JOURNAL OF CRUSTACEAN BIOLOGY, 22(4): 819–833, 2002

DESCRIPTION OF *BOTRYLLOPHILUS SARSI*, NEW SPECIES (COPEPODA: CYCLOPOIDA: ASCIDICOLIDAE), REPLACING *B. BREVIPES* SARS, 1921

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A B S T R A C T

The female of *Botryllophilus sarsi* is described as a new species, replacing *B. brevipes* Sars, 1921, which is a junior homonym of *B. brevipes* Brément, 1909. The description is based on specimens on loan from the Zoological Museum, University of Oslo. These copepods, living in a polycitorid ascidian, were collected on the west coast of Norway in 1937 and had been identified as *B. brevipes* Sars. *Botryllophilus sarsi* belongs to subgroup 1 of morphotype A of the genus and is distinguished from its five congeners by a combination of minor morphological features of body form, antennule, legs, and genitalia. Comparison of *B. sarsi* with similar botryllophilins and consideration of their ascidian hosts may lead us to question whether the host for *B. brevipes* Sars is a botryllid.

Sars (1921) described the female of *Botryllophilus brevipes*, which had been living in a colonial ascidian, *Botryllus* sp., from the North Sea (Espevær). Many authors have referred to *B. brevipes* Sars in their studies on botryllophilins from various coastal waters, but there are still difficulties in identifying their specimens with certainty as *B. brevipes* Sars or as any other species.

Wilson (1932) gave an account of several specimens of *Botryllophilus* that he identified as *B. brevipes* Sars; the specimens were obtained from the solitary ascidian *Phallusia obliqua* (probably a synonym of *Ascidia obliqua* Alder) in the Woods Hole region (northeastern United States). Dudley and Illg (1991) examined many botryllophilins, resembling *B. brevipes* Sars or Wilson's specimens mentioned above, collected from the compound ascidian *Aplidium glabrum* (Verrill) in the northeastern United States (Maine, Massachusetts). These authors, however, designated their specimens as *Botryllophilus* sp. because of difficulties in distinguishing their specimens from *B. brevipes* Sars, *B. bergensis* Schellenberg (found in a didemnid from Bergen), or from Wilson's specimens. They pointed out that the taxonomic problems are due to inadequacies in the original descriptions of the two Norwegian species.

Ruppert and Fox (1988) thought that orange-red copepods living in the compound ascidian *Eudistoma hepaticum* (Van Name) were *B. brevipes* Sars and listed it as one of the copepods from the southeastern United States. However, no reasons for designating them as *B. brevipes* Sars were presented.

Lang's (1948) embarrassing idea that *B. brevipes* Sars is a synonym of *B. ruber* Hesse added confusion to succeeding studies on the genus. It seems that Gotto's (1993) treatment of *B. brevipes* Sars was obviously influenced by this. Lang's idea was corrected when *B. ruber* was redescribed by Ooishi (1999).

In my study of *Botryllophilus* living in species of *Aplidium* from the eastern (Monterey Peninsula, California) or western (Zaga Island, Japan) North Pacific Ocean, I also had a problem in identifying specimens that resemble *B. brevipes* Sars. These Pacific botryllophilins were reported only by the alphanumeric symbols MB2 and ZB1, respectively (see Ooishi, 1991). I decided that restudying Sars' species from type specimens was necessaary for solving the taxonomic problem of the Pacific specimens.

Through the courtesy of Dr. M. Christiansen of the Zoological Museum, University of Oslo, I visited the museum in September 1992 in order to examine types and other ascidicolous copepods in the Sars collection. However, the collection did not include any type specimens of *B. brevipes* Sars.

In February 1995, Dr. Christiansen arranged to have several specimens identified as *B. brevipes* Sars sent to me. These had been returned to the museum at Oslo after being on loan to

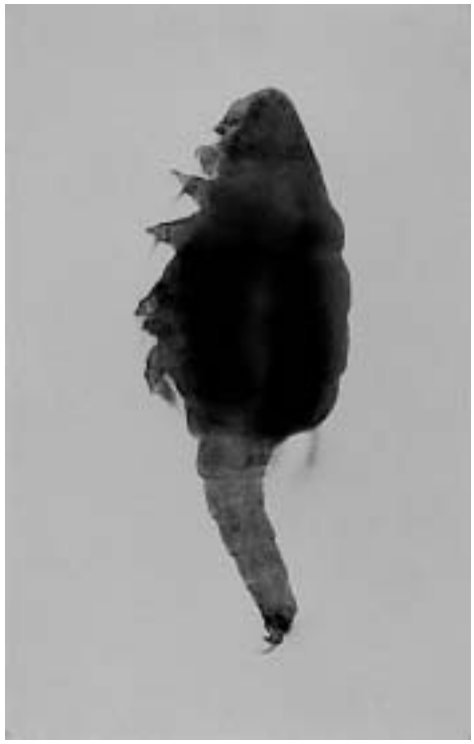

Fig. 1. *Botryllophilus sarsi*, new species, female, photomicrograph of body form, lateral.

another institution in Europe. They are not type specimens and were associates of a different colonial ascidian (*Polycitor vitreus*), collected from the west coast of Norway (Molldøra). The present study is based on these specimens.

Females of nine species of *Botryllophilus* are members of morphotype A (urosome 5-segmented); the remaining five are of morphotype B (urosome more than 5-segmented). Six of the nine belonging to type A (*B. brevipes* Sars and five congeners) have been assigned to subgroup 1, because they have pattern I of leg armature formula (see Ooishi, 2000). The five congeners are as follows: *B. bergensis* Schellenberg, 1921; *B. inaequipes* Hansen, 1923; *B. abbotti* Ooishi and Illg, 1989; *B. koreensis* Seo and Lee, 1995; and *B. bamfieldensis* Ooishi, 2000.

The fact that *B. brevipes* Sars is a primary junior homonym of *B. brevipes* Brément was pointed out by Illg and Dudley (1980, with synonyms presented for these species), Dudley and Illg (1991), Gotto (1993), and Ooishi (2000); Gotto noted that Sars' species, when restudied in detail, would require a change of name.

Botryllophilus brevipes Brément, 1909, has been included in subgroup 2 of type A species, because its leg armature formula is of pattern II (Ooishi, 2000); the two congeners in this subgroup are *B. banyulensis* Brément, 1909, and *B. norvegicus* Schellenberg, 1921.

For the reason mentioned above, it is evident that *B. brevipes* Sars differs from *B. brevipes* Brément and needs a new name. Thus, *Botryllophilus sarsi* is described here as a new species, replacing *B. brevipes* Sars.

