 1b) mostly white, opaque, but partially reddish in cephalosome (anterior portion), metasome (gut), and urosome (gut). Eye absent, but 2 red pigment spots present, as in female.

Body (Fig. 8a, b) 0.86 mm long, excluding long terminal caudal setae (0.22 mm long), showing cyclopoid swimming form. Ratio of length of prosome to that of urosome 1.4:1. Distal portions of terminal caudal setae crossing as seen in Fig. 8a.

Cephalosome (Fig. 8a, b) subtriangular. Appendages (Fig. 9a) comprising 6 pairs including maxillipeds. Rostrum long subtriangular; lateral margins sclerotized, 1.3 times as long as proximal width. Integument (Fig. 12a, b), except for

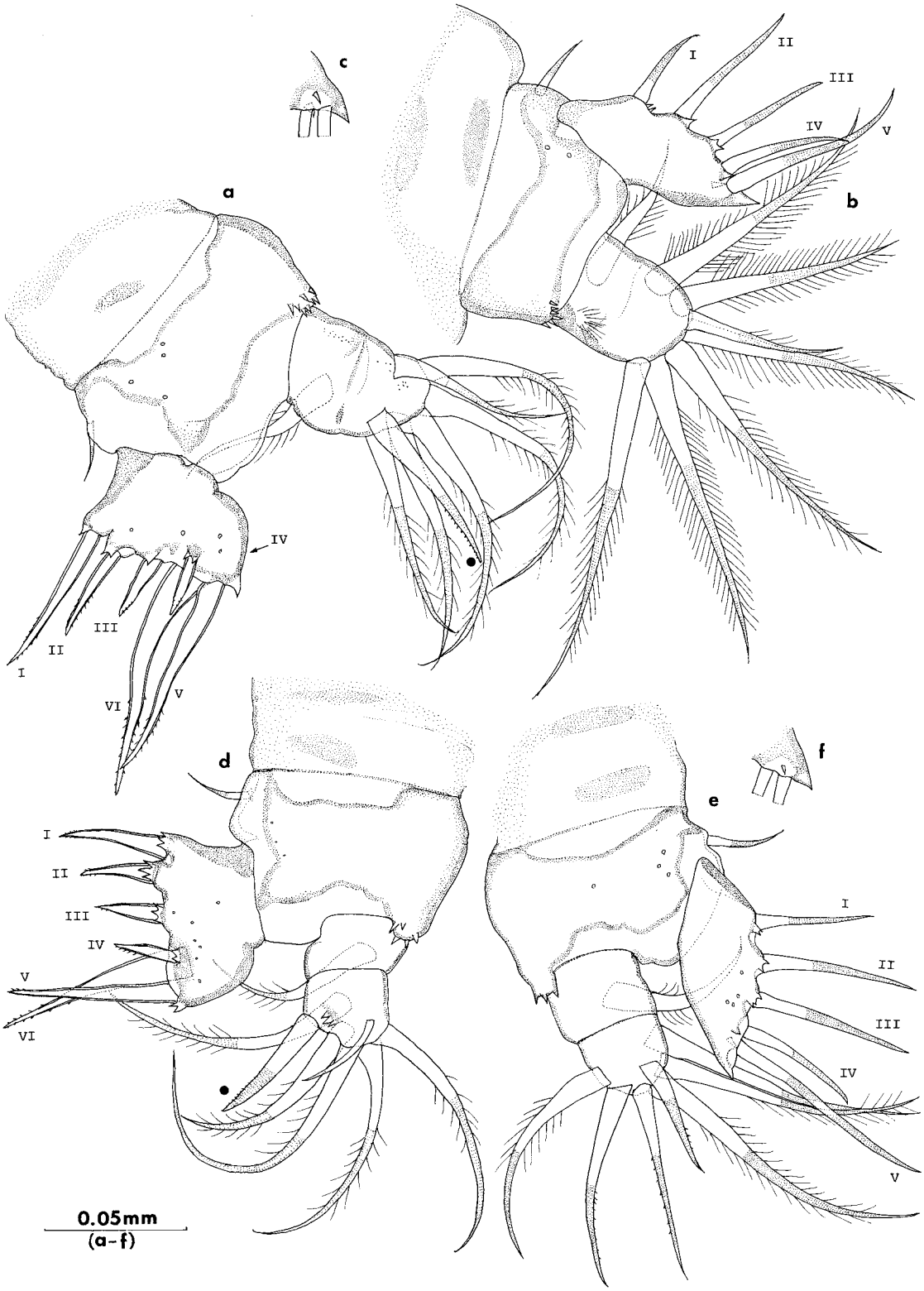

Fig. 4. *Botryllophilus banyulensis* Brément, female. a, right leg 1, anterior (dot indicates 1 spiniform element on endopod); b, left leg 1, anterior; c, distal portion of left leg 1 exopod, posterior, showing 1 vestigial element; d, right leg 2, anterior (dot indicates 1 spiniform element); e, left leg 2, anterior; f, distal portion of left leg 2 exopod, posterior, showing 1 vestigial element.

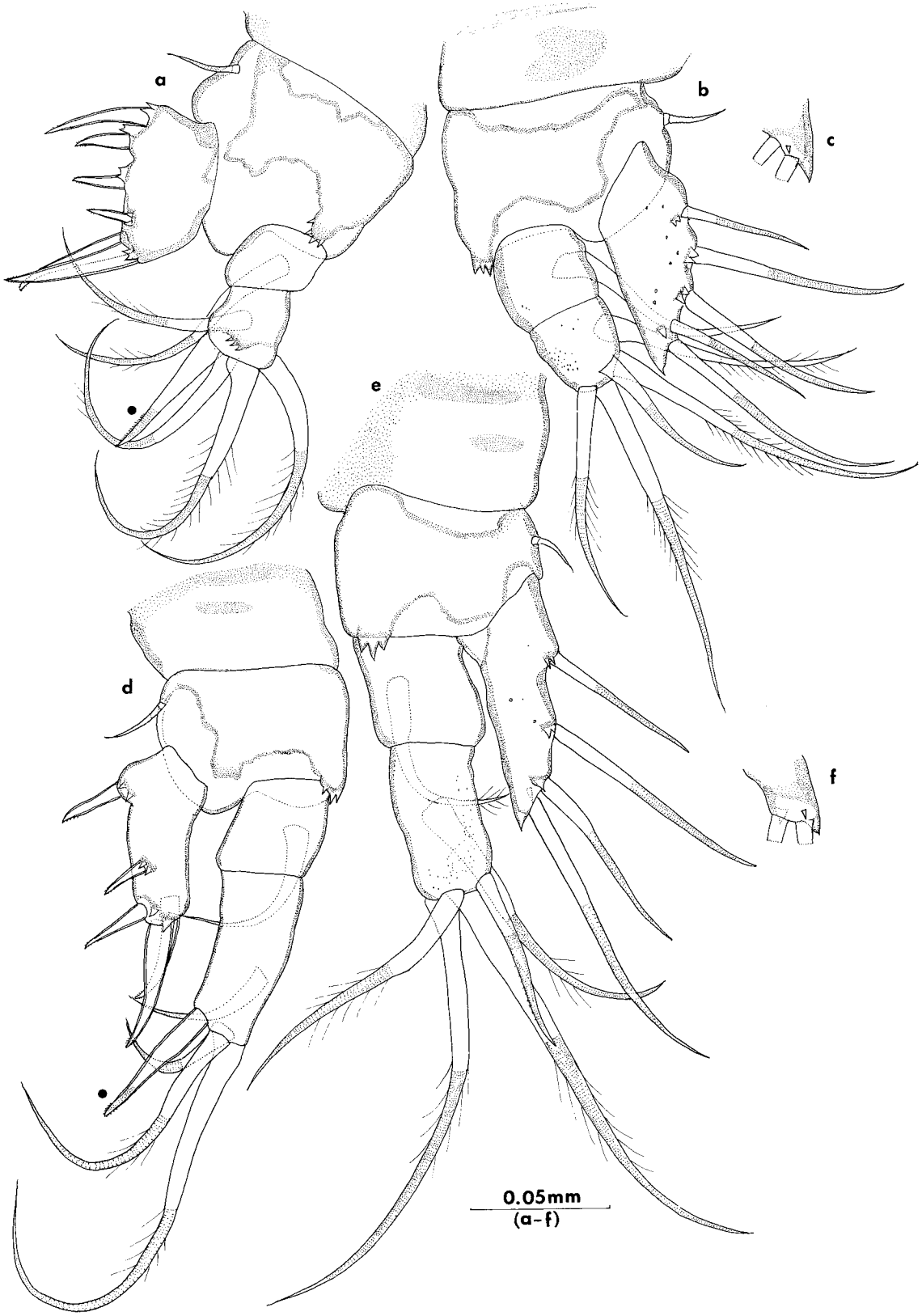

Fig. 5. *Botryllophilus banyulensis* Brément, female. a, right leg 3, anterior (dot indicates 1 spiniform element); b, left leg 3, anterior; c, distal portion of left leg 3 exopod, posterior, showing 1 vestigial element; d, right leg 4, anterior (dot indicates 1 spiniform element); e, left leg 4, anterior; f, distal portion of left leg 4 exopod, posterior, showing 1 vestigial element.

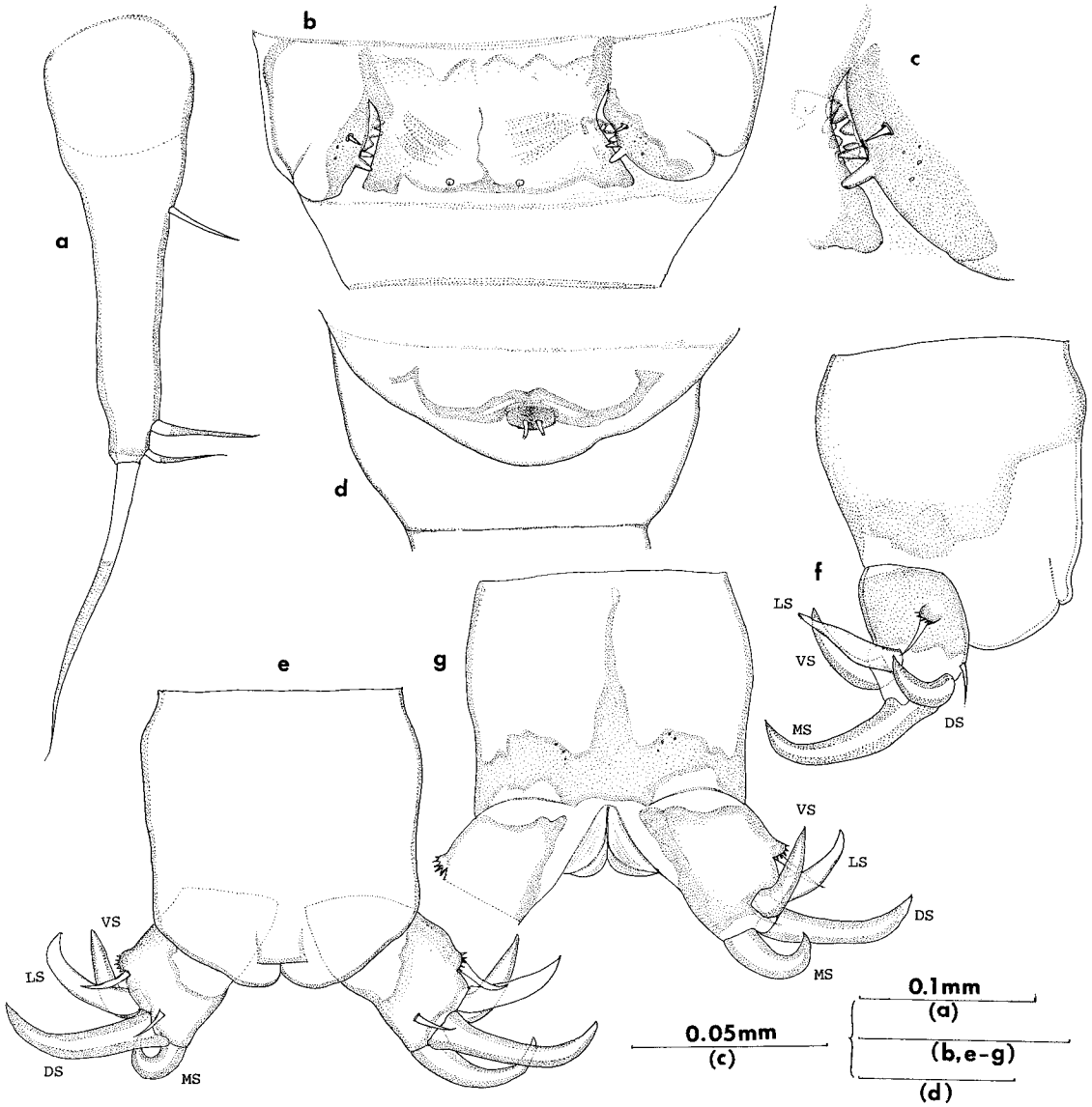

Fig. 6. *Botryllophilus banyulensis* Brément, female. a, left leg 5, lateral; b, genital segment with 2 gonopores, dorsal; c, right gonoporal apparatus, dorsal, showing 3 external spines (pair of unequal blunt long conical, 1 sharp conical) and 7 internal conical spines; d, subcuticular copulatory organ complex (2 tubular copulatory pores, seminal receptacles, receptacle ducts), viewed through prolonged fifth metasomal segment, ventral; e, anal segment and caudal rami with armature, dorsal; f, same specimen, with left caudal ramus, lateral; g, same specimen, ventral.

rostrum, with many minute pentagonal or hexagonal sections on surface; each section with probable minute sensillum.