Botryllophilus sarsi has been compared in detail with *B. brevipes* as described by Sars (1921) in order to confirm that these copepods are conspecific.

Materials and Methods

Nine intact specimens (stored in ethanol in one glass tube, with catalog number F2133) of *Botryllophilus brevipes* Sars, on loan from the Zoological Museum of University of Oslo, were studied. These specimens, living in *Polycitor vitreus* (M. Sars, 1851), had been collected in 1937 by Hans Tambs-Lyche (Curator of the Zoological Department of the Bergen Museum from 1938 to 1947; General Secretary of the International Council for the Exploration of the Sea from 1965 to 1983). The copepods had been identified as *B. brevipes* Sars by Johan Huus (Curator of the Marine Invertebrate Section at the Zoological Museum of University of Oslo at that time; Professor of the Bergen Museum after the Second World War).

In preparation of a description of *B. sarsi*, the specimens of *B. brevipes* Sars were sorted by me into a future holotype and eight future paratypes. Two of the eight (of similar size) were immersed in lactic acid: one (intact) was used for a photomicrograph (Fig. 1) and making drawings (Fig. 2a–c); the other was dissected for making drawings (Figs. 2d, e, 3–6) and photomicrographs (Fig. 7a–m). Drawings were made with the aid of a *camera lucida*.

Dissected appendages or urosomal portions were mounted singly in polyvinyl lactophenol on 23 slides: (1) right and left antennules; (2) right antenna; (3) left antenna; (4) right mandible; (5) left mandibular coxa (later, it was found that the appendage was not on the slide); (6) left mandibular palp; (7) right maxillule; (8) left maxillule; (9) right maxilla; (10) left maxilla; (11) right maxilliped; (12) left maxilliped; (13) right leg 1; (14) left leg 1; (15) right leg 2; (16) left leg 2; (17) right leg 3; (18) left leg 3, (19) right leg 4; (20) left leg 4; (21) right and left leg 5; (22) urosomal portion with genital and first two abdominal segments; and (23) urosomal portion with third abdominal segment and anal segment with caudal rami. Eight intact specimens (holotype, 7 paratypes) and one dissected specimen (paratype) on slides (see *Material Examined*) were returned to the Zoological Museum in October 1995 and November 1996, respectively.

In the armature formula for legs 1–4, the total number of spines or spiniform elements (Roman numerals) is noted first and connected by a dash with the number of setae or setiform elements (Arabic numerals) in each segment. The total number (T) of these elements is given in parentheses for protopod (coxa, basis), endopod, and exopod. This differs from the traditional formula style.

The abbreviations used are: A1 = antennule, A2 = antenna, MD = mandible, MX1 = maxillule, MX2 = maxilla, MXP = maxilliped, P_1 = leg 1, 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 of antennule, and +1 = 1 subordinate seta associated with a major seta of antennule or maxilla.

Systematics

Family Ascidicolidae Thorell, 1859

Subfamily Botryllophilinae Sars, 1921

Genus *Botryllophilus* Hesse, 1864

Botryllophilus sarsi, new species
Figs. 1–7

Material Examined.—Holotype ♀ (F2133a), living in *Polycitor vitreus* (M. Sars) (Aplousobranchia: Polycitoridae), collected by H. Tambs-Lyche, at Molldøra (68°13′N, 14°50′E), Lofoten, Norway, depth 60 m, 7 July 1937; paratypes 8 ♀♀ (F2133b [1 specimen]; F2133c [6 specimens]; F2133d-z [23 dissected portions of 1 specimen, on slides]), same ascidian host, locality, and date.

Female.—Body (Figs. 1, 2a–c) stout, compact, consisting of subtriangular cephalosome, barrel-shaped metasome, and cylindrical urosome. Proportional lengths about 1:3.2:2.5 for 3 regions. Body length (excluding caudal spines) about 1.57 mm, measured along body axis, in illustrated specimen. Ratio of length of prosome to that of urosome about 1.6:1. Body surface with sparsely scattered hairlike sensilla.

Cephalosome (Fig. 2a, c) wider than long, anterior margin rounded, bearing appendages through maxillipeds (Fig. 2d, e); antennae asymmetrical. Pleural folds weakly developed, and rostral region not prominent.

Metasome (Fig. 2a–c) unsegmented, expanded dorsoventrally, but first to fifth pedigerous segments indistinctly demarcated on ventral side. First pedigerous segment (Fig. 2c) slightly narrower than second to fourth pedigerous segments. Biramous legs 1–4 asymmetrical in morphology and arrangement; intercoxal sclerite absent. In first pair, right and left legs widely separated from each other, but right legs coming gradually closer to left legs in second to fourth pairs (Fig. 2c). This condition causing slight asymmetry of prosome, curvature to right side. Fifth pedigerous segment narrowing toward urosome, bearing dorsolaterally directed uniramous fifth legs, these close to posterolateral corners of fourth pedigerous segment. Greatest width and thickness about 0.47 mm in second and third pedigerous segments.

Urosome (Fig. 2a–c) 5-segmented (1 genital, 3 abdominal, 1 anal). Anterior margin of genital segment demarcated from metasome. In genital segment, 2 gonopores dorsolateral, and transverse slit for genital atrium midventral. Anal segment bearing small caudal rami with ventrally directed terminal spines. Anus opening posterodorsally.

Antennule (Fig. 3a) 4-segmented. First segment broad, as long as total length of gradually narrowing second to fourth segments. Antennule armature consisting of 28 simple setae, including 1 aesthete-like seta (arrow) on fourth segment. First segment with 9 setae (I_1 + 2, II_1, III_1 + 1, IV_1, V_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, 4 long major setae (II_1–V_1) on distal margin relatively short, and longest major seta (III_1) about as long as basal width of segment; single independent seta (arrow) at anterodistal corner extremely short.

Antenna 4-segmented; armature elements asymmetrical in composition. In right antenna (Fig. 3b), proportional lengths about 1:3:0.7:3 for segments 1–4, measured along medial axis on anterior side. Fourth segment with 7 elements: 2 spines (I, II) on medial margin, and 3 spines [III–V] and 2 long setae [VI, VII], from medial to lateral on terminal margin. All elements with minute serrations distally; spinular serrations on terminal spines (III–V) distinctive (Fig. 7a). Proportional lengths about 1:1.2:1:1:1.5:2:3 for 7 elements (I–VII). Longest terminal seta (VII) slightly shorter than fourth segment. In left antenna (Fig. 3c), 7 elements (I–VII) replaced by simple setae, these (except for I) longer than those on right antenna.