Metasome (Fig. 8a, b) 4-segmented. Surface of each tergum with similarly minute pentagonal or hexagonal sections. First segment widest (0.21 mm), fourth segment narrowest (0.13 mm). Legs 1–4 of biramous swimming type.

Urosome (Fig. 8a–c) 6-segmented, with proportional lengths 1:2.5:1:1:1:1. First segment bearing setiferous fifth thoracic legs, enlarged second (genital) segment enclosing pair of ovoid spermatophores and bearing setiferous sixth thoracic legs, 3 abdominal segments, and anal segment bearing narrow caudal rami terminally. Anal segment shorter than caudal rami; anus opening posterodorsally.

Antennule (Fig. 9b, c) 4-segmented; first segment enlarged ventrally, second to fourth segments narrower and shorter than first. Proportional lengths 1:0.37:0.37:0.47 for 4 segments. First segment with 9 se (8 long, 1 short), 160 ae (at least); second segment with 4 se (3 long, 1 short), 2 ae; third segment with 2 se (long, short), 1 ae; and fourth segment with 10 se (7 long, 3 short), 2 ae (long, short). Total setal number 25.

Antenna (Figs. 9d, 12c) 4-segmented; second segment markedly elongated. Fourth segment with 6 elements (I–VI); 2 relatively long spines (I, II, with minute serrations distally) on medial margin and 4 relataively short simple setae (III–VI, from medial to lateral), on terminal margin. Proportional lengths 1:1:1.2:1.4:1.5:1.6 for 6 elements; longest seta (VI) almost as long as fourth segment.

Mandible (Fig. 9e) reduced. Small coxa setalike, directed medially. Palp (basis, exopod, and endopod fused) 5.3 times as long as wide, slightly narrowed distally. Armature comprising 6 setae: exopodal region with 2 unequal setae (small

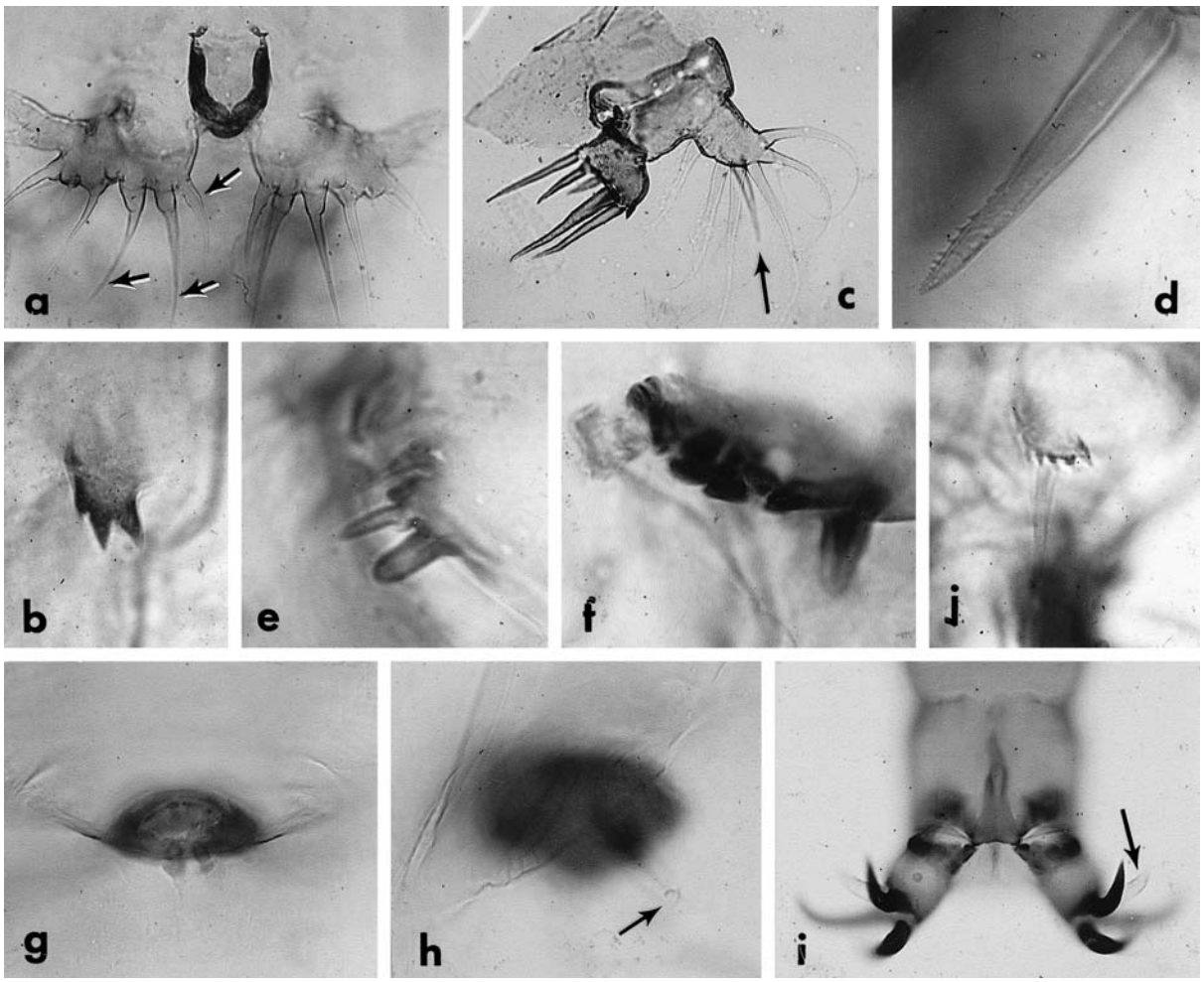

Fig. 7. *Botryllophilus banyulensis* Brément, female, photomicrographs. a, rostrum and antennules, anteroventral (arrows indicate 3 major setae on first segment of right antennule); b, 3 enlarged spinules fused at base on basis of left leg 4 endopod, anterior; c, right leg 1, anterior (arrow indicates 1 spiniform element on endopod); d, spiniform element on right leg endopod; e, right gonoporal apparatus, dorsal, showing 3 external spines (pair of unequal, 1 lateroproximal); f, same specimen, dorsal, showing 7 internal conical spines; g, subcuticular copulatory organ complex, viewed through midventral metasomal segment (2 tubular copulatory pores protruded), ventral; h, left tubular copulatory pore (arrow indicates its opening), viewed after midventral portion of metasomal segment partly removed, ventral; i, anal segment and caudal rami with armature, ventral (arrow indicates less-sclerotized, pointed lateral spine); j, 5 spinules close to base of lateral seta on caudal ramus, lateral.

simple proximal, markedly long plumose distal); endopodal region (Fig. 9f) with 4 setae (1 short simple mediodistal, 2 long terminal, 1 small terminal on posterior side).

Maxillule (Figs. 9g, 12d) reduced, bilobed distally (longer inner, shorter outer). Inner lobe with 5 setae (numbers 1–5); 1 large plumose seta (number 1) and 4 subequal small simple setae (numbers 2–5) on terminal margin. Outer lobe with integumental wrinkles, without armature.

Maxilla (Figs. 9h, 12e) saclike, medially protruded, with 4 short simple setae (numbers 1–4) on protruded apex: 2 setae (numbers 1 and 2) on common prominence from apex; 2 setae (numbers 3 and 4) inserted directly and anteriorly.

Maxilliped (Fig. 10a, b) consisting of 2-segmented large protopod and 3-segmented elongate endopod. Coxa (Fig. 12f) with 2 vestigial elements proximally on medial margin. Basis with 2 long simple setae (anterior, posterior) on medial margin. Coxa and basis each with 1 long hairlike sensillum laterally. Proportional lengths 1:3.3:2.2 for 3 segments of endopod; elongate second segment with 2 small simple setae (proximal, distal) on posterior side, and terminal segment claw-shaped, with notch medioproximally and tridentate apex.

Legs 1–4 (Figs. 10c, f, 11a, b) consisting of coxa, basis, and rami; intercoxal sclerite present. Coxa with 1 plumose seta on mediodistal margin in legs 3 and 4. Basis with 1 short simple seta on lateral margin in legs 1–4 and also with setules on mediodistal margin in legs 2–4. Endopod 2-segmented in legs 1 and 4, and 3-segmented in all others. Leg 1 endopod characteristically modified. Exopod of leg 1 and rami of legs 2–4 with long plumose setae and spines with serrated hyaline flanges.

Leg 1 endopod (Figs. 10c–e, 12g) protruded from posterior side of basis, longer than wide, and half as long as exopod. First segment longer and wider than second segment, with 1 short plumose seta on medial margin. Second segment with 4 similar medial setae (distalmost longest) and 4 laterally curved modified spines (numbers 1–4) along rounded apical margin. Two slender short spines (numbers 1 and 2) lateral,