Labrum (Fig. 3d) subtriangular; distal margin rounded and without armature.

Mandible (Fig. 3e, f) consisting of coxa and palp (basis, exopod, and endopod fused). Gnathobasic medial margin of coxa (Fig. 3e) with comblike spinules (double rows, except for anteriormost and posteriormost elements [arrows in figure]) and single row of 2 conical and 2 sharp conical spines on common base (or 1 bifurcate spine), from anterior to posterior. Posterior 2 sharp conical spines (anterior one with minute serration anteriorly) widely separated from anterior 2 conical spines (Fig. 7b). Palp (Fig. 3f) with 9 setae: exopodal region with 3 long setae (1 proximal, 2 distal on common base), and endopodal region with 6

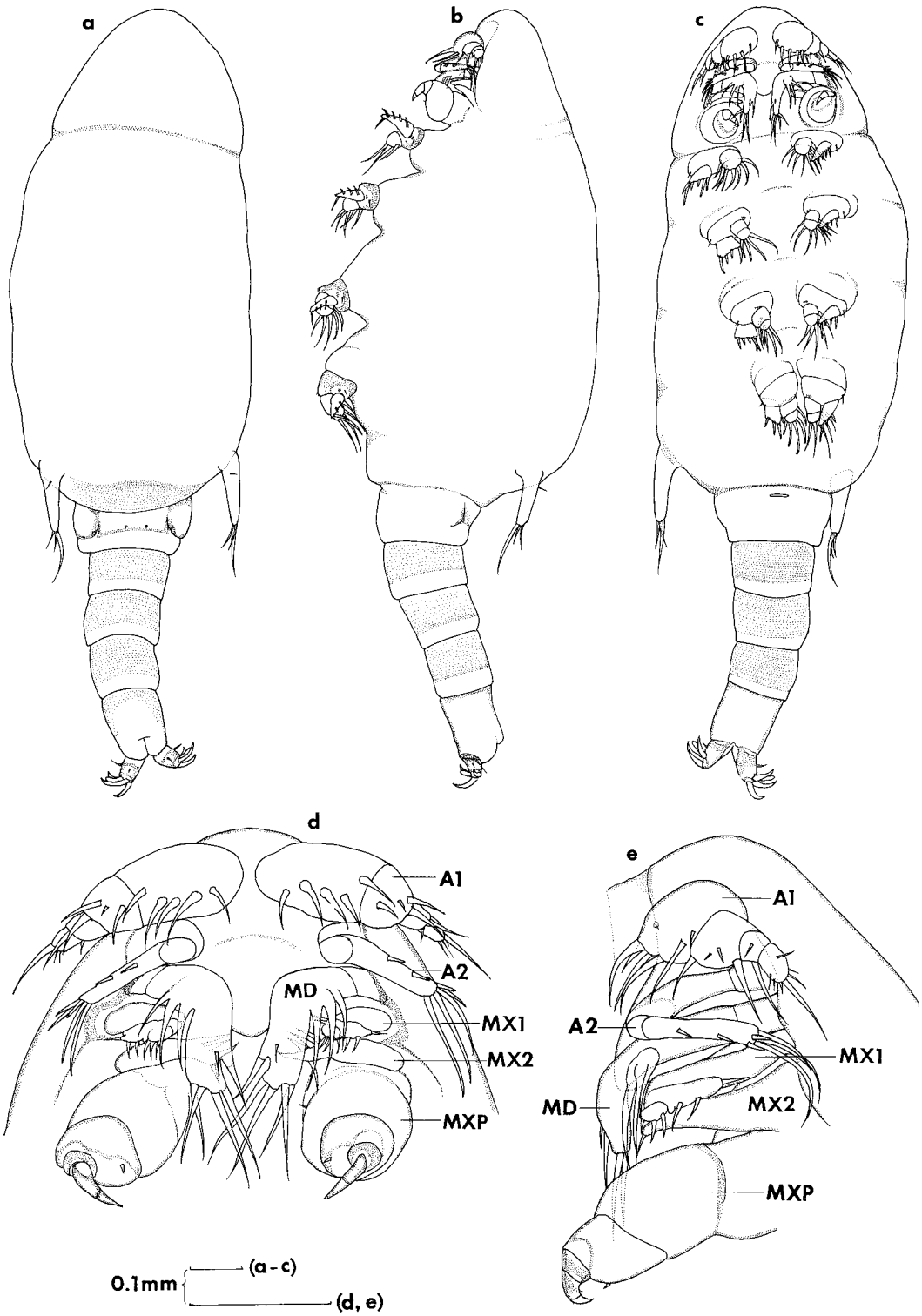

Fig. 2. *Botryllophilus sarsi*, new species, female. a, body form, dorsal; b, same specimen, lateral; c, same specimen, ventral; d, cephalosome, ventral; e, cephalosome, lateral.