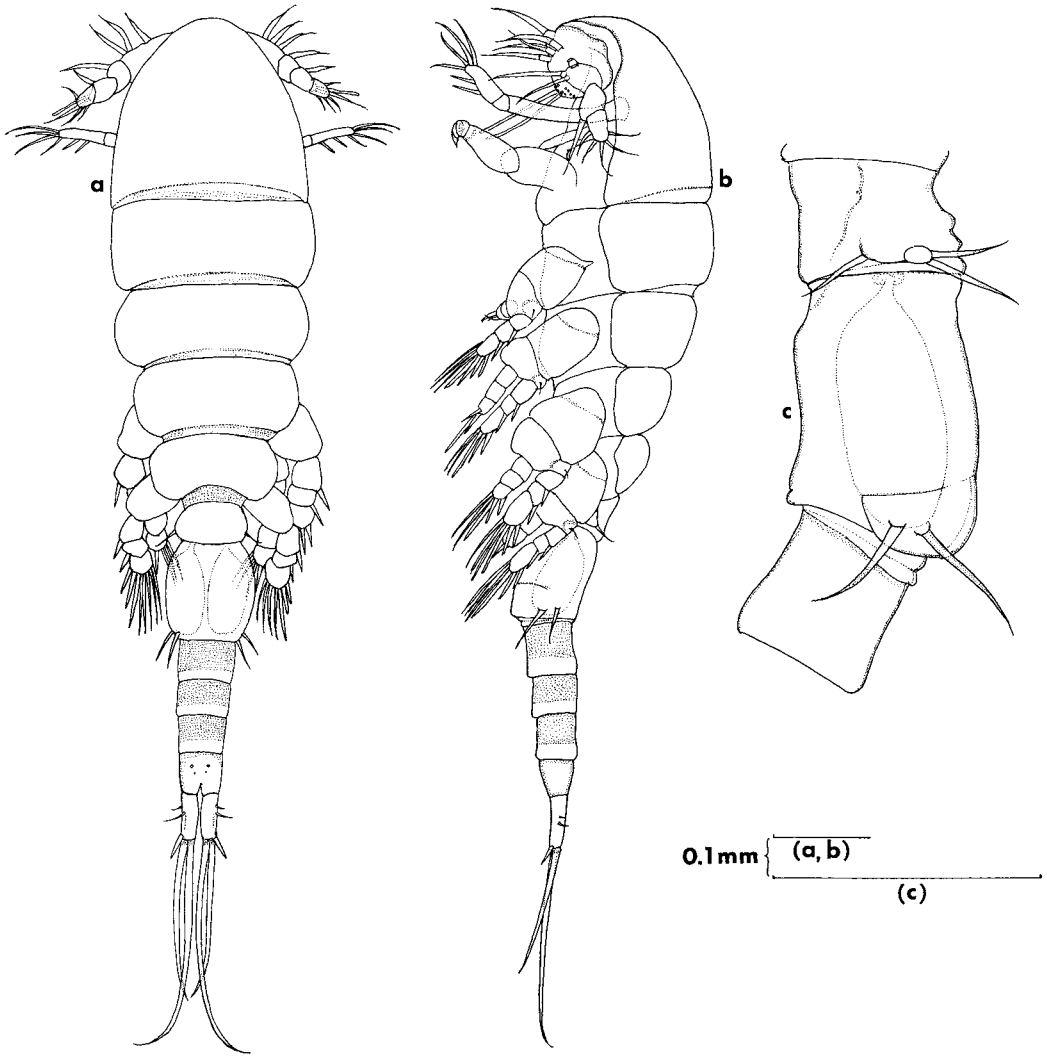

Fig. 8. *Botryllophilus banyulensis* Brément, male. a, body form, dorsal; b, body form, lateral; c, first (with leg 5), second (with leg 6), and third urosomal segments, right side.

1 short spine (number 3, from sclerotized anterior surface of segment) subterminal, and 1 large spine (number 4) terminal. Armature formula for legs 1–4 as follows:

	Coxa; Basis (T)	Endopod (T)	Exopod (T)
P_1	0–0; 0–1. . .(1)	0–1; IV–4. . . . . .(9)	I–0; I–1; IV–4. . .(11)
P_2	0–0; 0–1. . .(1)	0–1; 0–2; III–3. . .(9)	I–0; I–1; III–5. . .(11)
P_3	0–1; 0–1. . .(2)	0–1; 0–2; II–2. . . .(7)	I–0; I–1; III–5. . .(11)
P_4	0–1; 0–1. . .(2)	0–1; II–3. . . . . .(6)	I–0; I–1; III–5. . .(11)

Leg 5 (Fig. 11c, d) consisting of 2 portions. Proximal portion, unarticulated on first urosomal segment, with 1 simple lateral seta. Small distal portion articulated, with 2 similar setae (shorter inner, longer outer) on distal margin.

Leg 6 (Fig. 11c, e) represented by 2 similar setae near distolateral margin of genital operculum.

Anal segment (Fig. 11f, g) longer than wide. Dorsal surface with 2 pairs of sensilla (larger anterior, smaller posterior) at base of proximal one-third, and ventral surface with 2 semicircular depressions near distal margin.

Caudal ramus (Figs. 8a, 11f) 4 times as long as wide, 1.3 times as long as anal segment. Two unequal simple setae (shorter lateral, longer dorsolateral) midway on dorsal surface, 1 spine with serrated hyaline flanges (Fig. 11h) at distolateral corner, and 2 unequal long setae (inner, outer) terminally; inner seta 1.5 times as long as outer seta (Fig. 8a, b).

Remarks.—The female of *B. banyulensis* from Port-Vendres, as described by Brément (1909), shares many common characteristics with the female from Naples, as redescribed in this paper. The fact demonstrates that these females are conspecific. The common or unique characters are given below.

(1) The body color (reddish) and morphology (1.5 mm long, unsegmented metasome, 5-segmented urosome, proportional length 2:1 for prosome and urosome) of specimens from Port-Vendres (Brément 1909: 72, 73) are comparable to those of specimens from Naples (similar body color and length; same proportion for body regions).

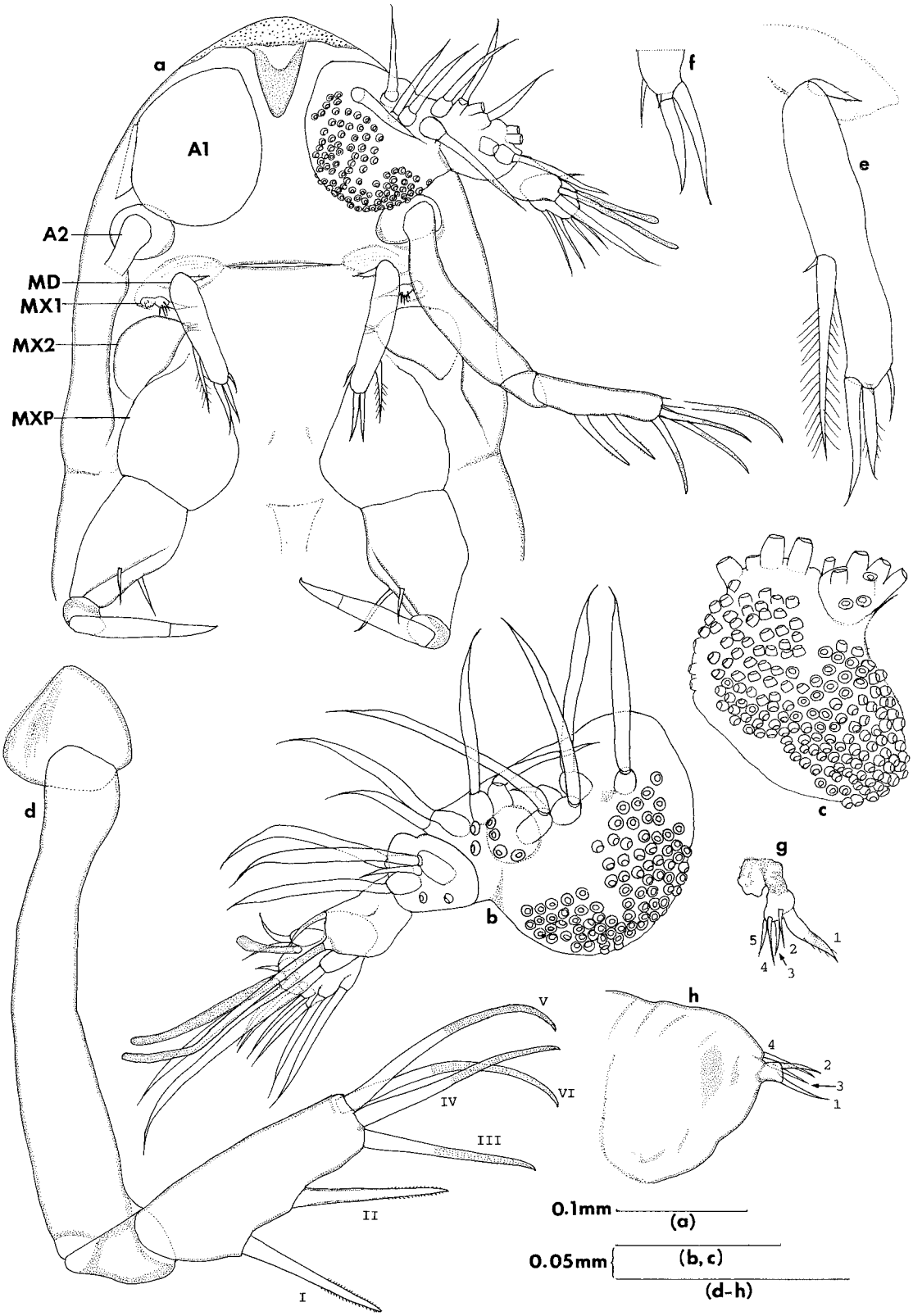

Fig. 9. *Botryllophilus banyulensis* Brément, male. a, cephalosome, ventral; b, right antennule (only bases of aesthetes on first and second segments shown), anteroventral; c, first segment of left antennule (only bases of setae and aesthetes shown), ventral; d, left antenna, anterior; e, right mandible, anterior; f, distal portion of right mandible, posterior, showing 1 small seta on posterior side; g, right maxillule, anterior, showing 5 setae (numbers 1–5) on inner lobe; h, right maxilla, anterior, showing 4 setae (numbers 1–4) on apical margin.

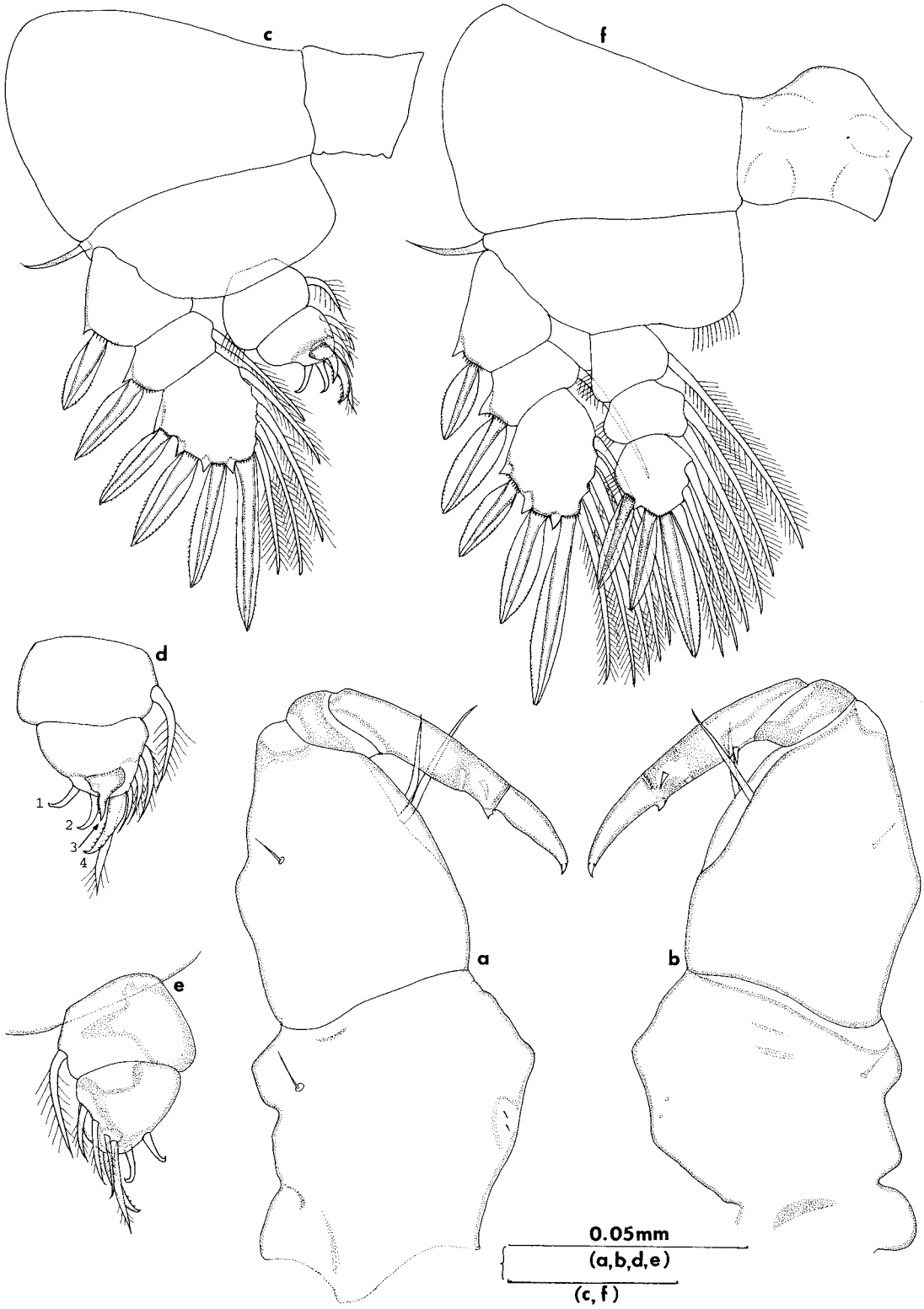

Fig. 10. *Botryllophilus banyulensis* Brément, male. a, left maxilliped, anterior; b, left maxilliped, posterior; c, right leg 1, anterior; d, endopod of right leg 1, with 5 plumose setae and 4 modified spines (numbers 1–4), anterior; e, endopod of right leg 1, posterior; f, right leg 2, anterior.

(2) Armature formulas (8 and 6) for endopods of right and left legs 1 and 4, as shown by Brément (figs. IX, XI), are symmetrical. The similarly symmetrical formula (8,8,6,6) for endopods of legs 1–4 has been confirmed in specimens from Napoli and all other species examined of subgroup 2. Thus, endopods of legs 2 (right, left) and 3 (left), which were not illustrated by Brément, should have eight and six, respectively. Three

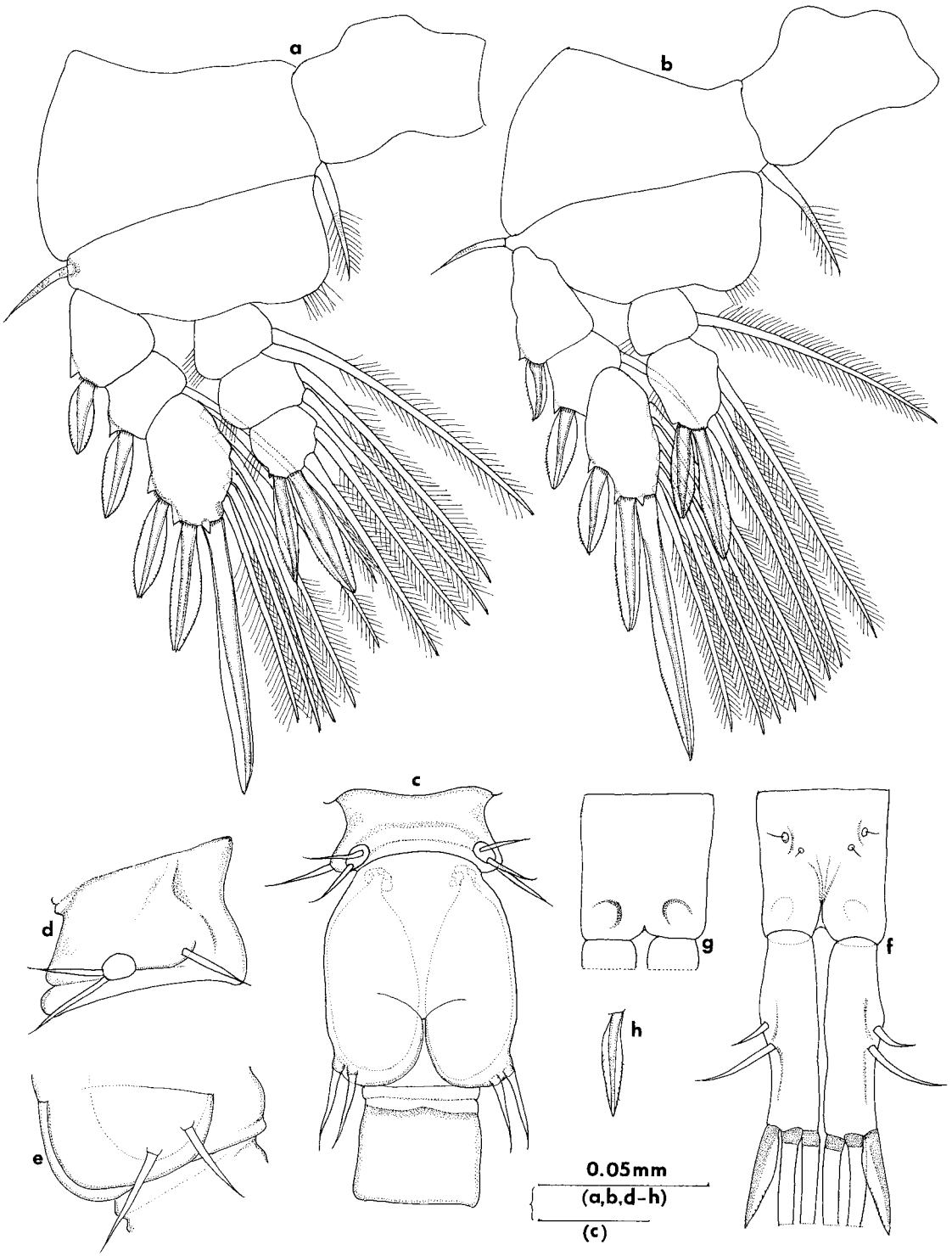

Fig. 11. *Botryllophilus banyulensis* Brément, male. a, right leg 3, anterior; b, right leg 4, anterior; c, first (with leg 5), second (with leg 6), and third urosomal segments, ventral; d, left leg 5 with 3 setae, anterior (for leg); e, left leg 6 with 2 setae, anterior (for leg); f, anal segment and caudal rami with armature (only proximal portions of 4 terminal setae shown), dorsal; g, anal segment with 2 depressions near distal margin, ventral; h, caudal spine with serrated hyaline flanges, viewed from lateral side.

spinules (fused at base) on the basis (mediodistal) of leg 4 pair (Brément, fig. XI) are comparable in number and morphology to those in specimens from Napoli (Fig. 5d, e).

(3) Brément's illustrations (figs. IX–XI) indicate that armature elements on right endopods (legs 1, 3, 4) consist exclusively of plumose setae, except for one slender seta on the second segment of leg 1 endopod. In specimens

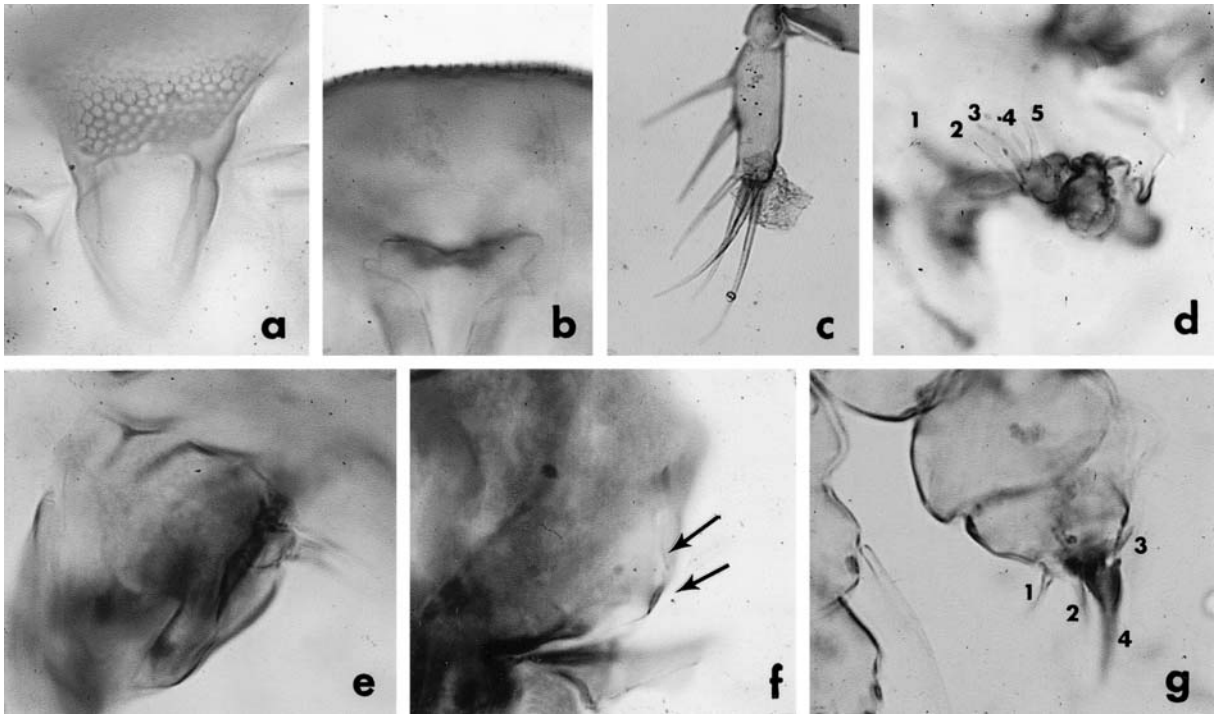

Fig. 12. *Botryllophilus banyulensis* Brément, male, photomicrographs. a, rostrum and anterior cephalosome, anteroventral, showing cephalosome with pentagonal or hexagonal sections on surface; b, same specimen, anterior, showing minute sensilla(?) from surface of cephalosome; c, left antenna (mainly fourth segment), anterior; d, left maxillule with 5 setae (numbers 1–5), viewed from posterior side; e, right maxilla, anterior; f, left maxillipedal coxa, anterior (arrows indicate 2 vestigial elements on medioproximal margin); g, endopod of right leg 1, anterior, showing 4 modified spines (numbers 1–4; number 3 spine turned to lateral in this figure).

from Naples, however, all right endopods (legs 1–4) have one spiniform element in addition to mostly plumose setae (Figs. 4a, d, 5a, d). Three congeners of subgroup 2 also have similar modified elements on most or all right leg endopods: rigid setae in *B. brevipes* (Brément, 1909: 72); stout setae in *B. norvegicus* (Ooishi, 1996: 185, figs. 12a, c, 13a, c); and spiniform elements in *B. neapolitanus* n. sp. (as described later). All examined named and unnamed species of subgroup 1 also have similar modified elements. Right and left endopods armed with setae only can be seen in all named and unnamed species examined of type B. These facts have already been used as diagnostic characters for morphotypes A and B (see Ooishi and Illg, 1988: 562, 565). It is believed that the modified element was mistakenly illustrated as a seta by Brément; the composition of the armature elements has been emended here.

(4) The exopods of right legs 1, 3, and 4 and left legs 1 and 4, as given by Brément (1909: figs. IX–XI), are comparable in morphology (spines, right; setae, left) and armature formulas (6,6,5, right; 5,4, left) to those for corresponding legs in specimens from Naples. The formulas for these selected legs given by Brément have already been pointed out by Ooishi (2000: 587). The formulas for the remaining leg exopods (6, right leg 2; 5 and 5, left legs 2 and 3), which were described but not illustrated by Brément (p. 73), have been confirmed based on the formulas for all legs (6,6,6,5, right legs 1–4; 5,5,5,4, left legs 1–4), as shown in this paper. Proportional lengths for six spines on the right leg 1 exopod given by Brément (fig. IX) closely resemble those described in this paper (Fig. 4a); three spines (first, fifth, sixth) are remarkably elongate. The elongate right leg 4 exopod (Brément, fig. XI) also agrees in morphology and armature formula to that reported in this paper (Fig. 5d).

(5) The armature formula for legs 1–4, as emended in this paper, represents pattern II–1, differing from the formulas in three congeners, as explained later. The V-shaped rostrum (Fig. 2d) and small copulatory organ complex (Fig. 6d) are thought to be unique.

The female specimen of *Botryllophilus* cf. *banyulensis* (living in *Aplidium benhami*) reported by Ooishi (2001: 425) from New Zealand should be assigned to *B. banyulensis*. The identification of the specimen at that time was uncertain because the rigth leg endopods of the specimen had a spiniform element in addition to setae. The problem has been resolved for the reason just mentioned above. The fact that the specimen from New Zealand is reddish and lacking an eye strongly supports this assignment. Differences in the specimen from New Zealand are as follows: leg 5 has the longer terminal seta, and the lateral margin of the caudal ramus, close to the lateral seta, bears fewer (2) spinules. It is remarkable that the Mediterranean species lives in the southern portion of the Pacific Ocean.