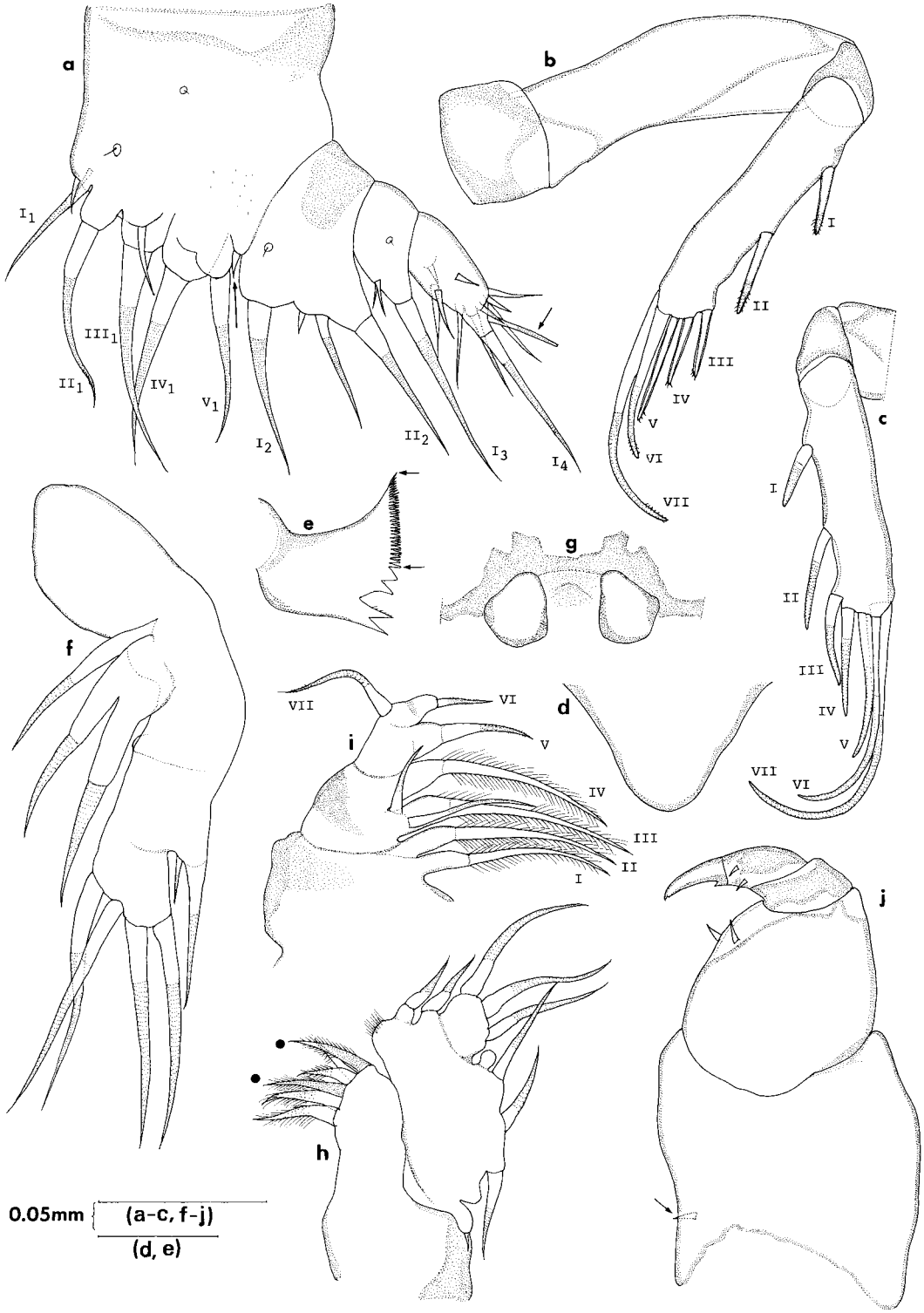

Fig. 3. *Botryllophilus sarsi*, new species, female. a, left antennule, anterior; b, right antenna, anterior; c, left antenna (third and fourth segments), anterior; d, labrum, anterior; e, coxa of right mandible, anterior; f, palp of right mandible, anterior; g, paragnaths, ventral; h, left maxillule, posterior; i, right maxilla, posterior; j, left maxilliped, posterior.

setae (2 unequal medial, 2 long distolateral, 2 long terminal).

Paragnaths (Figs. 3g, 7c) large, saclike, as long as wide, each located close to medial margin of oral sclerite surrounding mandible and maxillule.

Maxillule (Fig. 3h) consisting of precoxa and palp (coxa, basis, and exopod fused; endopod distal). Precoxa with 6 plumose medial setae including 2 rather stout setae (dots in figure). Epipodite of coxa represented by small lateral lobe with 1 small apical seta. Basis represented by 2 medial setae directed distally and setules posterior to them. Exopodal region with 3 lateral setae (1 directed proximally, 2 directed distally) and 1 small, rounded projection next to endopod. Endopod with 3 setae on distal margin.

Maxilla (Fig. 3i) weakly divided into 3 portions, bearing 9 setae (7 major [I–VII], 2 subordinate). Proximal portion (precoxa) with 2 setae (I, II), middle portion (coxa) with 4 setae (III + 2, IV), and distal portion (basis and endopod fused) with 3 setae (V–VII); 2 subordinate setae (Fig. 7d, arrows) set on posterior base of major seta III. Proximal 4 major setae (I–IV) plumose, remaining 5 setae (3 major [V–VII], 2 subordinate) simple.

Maxilliped (Fig. 3j) consisting of coxa with 1 simple medial seta (arrow in figure) proximally, basis with 2 similar setae (anterior, posterior) midway on medial margin, and endopod of 3 segments. Second endopodal segment (Figs. 3j, 7e), consisting of fused segments, with 2 small simple setae (arrow in figure, for seta near medial margin) on posterior side. Terminal segment medially curved stout claw with small notch medioproximally; apex slightly bifid (tridentate?). Major articulation in endopod between first and second segments; thus distal 2 segments appearing to form long claw.

In right and left legs 1–4 (Figs. 4a–c, e, 5a–e, 7f), protopod without articulation at base and partially sclerotized; coxa without armature, and basis with 1 simple lateral seta. In legs 2–4, mediodistal margin of basis with row of conical spinules (4–6).

Endopods of right and left legs 1–4 distinctly 2-segmented, longer than wide. In right leg 1 and left legs 1–4, endopods with only sharply pointed long setae. In right legs 2–4 (Figs. 4c, 5a, c), endopod with 2 (legs 3 and 4) or 3 (leg 2) spiniform elements (dots in figure) protruding from lateral margin of second segment, in addition to long setae. These spiniform elements not pointed at apex and with minute serrations distally (Figs. 4d, 7g, arrows). In each ramus, proximal spiniform element distinctly shorter than remaining elements (2 in leg 2; 1 in legs 3 and 4); 2 spiniform elements on leg 4 much longer than those on legs 2 and 3. Setae on right legs 2 and 3 sharply pointed at apex (Figs. 4c, 5a, 7h), but those on leg 4 blunt at apex (Figs. 5c, 7i). Second segment of leg 2 with 3 conical spinules around distal margin (Fig. 4c).

Exopods of right legs 1–4 (Figs. 4a, c, 5a, c, d) 1-segmented, approximately trapezoidal, wider than long in legs 1–3, and longer than wide in leg 4. Armature consisting only of spines with minute spinular serrations distally. Most of them (I–V, in case of leg 1) stout, protruding from uneven truncated distal margin and directed distally. Remaining single spine (VI, in case of leg 1) protruding from posterior side (in legs 1–3) or medial margin (in leg 4) of ramus and directed mediodistally. This spine (Fig. 7f, arrow) somewhat slender and distinctly shorter than distalmost spine (V, in case of leg 1) in legs 1–3, but large and stout in leg 4 (Fig. 5d, IV). In right leg 1 exopod (Fig. 4a), proximalmost spine (I, Psp) slightly longer than distalmost spine (V, Dsp). Proportional lengths 1:0.63:0.48:0.33:0.77:0.45 for 6 spines (I–VI). Three shorter spines (II–IV) between proximalmost (I) and distalmost (V) spines in leg 1 represented by 2 in legs 2 and 3, and by 1 in leg 4.