The male of *B. banyulensis* shares common features with the female by possessing the reddish body and lacking an eye. However, there is a question in regard to the

maxilliped, because the female specimens have two setae on the coxa whereas these are visible as vestigial elements in the male specimens.

This male shows a characteristic feature of the males of *Botryllophilus* (leg 2 endopod with 3 spines in addition to setae on third segment) and a specific feature for the endopod of leg 1. It resembles the males of *B. abbotti* and *B. bamfieldensis*, whose females represent morphotype A (subgroup 1), but differs from them with respect to leg 1 endopod: (1) *B. banyulensis* (Fig. 10d) with 5 setae and 4 spines (2 slender, 1 short, 1 large); (2) *B. abbotti* (Ooishi, 1989: 461) with 4 setae and 4 spines (2 forked, 2 simple); and (3) *B. bamfieldensis* (Ooishi, 2000: 583) with 5 setae and 5 spines (2 bifurcate, 3 rodlike). In *B. ruber* which has the female of morphotype B, the armature consists of only four curved spines; there are no setae (Ooishi, 1999: 571). A similar comparison had been done for the latter three males (see Ooishi, 2000: 588).

Botryllophilus neapolitanus n. sp.
Figs. 13–18

Material Examined.—Holotype ♀ (BMNH2005.196), paratype ♀ (BMNH2005.197), living in *Aplidium* sp., collected on 25 October 1989, from The Gulf of Naples, deposited in the Natural History Museum, London, March 2005.

Description of Female.—In living specimen (Fig. 1c), dorsal cuticle of metasome light brownish; gut in metasome and urosome distinctly brownish, and eggs on both sides of gut light brownish. Small red eye internally near anterior margin of cephalosome. Egg sac not observed.

Body (Fig. 13a–c) hump-shaped, consisting of small cephalosome, dorsally expanded large metasome, and long cylindrical urosome directed posteroventrally. Proportional lengths 1:3.2:3.4 for 3 regions. Ratio of length of prosome to that of urosome 1.23:1. Body length, excluding caudal spines, 1.2 mm. Body surface with sparsely scattered hairlike sensilla.

Cephalosome (Fig. 13a–c) subtriangular, wider than long; anterior margin rounded. Appendages (Fig. 13d, e) consisting of 6 pairs including maxillipeds. Rostrum (Figs. 13f, 18a) small semicircular protrusion with 2 hairlike sensilla (right, left).

Metasome (Fig. 13a–c) unsegmented on dorsal side, 5-segmented on ventral side. Greatest width and thickness 0.38 mm in third pedigerous segment. Right and left legs 1–4 modified, asymmetrical, without intercoxal sclerite. Right and left legs of first pair widely spaced, but right legs coming gradually closer to left legs in second to fourth pairs; right and left legs of fourth pair with almost no space between them. Prosome showing distinct curvature from left to right. Fifth segment with uniramous short fifth legs anterolaterally and 2 large lobes (metasomal lobes) ventrally (Figs. 13c, 17c, 18e).

Urosome (Fig. 13a–c) 5-segmented; proportional lengths 1:0.7:0.8:0.7:1. Widest first (genital) segment with 2 gonopores dorsolaterally and copulatory organs midventrally; 3 abdominal segments each slightly wider than long; and anal segment with short caudal rami terminally. Anus opening posterodorsally.

Antennule (Fig. 14a) 4-segmented. First segment about as long as total length of second to fourth segments. Armature: first segment with 9 setae ($I_1 + 2$, $II_1 + 2$, $III_1 + 1$, 1); second segment with 4 setae (I_2, $II_2 + 2$); third segment with 3 setae ($I_3 + 2$); and fourth segment with 12 setae (I_4, 11). Total setal number 28. In first segment, each of 3 major setae inserted on rather short prominence; in third segment, 2 subordinate setae subequal in length.

Antenna 4-segmented. Right antenna (Fig. 14b) with proportional lengths, measured on anterior side, 1:3:0.6:2.3 for 4 segments. Fourth segment bearing 6 armature elements (I–VI); 2 blunt slender spines (I, II, each with minute serrations distally) on medial margin and 4 blunt setae (III–VI) on terminal margin. Proportional lengths 1:1:1:1:1.3:1.8 for 6 elements (I–VI); longest distolateral seta (VI) nearly as long as fourth segment. In left antenna (14c), these 6 elements replaced by blunt setae; distolateral seta longer than fourth segment, 1.4 times as long as corresponding seta in right antenna.

Labrum (Fig. 14d) sclerotized proximally; distal margin rounded.

Mandible (Fig. 14e) comparable to that of *B. banyulensis*, except for morphology of 2 conical spines (first, second) on coxa; first spine fused with 2 smaller spines anteriorly, and second spine without them.

Paragnath (Fig. 14d) bean-shaped; distal margin sclerotized.

Maxillule (Fig. 14f) comparable in morphology and setation (15 setae) to that for *B. banyulensis*.

Maxilla (Fig. 14g) weakly divided into 3 portions, bearing 9 setae (7 major, 2 subordinate on posterior side). Proximal portion (precoxa) with 3 setae (I, II+1), middle portion (coxa) with 3 setae (III+1, IV), and distal portion (basis and endopod fused) with 3 setae (V–VII). Two subordinate setae (slender, long) and sixth major seta (short) simple; all others plumose.

In maxilliped (Fig. 14h, i), coxa with 2 simple setae medioproximally, but without patch of spinules. Basis and 3-segmented endopod comparable in morphology and setation to those in *B. banyulensis*.

In right and left legs 1–4 (Figs. 15a–f, 16a–e), coxa unarticulated basally, without armature. Basis with 1 simple seta on lateral margin in all legs, and 5–7 small conical spinules (not fused at base) on mediodistal margin in most legs. Endopods 2-segmented: endopods of legs 1–3 as long as respective exopods; endopod of right leg 4 elongated, 1.5 times as long as its exopod. In leg 1 endopods (Fig. 15a, c), first segment with 2 lobes (with many long setules) protruded from anteromedial surface.

Endopods of right and left legs 1–4 with symmetrical armature formulas (8,8,6,6). Endopods of right legs 1–4 (Figs. 15a, e, 16a, c) with spiniform elements in addition to setae on second segment: 1 element (anterior surface) in leg 1; 3 elements (1, anterior surface; 2, distal margin) in leg 2; and 2 elements (distal margin) in legs 3 and 4. Second segment, close to bases of spiniform elements, with 1 (leg 3) or 2 (legs 2 and 4) rows of small conical spinules. Endopods of left legs 1–4 (Figs. 15c, f, 16b, e) exclusively with setae (mostly plumose); setae on second segment including 1 short seta (anterior surface), this homologous to single (in

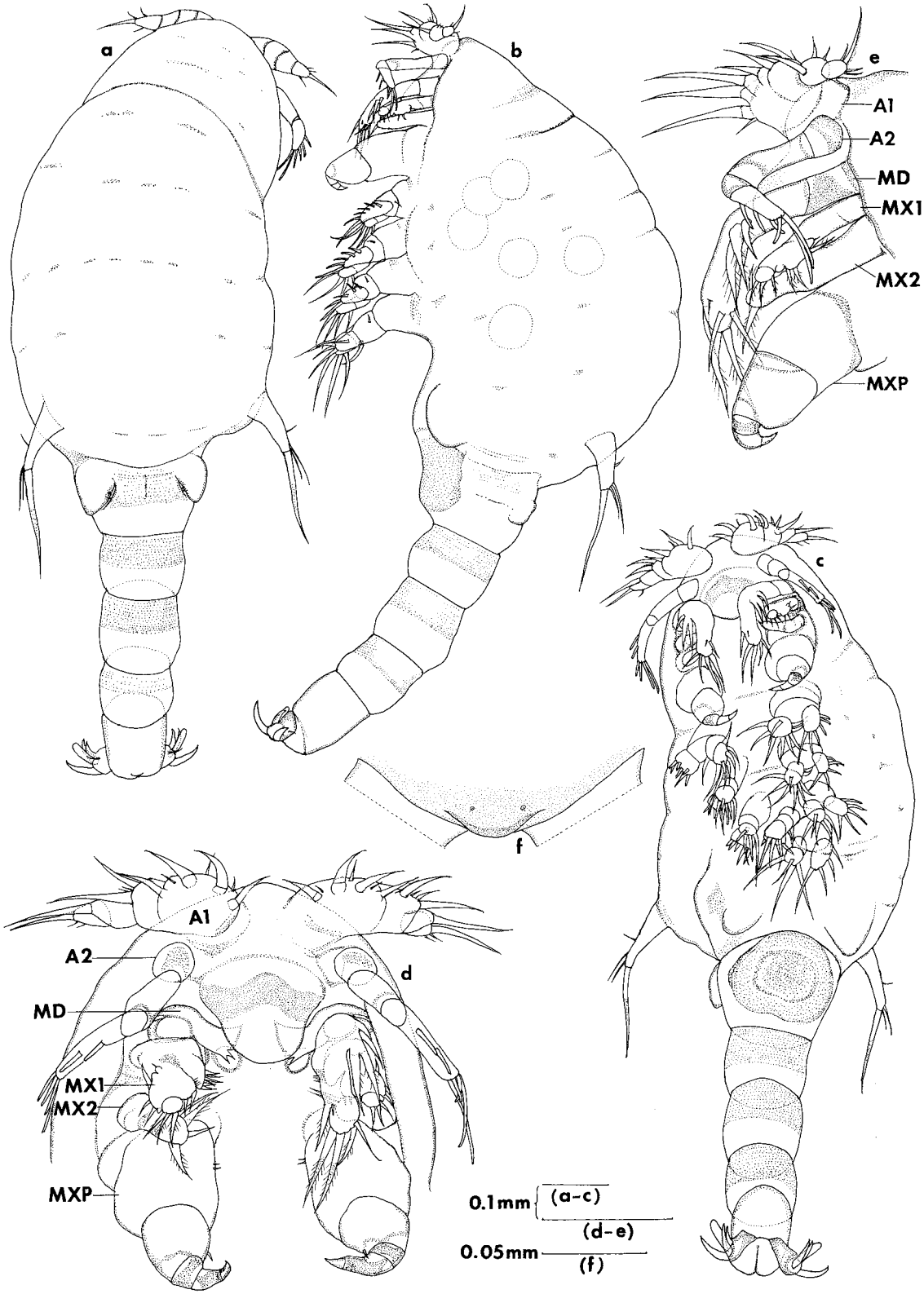

Fig. 13. *Botryllophilus neapolitanus* n. sp., female. a, body form, dorsal; b, body form, lateral; c, body form, ventral; d, cephalosome, ventral; e, cephalosome, lateral; f, distal portion of cephalosome, anterior, showing small semicircular rostrum.

Fig. 14. *Botryllophilus neapolitanus* n. sp., female. a, left antennule, anterior; b, right antenna, anterior; c, left antnna (mainly fourth segment), anterior; d, labrum and paragnaths, ventral; e, left mandible, anterior; f, left maxillule, posterior; g, left maxilla, posterior; h, right maxilliped, anterior; i, same specimen, posterior.