Distal margin of right exopod, close to each spine (I–IV, in case of right leg 1), slightly protruding and with 2 or 3 small conical spinules (not fused at base). Spinules (2) close to distalmost spine (V, in case of leg 1) fused basally and protruding distally, forming mediodistal corner of ramus; spinules absent around spine protruding from posterior side (in legs 1–3) or medial margin (in leg 4).

Exopods of left legs 1–4 (Figs. 4b, e, 5b, e) 1-segmented, approximately rhomboid; lateral margin of each exopod corresponding to lateral and distal margins of right exopod. Ratio of length to width about 2.5:1 in leg 1. Legs 1–3 exopods longer than leg 4 exopod and also longer than their respective endopods. Setiform elements (I–V, in case of left leg 1) arranged on distal three-fifths of lateral margin; no elements on posterior side of ramus near distalmost setiform element. One element, therefore, lacking on each exopod of left legs 1–4. Pro-

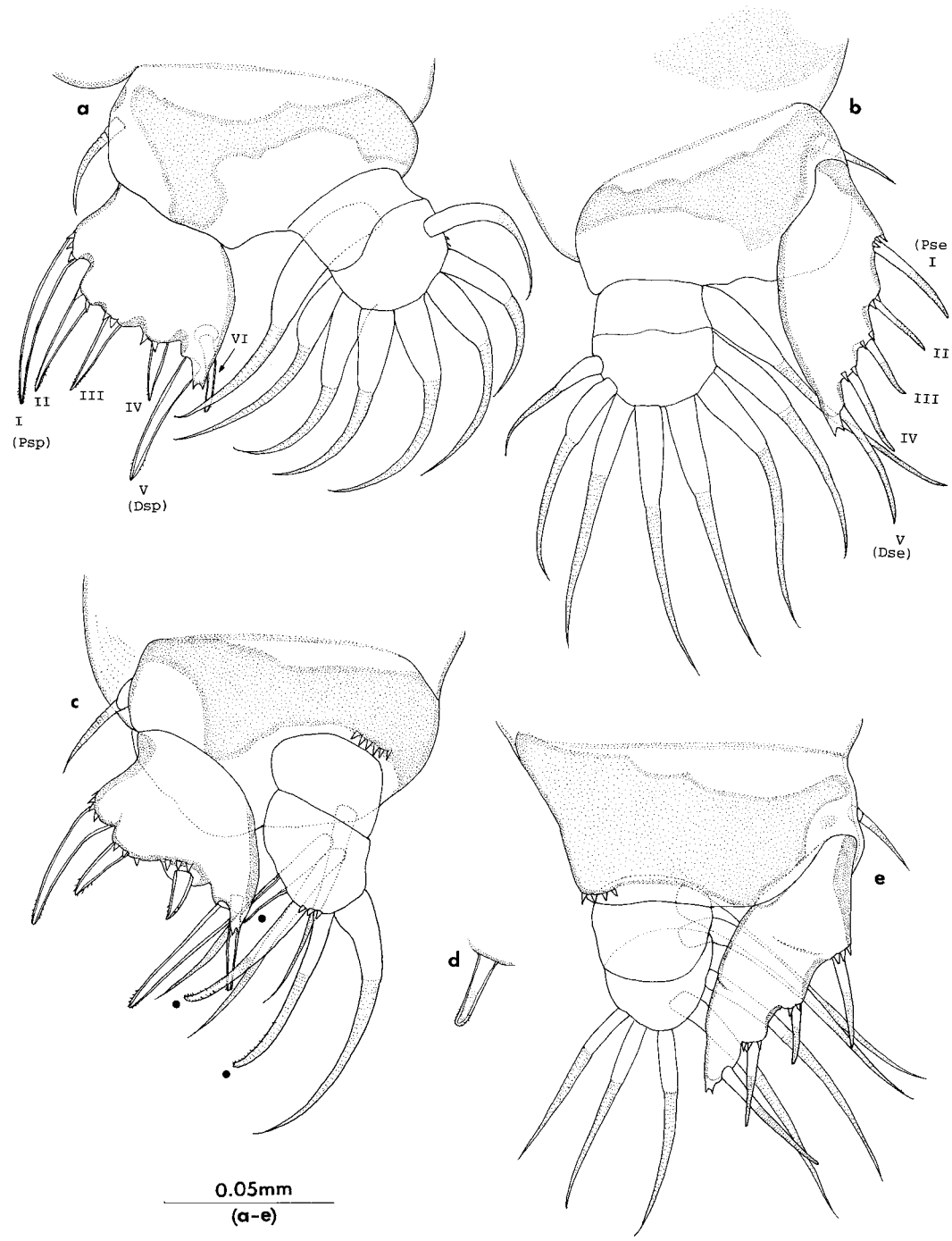

Fig. 4. *Botryllophilus sarsi*, new species, female. a, right leg 1, anterior; b, left leg 1, anterior; c, right leg 2, anterior (dots indicate 3 spiniform elements); d, proximal spiniform element on right leg 2 endopod, anterior; e, left leg 2, anterior. Dse = distalmost setiform element, Dsp = distalmost spine, Pse = proximalmost setiform element, Psp = proximalmost spine.

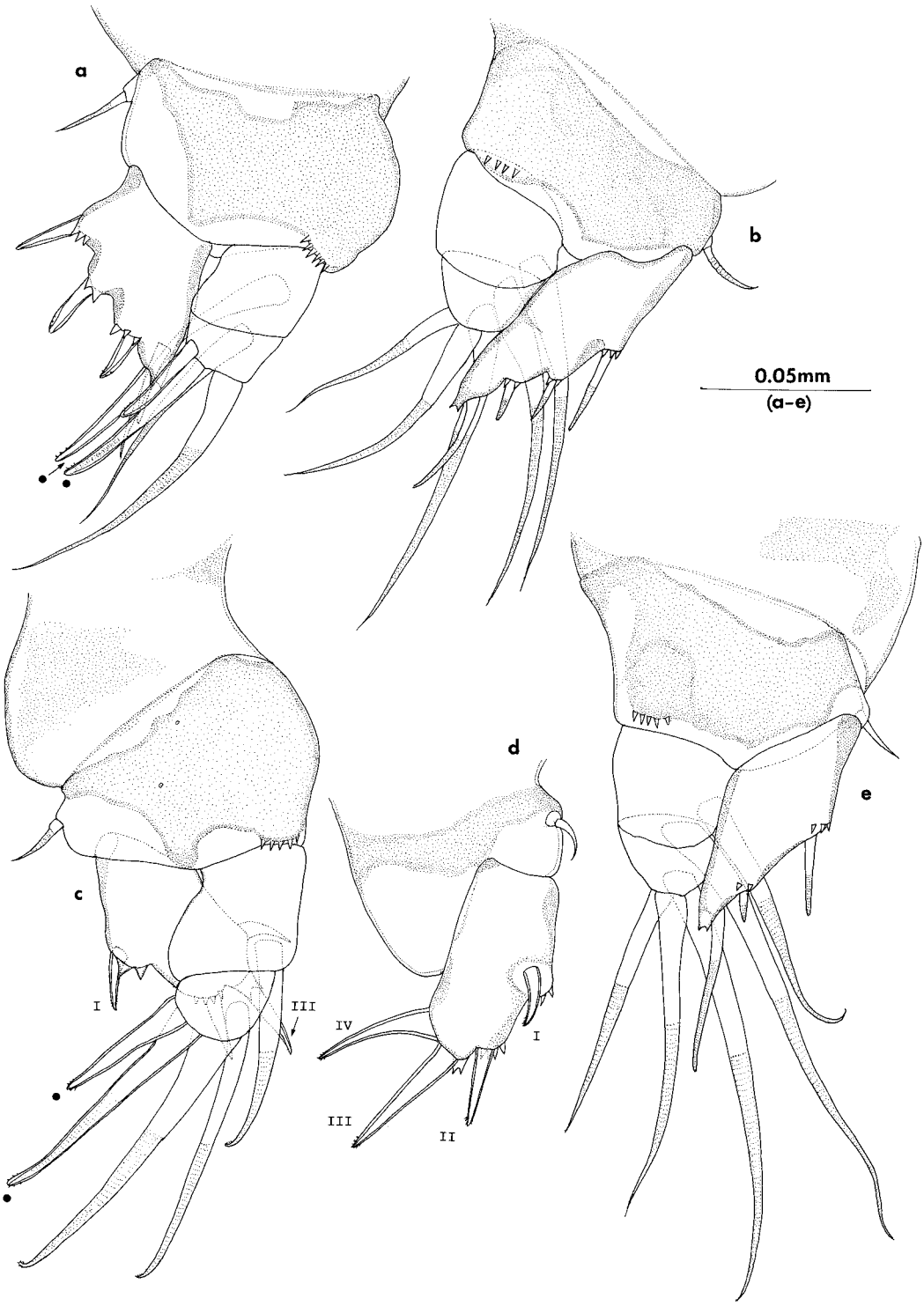

Fig. 5. *Botryllophilus sarsi*, new species, female. a, right leg 3, anterior (dot with arrow indicates proximal spiniform element; dot indicates distal spiniform element); b, left leg 3, anterior; c, right leg 4, anterior (dots indicate spiniform elements); d, right leg 4 exopod, posterior; e, left leg 4, anterior.

portional lengths 1:0.68:0.63:0.89:1.26 for elements I–V of leg 1. In legs 1–4, distalmost element (V, Dse, in case of left leg 1) longest. Distalmost element in leg 4 (Fig. 5e) markedly elongated, twice as long as proximalmost element.

Arrangement of spinules on lateral margin of left exopod, close to each setiform element (Fig. 4b, I–V, in case of left leg 1), comparable to that on distal margin of right exopod.

Armature formula for legs 1–4 as follows:

(Right)	Coxa; Basis (T)	Endopod (T)	Exopod (T)
P_1	0–0; 0–1. . .(1)	0–1; 0–7. . . .(8)	VI–0. . . (6)
P_2	0–0; 0–1. . .(1)	0–1; III–3. . .(7)	V–0. . . . (5)
P_3	0–0; 0–1. . .(1)	0–1; II–2. . . .(5)	V–0. . . . (5)
P_4	0–0; 0–1. . .(1)	0–1; II–2. . . .(5)	IV–0. . . (4)
(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; 0–6. . . .(7)	0–4. . . . (4)
P_3	0–0; 0–1. . .(1)	0–1; 0–4. . . .(5)	0–4. . . . (4)
P_4	0–0; 0–1. . .(1)	0–1; 0–4. . . .(5)	0–3. . . . (3)

Leg 5 short, almost symmetrical. In right leg (Fig. 6a), length about 20% of that of urosome and 1.8 times as long as proximal width. Armature consisting of 3 short simple setae (1 at proximal fifth, others subterminal and almost terminal) and 1 long terminal seta. Two short distal setae without conspicuous gap between them. Proportional lengths 1:2:2:4.3 for 4 setae; terminal seta approximately 0.8 times as long as appendage. One minute, hairlike sensillum protruding from mammiform projection (Figs. 6a, b, 7j, arrow) at distal fifth on dorsal margin. Setae (4) on left leg (Fig. 6b) slightly longer than those on right leg.

In dorsal genital segment, cuticle between gonopores with 2 hairlike sensilla posteriorly (Fig. 6c). Apparatus (Fig. 6d) at gonopore consisting of 2 closely set small conical spines (larger proximal and smaller distal [Fig. 7k, arrow], both articulated at base) externally, and 5 small sclerites (Fig. 7l) internally, on medial margin of cuticular flap covering gonopore. In ventral genital segment, transverse slit (Figs. 2c, 6e, 7m, arrow) located anterocentrally, but not close to anterior margin of segment, representing opening for genital atrium enclosing copulatory organs. Details of these organs not studied.

Anal segment (Fig. 6f–h) longer than wide, with hairlike sensilla beyond middle of segment; spinules or pubescence absent. Short caudal ramus (Fig. 6f–h) sclerotized, longer than wide, with 2 simple setae (dorsal, lateral) and 4 ventrally curved stout spines terminally. Lateral spine (LS) rounded at apex, but medial (MS), dorsal (DS), and ventral (VS) spines sharply pointed. These spines with spinular serrations distally.

Male.—Unknown.

Etymology.—*Botryllophilus sarsi* is named for the late Professor Georg Ossian Sars, who originally described this species in 1921 as *B. brevipes*.

Discussion

Morphological Comparison of Specimens of *B. sarsi* and *B. brevipes* Sars

Because *B. brevipes* Sars was inadequately described in the original paper (Sars, 1921), it is necessary to explain why *B. sarsi* is the same species. A confirmation, based on morphology of the body and appendages, has been made.

(1) Body: The body form (1.57 mm long; anteriorly rounded cephalosome; unsegmented metasome) and the proportional lengths (1.6:1) for the prosome and urosome in the specimen of *B. sarsi* are comparable to those in the specimen of *B. brevipes* studied by Sars (1921: 68, pl. XXXII). Sars' specimen (1.70 mm long) is, however, slightly longer.