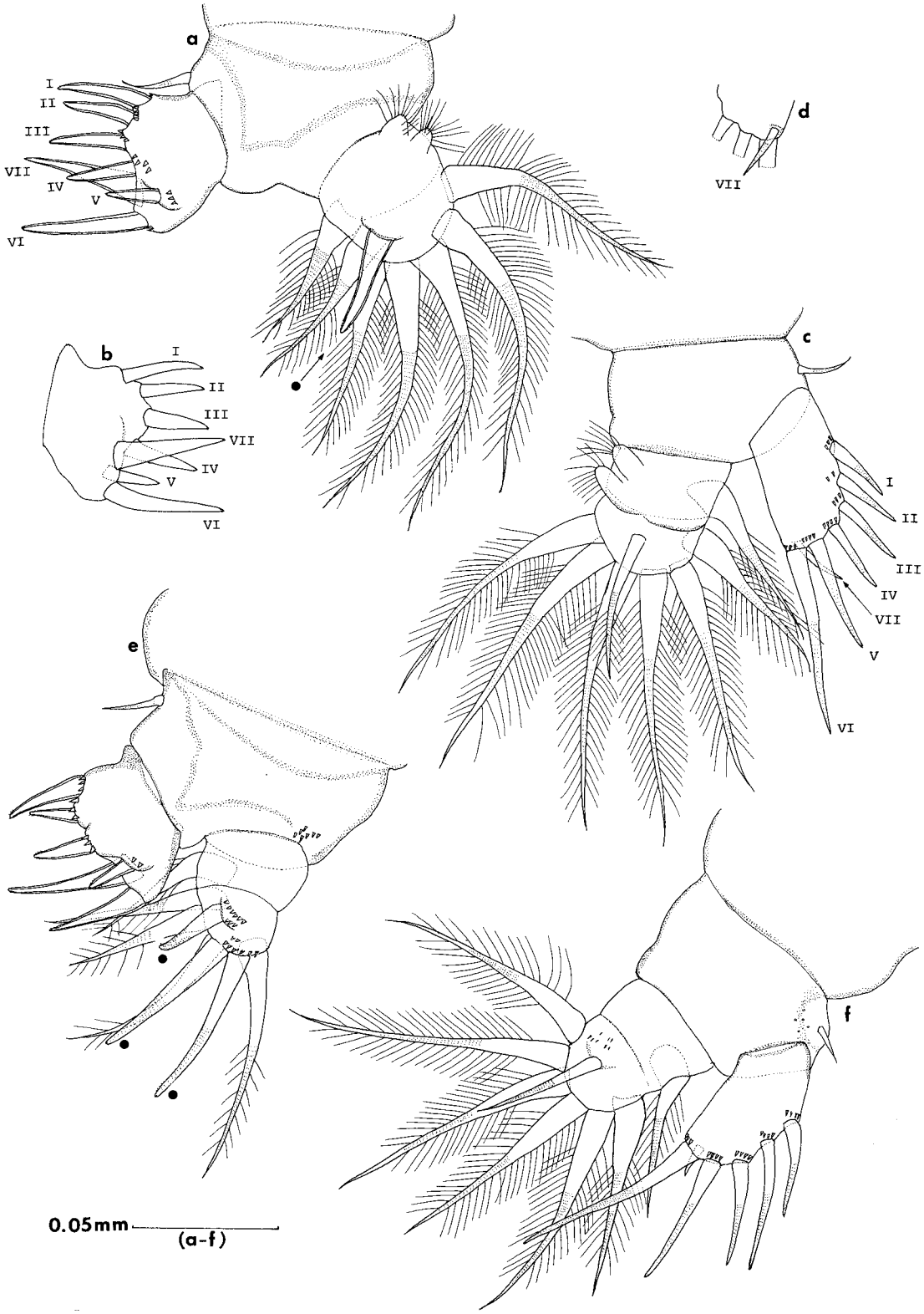

Fig. 15. *Botryllophilus neapolitanus* n. sp., female. a, right leg 1, anterior (dot indicates 1 spiniform element on endopod); b, exopod of right leg 1, posterior; c, left leg 1, anterior; d, distal portion of left leg 1 exopod, posterior, showing 1 reduced seta (VII); e, right leg 2, anterior (dots indicate 3 spiniform elements); f, left leg 2, anterior.

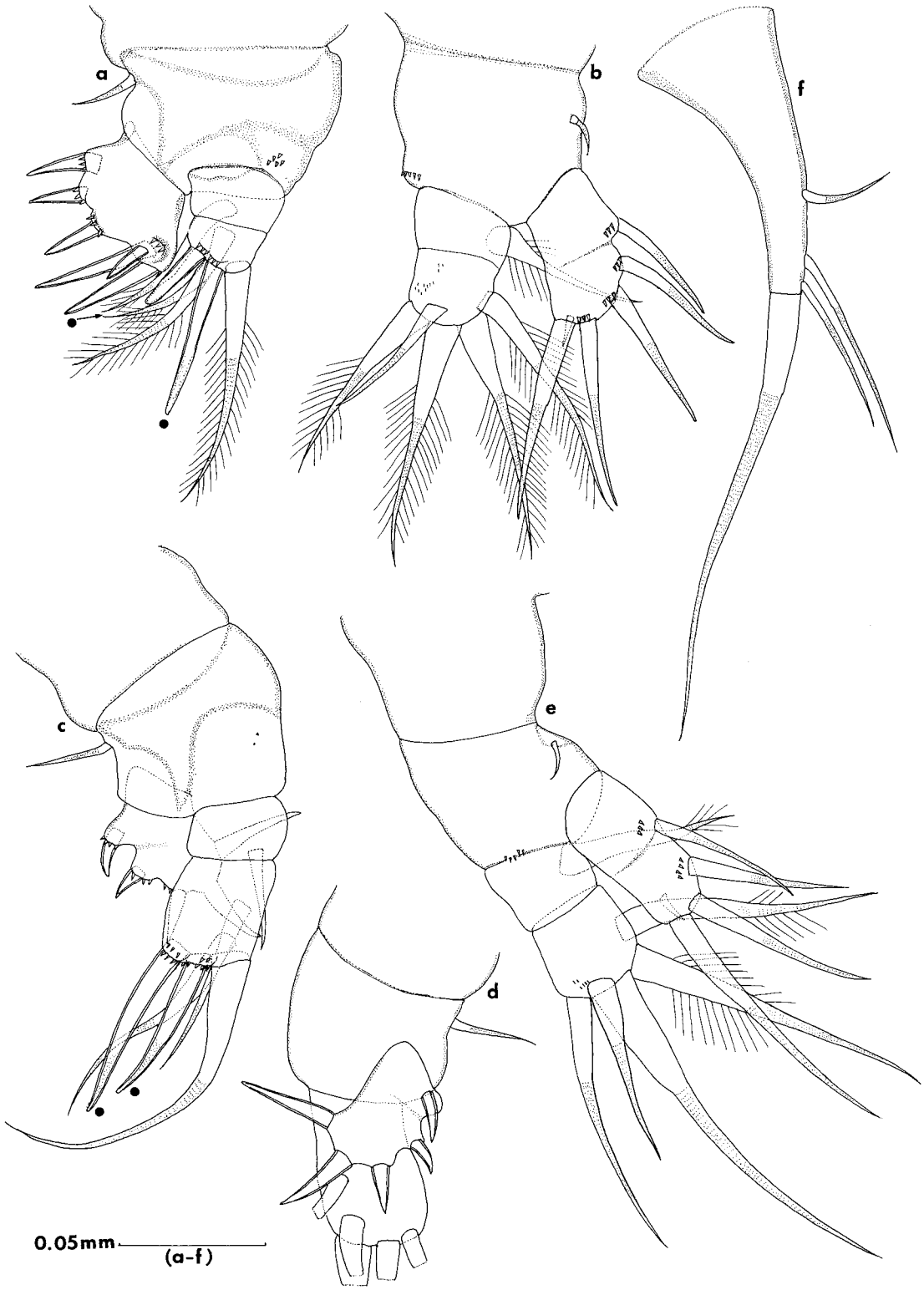

Fig. 16. *Botryllophilus neapolitanus* n. sp., female. a, right leg 3, anterior (dots indicate 2 spiniform elements); b, left leg 3, anterior; c, right leg 4, anterior (dots indicate 2 spiniform elements); d, right leg 4, posterior, showing exopod with 5 spines; e, left leg 4, anterior; f, left leg 5, lateral.

leg 1) or proximal first (in legs 2–4) spiniform element in right endopods.

Exopods of right legs 1–4 (Figs. 15a, e, 16a, c) 1-segmented, approximatly trapezoidal. Armature elements (formula 7,6,6,5) on legs 1–4 consisting of stout spines. In leg 1 exopod (Fig. 15a, b), 7 spines (I–VII) protruded from unevenly truncated distal margin and directed distally, but shortest fifth spine (V) on anterior side and seventh spine

(VII) on posterior side of margin. Proportional lengths 1:0.7:0.8:0.7:0.6:1.3:1.3 for 7 spines (I–VII). Proximalmost spine (I) slightly shorter than lateral margin of ramus; distalmost spine (VI) and spine from posterior side (VII) longer than first spine (I). Four short spines (II–V) between proximalmost and distalmost spines in leg 1 represented by 3 spines in legs 2 and 3, and by 2 spines in leg 4. In leg 4 (Fig. 16c, d), mediodistal spine (fifth) homologous to long spine from posterior side in legs 1–3. Distal margin of all right exopods, close to spines (except for spines from posterior side or mediodistal corner), with 3 or 4 small conical spinules (not fused at base).

Exopods of left legs 1–4 (Figs. 15c, f, 16b, e) rectangular, 1-segmented, but slight integumental flexure (indication of 2 segments) visible in legs 3 and 4. Ratio of length to width 1.8:1 in legs 1–3, and 2:1 in leg 4; leg 4 exopod longer than legs 1–3 exopods. All left exopods with relatively short simple setae on lateral and distal margins; these setae not sharply pointed in legs 1–3, but pointed in leg 4. Four setae between proximalmost and distalmost (or distolateral) setae in leg 1 represented by 3 setae in legs 2 and 3, and 2 setae in leg 4. In addition, 1 reduced or feeble seta (Fig. 15d) from posterior side present near distalmost seta, thus armature formula for exopods of left legs 1–4 indicated as 7*,6*,6*,5*. Proportional lengths 1:1:1:1:1.6:2.7:0.9 for 7 setae (I–VII, in case of leg 1); longest distalmost seta (VI) 1.4 times as long as ramus. Reduced seta in left legs 1–4 homologous to long spine from posterior side in right legs 1–3 or mediodistal spine in right leg 4. Spinules on distal margin of left exopods similar to those on right exopods. Armature formula for right and left legs 1–4 given below, this showing pattern II–3.

(Right)	Coxa; Basis (T)	Endopod (T)	Exopod (T)
P_1	0–0; 0–1…(1)	0–1; I–6…..(8)	VII–0…(7)
P_2	0–0; 0–1…(1)	0–1; III–4…(8)	VI–0….(6)
P_3	0–0; 0–1…(1)	0–1; II–3….(6)	VI–0….(6)
P_4	0–0; 0–1…(1)	0–1; II–3….(6)	V–0…..(5)
(Left)			
P_1	0–0; 0–1…(1)	0–1; 0–7…(8)	0–7…(7*)
P_2	0–0; 0–1…(1)	0–1; 0–7…(8)	0–6…(6*)
P_3	0–0; 0–1…(1)	0–1; 0–5…(6)	0–6…(6*)
P_4	0–0; 0–1…(1)	0–1; 0–5…(6)	0–5…(5*)

Leg 5 (Fig. 16f) short, approximately 2.2 times as long as proximal width, and one-sixth as long as urosome. Armature: 3 unequal simple setae on dorsal side (1 at base of distal two-thirds, 1 subterminal, 1 almost terminal), and 1 long simple seta terminally. Two distal setae on dorsal side not closely spaced, and terminal seta extremely long (1.5 times as long as appendage). Proportional lengths 1:2.3:1.7:5 for 4 setae.

Dorsal genital area (Fig. 17a) between gonopores with 2 minute hairlike sensilla posteriorly. Apparatus at gonopore (Figs. 17b, 18b, c): pair of unequal slender conical spines (shorter proximal, articulated; longer distal, unarticulated) externally; 10 small conical spines (most in 2 rows) internally. Largely and complexly sclerotized midventral genital area with subcuticular copulatory organ complex (Figs. 17c, d, 18d–f); genital atrium not present. Subcuticular copulatory organ complex involving 2 extremely large seminal receptacles, 2 tubular copulatory pores externally protruded from these receptacles, and receptacle ducts extending from seminal receptacles toward lateral antra.

Anal segment (Figs. 17e, f, 18g) distinctly longer than wide on dorsal side, and slightly longer than wide on ventral side; several hairlike sensilla on segment. Posterior half of centroventral surface longitudinally sclerotized.