(2) Appendages: In *B. brevipes* Sars, the asymmetry of antennae and legs 1–4 was not mentioned by Sars. Therefore, one of the antennae and many legs were omitted from his illustrations. In addition, one or more armature elements were not shown for most of the appendages.

As seen in Table 1, it is easy to recognize the appendages that are omitted and the armature elements that are lacking in the description (with illustrations) of *B. brevipes* Sars. In spite of the deficiencies of the description, there are no conspicuous morphological differences between appendages of *B. sarsi* and *B. brevipes* Sars.

(a) Antennule. The 4-segmented antennule (pl. XXXII, a^1) of *B. brevipes* Sars is like that (Fig. 3a) described here for *B. sarsi*, because the rather broad first segment bears relatively short major setae. A small independent seta on the anterodistal corner of the same segment was not shown for *B. brevipes* Sars. It is probable that the seta was overlooked by Sars because it was so small.

(b) Antennae. The composition of armature elements of the antenna (pl. XXXII, a^2, posterior view) of *B. brevipes* Sars corresponds to that of the right antenna (Fig. 3b, anterior

Fig. 6. *Botryllophilus sarsi*, new species, female. a, right leg 5, lateral; b, left leg 5, lateral; c, genital segment, dorsal; d, right gonoporal apparatus, dorsal; e, transverse slit for genital atrium on ventral surface of genital segment; f, anal segment and right caudal ramus with armature, dorsal; g, posterior portion of anal segment and right caudal ramus with armature, lateral; h, anal segment and right caudal ramus with armature, ventral.

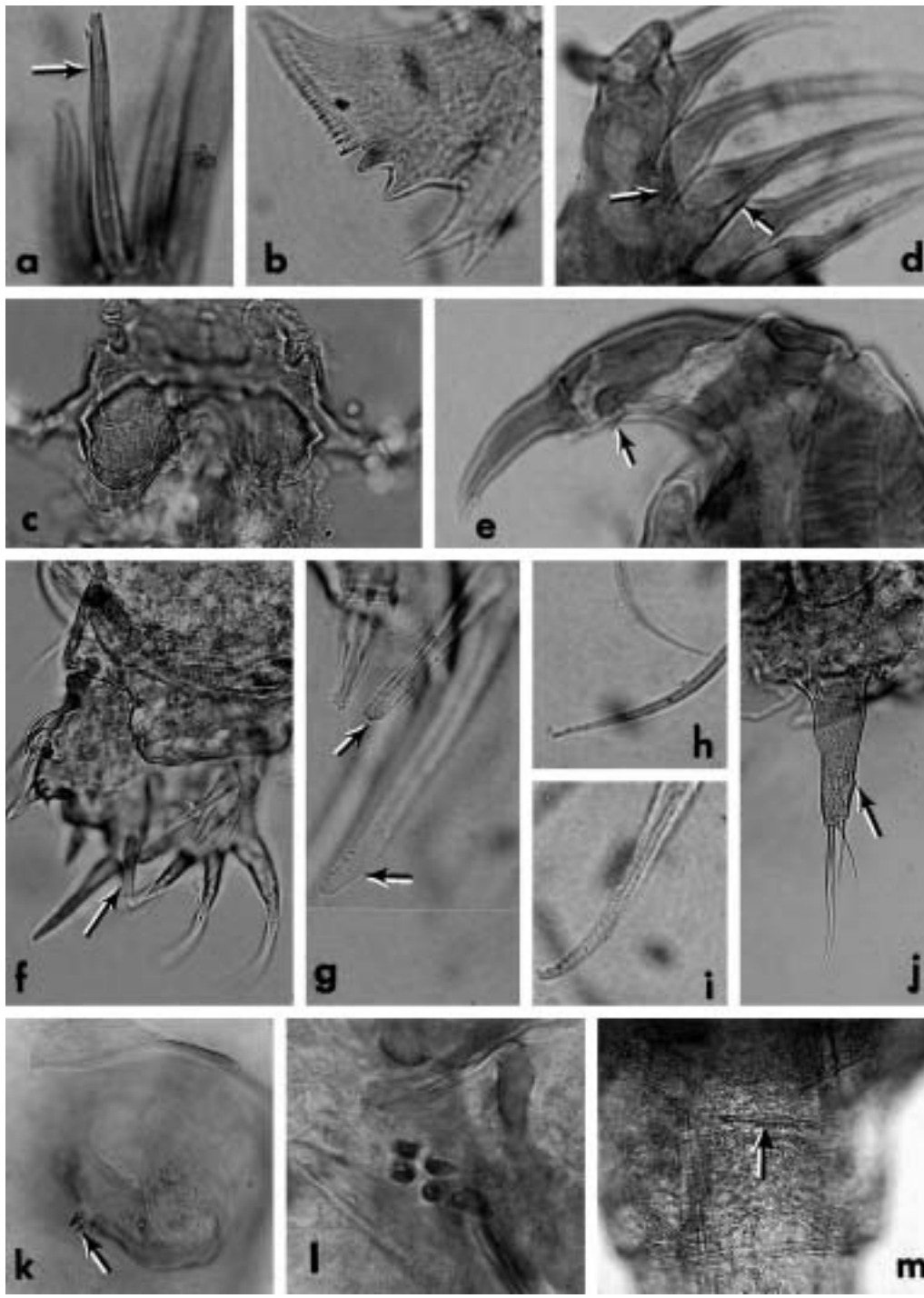

Fig. 7. *Botryllophilus sarsi*, new species, female, photomicrographs. a, spinulated spine (arrow) on terminal segment of right antenna, anterior; b, left mandibular coxa, anterior; c, paragnaths, ventral; d, right maxilla, posterior (arrows indicate 2 subordinate setae on major seta III); e, left maxilliped, distal portion, posterior (arrow indicates small seta near medial margin on second endopodal segment); f, right leg 1, anterior (arrow indicates spine protruded from posterior side of exopod and directed mediodistally); g, 2 spiniform elements (arrows) on right leg 3 endopod, anterior; h, sharply pointed seta on same endopod, anterior; i, blunt seta on right leg 4 endopod, anterior; j, left leg 5, lateral (arrow indicates mammiform projection for sensillum); k, 2 small spines at right gonoporal apparatus, dorsal (arrow indicates distal spine); l, 5 internal sclerites at right gonoporal apparatus, dorsal; m, genital segment, ventral (arrow indicates transverse slit for genital atrium).