Caudal ramus (Figs. 17e, f, 18g) sclerotized, with 2 simple setae (longer lateral, shorter dorsal) and 4 spines (without marginal serrations) terminally. Lateral spine (LS) less-sclerotized, blunt-tipped; medial (MS), dorsal (DS), and ventral (VS) spines sclerotized, claw-shaped, with pointed apex.

Male.—Unknown.

Etymology.—*Botryllophilus neapolitanus* is named for the type locality, The Gulf of Naples, Italy. It is the first species of the genus to be described from there.

Remarks.—The exopod (trapezoidal, 7 stout spines) and endopod (2-segmented, 7 long plumose setae, 1 modified element) of right leg 1 of *B. neapolitanus* n. sp. (Fig. 15a) seemingly resemble those of *B. brevipes* (Brément, 1909: 72, fig. VII, *Ex.d., En.d.*), but are, nevertheless, clearly distinguishable. In the new species, the exopod of right leg 4 (Fig. 16c) is 1-segmented (2-segmented, in *B. brevipes*, p. 72, fig. VIII, *Ex.d.*) and the exopods of left legs 1–4 (Figs. 15c, f, 16b, e) are 1-segmented (2-segmented, in *B. brevipes*, p. 72, figs. VII, *Ex.g.*, VIII, *Ex.g.*). On the other hand, the new species resembles, in part, *B. norvegicus* by having a hump-shaped body and an antenna with blunt armature elements, although the numbers of tne blunt elements differ (6 in *B. neapolitanus*; 5 in *B. norvegicus*, Ooishi, 1996, fig. 11b). The armature formula pattern II–3 for *B. neapolitanus* differs from the formulas of three congeners, as explained later. The semicircular small rostrum (Fig. 13f) and large copulatory organ complex (Fig. 17c) appear to be specific.

Revision of Female Morphotype A

A revised diagnosis for morphotype A is given for all examined species of subgroups 1 and 2. This diagnosis emphasizes characters that are common to both subgroups and characters that are different. Leg armature formula patterns (I, II) are treated as main characters.

Characteristics Common to Subgroups 1 and 2.—Major common characteristics are summarized based on the original diagnostic characters for type A given by Ooishi and Illg (1988: 562, fig. 1): (1) urosome 5-segmented (fig. 1a); (2) antennule 4-segmented (fig. 1d); (3) mandibular coxa with 2 sharp conical spines on common base, posteriorly (fig. 1f); (4) maxillular precoxa with 6 setae (fig. 1g); (5) endopods of right legs (all or legs 2–4) with modified elements (spiniform, etc.) in addtion to setae on second segment (fig. 1j, l); and (6) anal segment and caudal rami usually without ornamental elements except for hairlike sensilla (fig. 1b).

Leg Armature Formula Pattern I.—Except for *B. bergensis* Schellenberg, 1921, all five species of subgroup 1 have

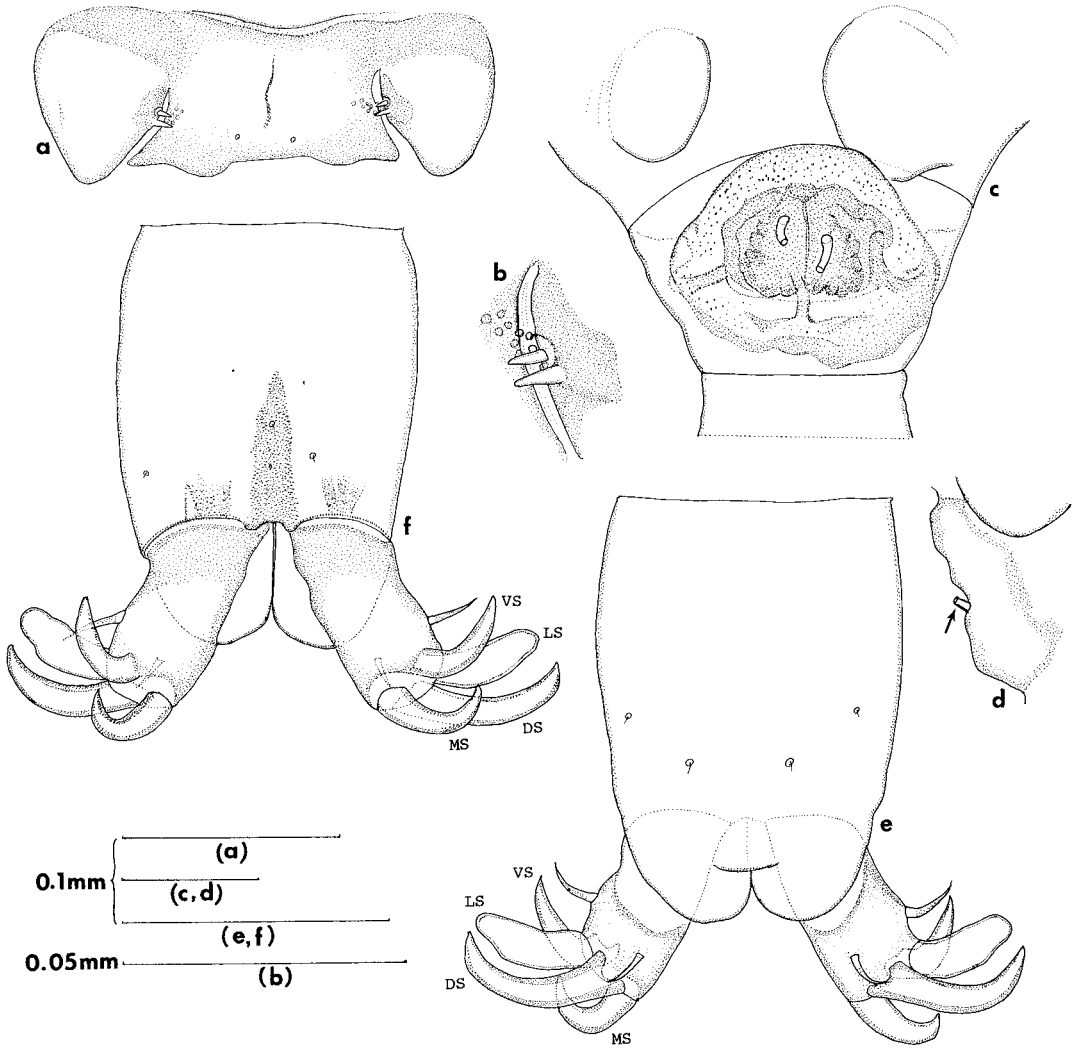

Fig. 17. *Botryllophilus neapolitanus* n. sp., female. a, genital area with 2 gonopores, dorsal; b, right gonoporal apparatus, dorsal, showing pair of unequal slender conical spines externally and 10 small conical spines internally; c, 2 metasomal lobes and subcuticular large copulatory organ complex (2 tubular copulatory pores, seminal receptacles, receptacle ducts), ventral; d, left tubular copulatory pore (arrow) protruded from seminal receptacle, lateral; e, anal segment and caudal rami with armature, dorsal; f, same specimen, ventral.

a uniform leg armature formula of pattern I for right and left legs 1–4, as seen in *B. inaequipes*, *B. abbotti*, *B. koreensis*, *B. bamfieldensis*, and *B. sarsi*. In the following comparative study, the representative formula for pattern I is based on *B. sarsi* (Ooishi, 2002b: 827). In pattern I, the formulas (based on total numbers of setae, setiform elements, spines, spiniform elements) for right endopods (Ren) and exopods (Rex), and left endopods (Len) and exopods (Lex), are indicated as follows:

Pattern I	Ren = 8,7,5,5; Rex = 6,5,5,4 Len = 8,7,5,5; Lex = 5,4,4,3

Leg Armature Formula Pattern II.—Leg armature formulas for four species of subgruop 2 show four different formulas in pattern II. Each formula includes additional armature elements on most legs in comparison with that in pattern I. The four formulas of pattern II are expressed by adding Arabic numerals (1–4) after the term pattern II; in each formula, two numerals (Roman, Arabic) are connected by a dash, e.g. pattern II–1. Each formula is followed by another formula (given in parentheses) to show the composition of additional elements; one regular additional element is indicated by +1. When one reduced additional element (feeble) is included in the composition, it is denoted by an asterisk; the numeral 0 means that the ramus has no additional elements.

In *B. brevipes*, armature formulas for right and left legs 2 and 3 were not given and were not illustrated by Brément (1909). However, it is possible to predict them based on the formula for legs 1–4 (Ren = 8,8,6.6; Rex = 7,6,6,5; Len = 8,8,6,6; Lex = 6,5,5,4), as observed in one of the two unnamed species (manuscript in preparation). The fact is that the formulas for endopods (8,6, both sides) and exopods (7,5, right; 6,4, left) of legs 1 and 4, as given by Brément (figs. VII, VIII), are the same as those of corresponding legs of the unnamed species. (It has been

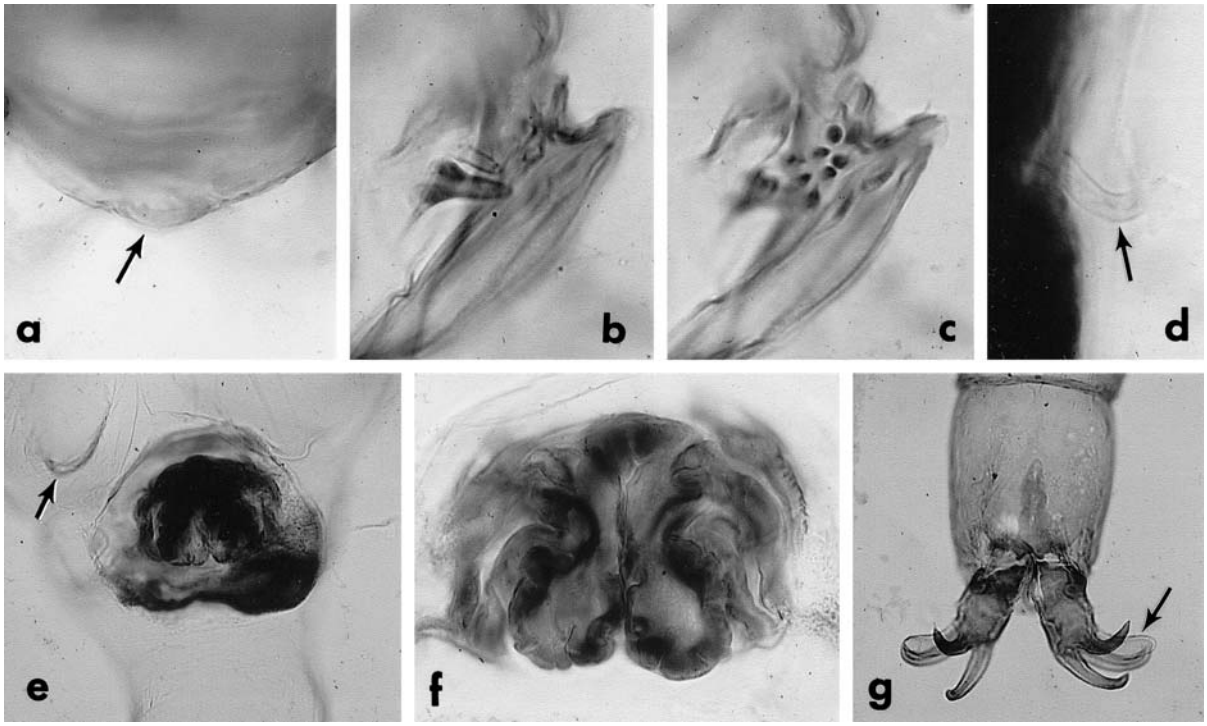

Fig. 18. *Botryllophilus neapolitanus* n. sp., female, photomicrographs. a, distal portion of cephalosome, anterior (arrow indicates small semicircular rostrum); b, left gonoporal apparatus, dorsal, showing pair of unequal external spines; c, same specimen, dorsal, showing small conical internal spines; d, tubular copulatory pore (arrow) protruded from seminal receptacle, lateral; e, right metasomal lobe (arrow) and subcuticular copulatory organ complex, ventral; f, same specimen (enlarged), ventral, showing internal structure of 2 large seminal receptacles; g, anal segment and caudal rami with armature, ventral (arrow indicates less-sclerotized, blunt-tipped lateral caudal spine).

confirmed that the unnamed species is distinguishable in morphology from *B. brevipes*.) The predicted formulas are shown in italics. Four different formulas in pattern II are given below.

Pattern II–1 (*B. banyulensis*):	
Ren = 8,8,6,6 (0,+1,+1,+1)	Rex = 6,6,6,5 (0,+1,+1,+1)
Len = 8,8,6,6 (0,+1,+1,+1)	Lex = 5,5,5,4 (0,+1,+1,+1)
Pattern II–2 (*B. brevipes*):	
Ren = 8,*8*,6,6 (0,+*1*, +*1*,+1)	Rex = 7,*6*,6,5 (+1,+*1*, +*1*,+1)
Len = 8,*8*,6,6 (0,+*1*, +*1*,+1)	Lex = 6,*5*,5,4 (+1,+*1*, +*1*,+1)
Pattern II–3 (*B. neapolitanus*):	
Ren = 8,8,6,6 (0,+1,+1,+1)	Rex = 7,6,6,5 (+1,+1,+1,+1)
Len = 8,8,6,6 (0,+1,+1,+1)	Lex = 7*,6*,6*,5* (+2*,+2*, +2*,+2*)
Pattern II–4 (*B. norvegicus*):	
Ren = 8,8,6,6 (0,+1,+1,+1)	Rex = 7*,6*,6*,6* (+1*,+1*, +1*,+2*)
Len = 8,8,6,6 (0,+1,+1,+1)	Lex = 7*,6*,6*,6* (+2*,+2*, +2*,+3*)

Armature formulas for Endopods in Patterns 1 and II (1–4).—Armature formulas for endopods of right and left legs 1–4 are symmetrical in patterns I (8,7,5,5, in Ren and Len) and II (8,8,6,6, in Ren and Len). In pattern II, armature formula (8, in Ren and Len) for each leg 1 has no additional element (0), but formulas (8,6,6, in Ren and Len) for right and left legs 2–4 have one additional regular element (+1) in each endopod.

Armature Formulas for Exopods in Patterns I and II (1–4).—In pattern I, armature formulas for right and left exopods are asymmetrical. In pattern II, which has four different formulas, the first three (II–1, II–2, II–3) are asymmetrical, but the fourth (II–4) is symmetrical. These four formulas are characterized as follows:

(1) In pattern II–1, leg 1 exopods (Rex = 6; Lex = 5) have no additional element (0), but legs 2–4 exopods (Rex = 6,6,5; Lex = 5,5,4) have one additional regular element (+1) in each exopod.
(2) In pattern II–2, legs 1–4 exopods (Rex = 7,6,6,5; Lex = 6,5,5,4) have one additional regular element (+1) in each exopod.
(3) In pattern II–3, the formula (Rex = 7,6,6,5) for exopods of right legs 1–4 is comparable to that in pattern II–2, but that (Lex = 7*,6*,6*,5*) for exopods of left legs 1–4 have two additional elements (+2*) consisting of one regular and one reduced element.
(4) In pattern II–4, armature formulas (7*,6*,6*,6*, in Rex and Lex) for exopods of right and left legs 1–4 are numerically symmetrical but asymmetrical in regard to the composition of additional elements. In the formula (Rex = 7*,6*,6*) for exopods of right legs 1–3, one additional element corresponds to a reduced element (+1*). When reduced elements are not counted for these exopods, this formula is comparable to that (Rex = 6,5,5) for the corresponding exopods in pattern I. The formula (Lex = 7*,6*,6*) for exopods of left legs 1–3 is comparable to that (Lex = 7*,6*,6*) for the

corresponding exopods in pattern II–3 by possessing two additional elements (+2*) for each exopod. However, armature formulas for right (Rex = 6*) and left (Lex = 6*) exopods of leg 4 are unique, because additional elements consist of +2* and +3*, respectively: +1 and +1, in patterns II–1 and II–2; +1 and +2*, in pattern II–3.

Cephalosomal Appendages and Genitalia in Subgroups 1 and 2.—Most cephalosomal appendages and genitalia are distinguishable in subgroups 1 and 2.

(1) Antennule. In subgroups 1 (Ooishi, 2002b: 821, fig. 3a) and 2 (Figs. 3a, 14a), the 4-segmented antennule bears 28 setae. In most species of both subgroups, the setal formula for four segments is indicated as 9,4,3,12, although *B. bamfieldensis* (subgroup 1) has the formula 8,5,3,12 (Ooishi, 2000: 574, fig. 2a). In subgroup 1, nine or eight setae on the first segment include five major setae. In most species of subgroup 2, however, the nine setae include three major setae (*B. banyulensis*, Fig. 3a; *B. neapolitanus*, Fig. 14a; two unnamed species); *B. norvegicus* (Ooishi, 1996, fig. 11a) is exceptional (total setal number 29 or 30; first segment with 6 major setae).
(2) Antenna. In both subgroups, armature elements are symmetrical in number but asymmetrical in shape (spines and setae in right; setae in left). In subgroup 1, armature elements uniformly consist of seven elements (Ooishi, 2002b, fig. 3b). In subgroup 2, they are fewer: six in most species (*B. brevipes*, Brément, 1909, fig. VI; *B. banyulensis*, Fig. 3b; *B. neapolitanus*, Fig. 14b; one unnamed species); five in one species (*B. norvegicus*, Ooishi, 1996, fig. 11b). However, one of the unnamed species of subgroup 2 has seven elements, as in subgroup 1.
(3) Mandible. In subgroup 1, two spines arranged posterior to comblike spinules on the coxal medial margin are merely conical (Ooishi, 2002b, fig. 3e). In most species of subgroup 2, these conical spines are modified in shape: anteriorly, the first spine has two fused smaller spines (*B. neapolitanus*, Fig. 14e); both conical spines have one fused smaller spine (*B. banyulensis*, Fig. 3d); the two conical spines are represented by five separated spines (*B. norvegicus*, Ooishi, 1996, fig. 11e).
(4) Maxillule. There is no distinction between the two subgroups.
(5) Maxilla. In subgroup 1, the maxilla has uniformly nine setae (Ooish, 2002b, fig. 3i). In subgroup 2, it has nine (*B. neapolitanus*, Fig. 14g; 2 unnamed species) or 11 (*B. banyulensis*, Fig. 3g; *B. norvegicus*, Ooishi, 1996, fig. 11i) setae.
(6) Maxilliped. In subgroup 1, the coxa has one simple seta medioproximally (Ooishi, 2002b, fig. 3j). In subgroup 2, it has two setae (*B. banyulensis*, Fig. 3h; *B. norvegicus*, Ooishi, 1996, fig. 11j; *B. neapolitanus*, Fig. 14h; 2 unnamed species).
(7) Apparatus at gonopore. In subgroup 1, a pair of external spines consists of one larger proximal and one smaller distal spine (Ooishi, 2002b, fig. 6d). In subgroup 2, these spines consist of one smaller proximal and one larger distal spine (*B. banyulensis*, Fig. 6c; *B. norvegicus*, Ooishi, 1996, fig. 14a; *B. neapolitanus*, Fig. 17b; 2 unnamed species).
(8) Copulatory organs. In subgroup 1, a small genital atrium is present. In *B. inaequipes* (Ooishi, 2002a, fig. 5f), it has a substantial opening and contains paired copulatory pores (slightly tubular), seminal receptacles, and receptacle ducts. In most species (Ooishi, 2002b, fig. 6e), the opening is slitlike and internal organs have not been studied. In subgroup 2 (except for *B. norvegicus*), these organs belong to the subcuticular copulatory organ complex; there is no genital atrium. Copulatory pores are externally protruded as tubular pores (*B. banyulensis*, Fig. 6d; *B. neapolitanus*, Fig. 17c) or opened directly on the surface (2 unnamed species).

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References

Brément, E. 1909. Contribution à l'étude des copépodes ascidicoles du Golfe du Lion. Archives de Zoologie Expérimentale et Générale 1 (Notes et Revue 5): 61–89.

Conradi, M., P. J. López-González, and J. C. García-Gómez. 1994. *Botryllophilus conicus* n. sp. (Copepoda: Cyclopoida: Ascidicolidae) associated with a compound ascidian from the Strait of Gibraltar. Systematic Parasitology 29: 97-104.

Damkaer, D. M. 2002. The Copepodologist's Cabinet. A Biographical and Bibliographical History. Memoirs of the American Philosophical Society 240. xx + 300 pp.

Gotto, V. 2004. Commensal and Parasitic Copepods Associated with Marine Invertebrates. Synopses of the British Fauna (new series). No. 46 (second edition). The Linnean Society of London and the Estuarine and Coastal Sciences Association by Field Studies Council. vii + 350 pp.

Illg, P. L., and P. L. Dudley. 1980. The family Ascidicolidae and its subfamilies (Copepoda, Cyclopoida), with descriptions of new species. Mémoires du Muséum National d'Histoire Naturelle 117: 1-192.

Nakauchi, M. 1980. Oozooids of *Parascidia areolata* (a polyclinid ascidian). Reports of the Usa Marine Biological Institute 2: 19-23.

Ooishi, S. 1991. North Pacific copepods (Cyclopoida: Ascidicolidae) associated mostly with compound ascidians. Bulletin of Plankton Society of Japan, special volume: 49-68.

———. 1996. Two ascidicolid copepods, *Botryllophilus macropus* Canu and *B. norvegicus* Schellenberg, from British waters. Journal of Crustacean Biology 16: 169-191.

———. 1999. Female and male *Botryllophilus ruber* (Copepoda: Cyclopoida) associated with the compound ascidian *Botryllus schlosseri*. Journal of Crustacean Biology 19: 556-577.

———. 2000. *Botryllophilus bamfieldensis*, new species (Copepoda: Cyclopoida: Ascidicolidae), living in a compound ascidian from the west coast of Vancouver Island, Canada. Journal of Crustacean Biology 20: 571-588.

———. 2001. Two ascidicolous copepods, *Haplostomides otagoensis* n. sp. and *Botryllophilus* cf. *banyulensis* Brément, living in compound

ascidians from Otago Harbor, New Zealand. Hydrobiologia 453/454: 417-426.
———. 2002a. Redescription of *Botryllophilus inaequipes* Hansen, 1923 (Crustacea: Copepoda: Cyclopoida: Ascidicolidae). Proceedings of the Biological Society of Washington 115: 636-649.
———. 2002b. Description of *Botryllophilus sarsi*, new species (Copepoda: Cyclopoida: Ascidicolidae), replacing *B. brevipes* Sars, 1921. Journal of Crustacean Biology 22: 819-833.
———, and P. L. Illg. 1977. Haplostominae (Copepoda, Cyclopoida) associated with compound ascidians from the San Juan Archipelago and vicinity. Special Publications from the Seto Marine Biological Laboratory, series V: i-v, 1-154, pl. 1.
———, and ———. 1988. Two morpho-types of *Botryllophilus* (Cyclopoida, Ascidicolidae). Hydrobiologia 167/168: 561-566.
———, and ———. 1989. *Botryllophilus abbotti* new species (Copepoda: Cyclopoida: Ascidicolidae) associated with a compound ascidian from the Monterey Peninsula. Bulletin of Marine Science 45: 447-466.
Salfi, M. 1931. Gli ascidiacei del Golfo di Napoli.. Publicazioni della Stazione Zoologica di Napoli 11293-360 pls. 6-10.
Schellenberg, A. 1921. Neue Norwegische Notodelphyiden. Kongelige Norske Videnskabers Selskabs Skrifter 3: 1-11.
Seo, I. S., and K. S. Lee. 1995. Copepod associated with ascidians from Korea. II. A new species of *Botryllophilus* (Copepoda, Cyclopoida, Ascidicolidae) from simple ascidians at Chindo Island in the South Sea, Korea. Korean Journal of Systematic Zoology 2: 79-86.

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