Table 1. Comparative armature formulas for appendages in *Botryllophilus sarsi* and *B. brevipes* Sars. endo = endopod, exo = exopod, maj = major seta, se = seta (or setiform element), sp = spine (or spiniform element), and sub = subordinate seta.

	B. sarsi	*B. brevipes* Sars
Antennule	28 se:	18 se:
segment I	5 maj, 3 sub, 1 se	5 maj, 1 sub
segment II	2 maj, 2 sub	2 maj, 2 sub
segment III	1 maj, 2 sub	1 maj
segment IV	1 maj, 11 se	1 maj, 6 se
Right antenna	5 sp, 2 se	5 sp, 2 se
Left antenna	7 se	not presented
Mandible	9 se: exo, 3 se; endo, 6 se	8 se: exo, 3 se; endo, 5 se
Maxillule	15 se: precoxa, 6 se; coxa, 1 se; basis, 2 se; exo, 3 se; endo, 3 se	13 se: precoxa, 5 sp; coxa [none]; basis, 2 se; exo, 3 se; endo, 3 se
Maxilla	9 se (7 maj, 2 sub)	7 se (7 maj)
Maxilliped	5 se: coxa, 1 se; basis, 2 se; endo, 2 se	without armature
Right legs 1–4	endo (se, sp) = 8, 7, 5, 5; exo (sp) = 6, 5, 5, 4	endo (se) = ?, ?, ?, 5; exo (sp) = ?, ?, ?, 4
Left legs 1–4	endo (se) = 8, 7, 5, 5; exo (se) = 5, 4, 4, 3	endo (se) = 8, 7, ?, ?; exo (sp) = 5, 4, ?, ?
Leg 5	4 se, 1 sensillum	4 se?
Caudal ramus	2 se, 4 sp	1 se, 4 sp

view) of *B. sarsi*. Although the left antenna was not shown by Sars, it is assumed that this appendage is also comparable to that (Fig. 3c) of *B. sarsi*.

(c) Mandible, maxillule, maxilla, and maxilliped. The three mouthparts (pl. XXXII, M, mx, mxp^1) and maxilliped (pl. XXXII, mxp^2) of *B. brevipes* Sars correspond to those (Fig. 3e, f, h–j) of *B. sarsi*, although some of the small setae on each appendage were not shown for *B. brevipes* Sars. In the mandible of Sars' specimen (pl. XXXII, M), the coxa was apparently illustrated in anterior view, whereas the palp was illustrated in posterior view.

(d) Right and left legs 1–4. Armature formulas for three legs (legs 1 and 2 [posterior view], and leg 4 [anterior view]) in *B. brevipes* Sars (pl. XXXII, p^1, p^2, p^4) are identical to those for three legs (left legs 1 and 2, and right leg 4 [all anterior view]) in *B. sarsi* (Figs. 4b, e, 5c), which has formula pattern I. Thus, it is easy to predict the formulas for the other five, unillustrated legs (left legs 3 and 4, right legs 1–3). However, the lack of illustrations for these right legs in the original paper makes it difficult to recognize other distinctive features that characterize *B. brevipes* Sars.

(e) Armature of left legs 1–4 exopods. Sars (1921: 69) thought that the armature elements on four anterior leg exopods on both sides consist only of spines. However, the elements on right side consist of spines, but those on left side are of setiform elements, as seen in *B. sarsi* (Fig. 4b) and all other species of *Botryllophilus* (see Ooishi, 2000: 586, fig. 6d).

(f) Armature of left leg 1 exopod. As illustrated by Sars (pl. XXXII, p^1) for his *B. brevipes*, the distalmost element on the exopod of left leg 1 is like that of *B. sarsi* (Fig. 4b), because it is not markedly longer than the proximalmost element.

(g) Segmentation of leg endopods. In *B. brevipes* Sars, leg endopods on both sides were described as consisting of one segment, as in the respective exopods (Sars, 1921: 69). Leg 1 endopods often appear to be unimerous, but endopods of legs 2–4 are weakly or distinctly bimerous in all known species (except for legs 1–3 endopods of *B. bergensis*, according to Schellenberg, 1921: 11). Therefore, *B. brevipes* Sars, and probably also *B. bergensis*, are not distinguished from *B. sarsi* or from other botryllophilins by leg endopodal segmentation.

(h) Leg 5. In *B. brevipes* Sars, leg 5 (p. 69, pl. XXXII, p^5) was shown to have four setae (1 long terminal; 2 short, nearly terminal; 1 much smaller, beyond the middle of the appendage). This setation apparently corresponds to three setae (1 long terminal, 1 short subterminal, 1 short almost terminal) and one sensillum (at the distal fifth of the dorsal margin) in *B. sarsi* (Figs. 6b, 7j); it is clear that one short seta on the proximal dorsal margin in *B. sarsi* was overlooked by Sars.

(i) Caudal ramus. It is obvious that the caudal ramus (with 4 terminal spines and 1 lateral

seta) of *B. brevipes* Sars (pl. XXXII, F) corresponds to the caudal ramus viewed from ventral side in *B. sarsi* (Fig. 6h). In *B. brevipes* Sars, however, one dorsal seta on the ramus was omitted, and the lateral caudal spine (not pointed at apex) was not clearly distinguished from three other spines (pointed at apex) in the illustration.

Characteristic Features of *B. sarsi*

Formulas for cephalosomal appendages of *B. sarsi* shown in Table 1 are thought to represent the basic armature formulas for subgroup 1 of type A species. Setal variations may occur on the antennule in some species. The setation on the mandible (on palp), maxillule, maxilla, and maxilliped does not vary in general.

In *B. sarsi* and its five congeners of subgroup 1, which have leg armature formula pattern I, the shape of right exopods (1-segmented) is approximately trapezoidal. In most species, except for *B. bamfieldensis*, which has sickle-shaped exopods, the shape of left leg exopods (1-segmented) is approximately rhomboid. In all six species, however, the comparative lengths of the armature elements on the exopods of right and left leg 1 are not the same. It is possible that length ratios of two elements (proximalmost, distalmost) on each ramus can be used as a basis for understanding characteristic features of leg armature.

For comparison, the lengths of spines on right leg 1 exopod (Rex) and setiform elements on left leg 1 exopod (Lex) of six species were obtained from the following references: (1) *B. sarsi* in Fig. 4a (Rex), b (Lex); (2) *B. bergensis* in Schellenberg, 1921: fig. 9a (Rex); (3) *B. inaequipes* in Hansen, 1923: pl. III, 2d (Lex); (4) *B. abbotti* in Ooishi and Illg, 1989: fig. 3o (Rex), p (Lex); (5) *B. koreensis* in Seo and Lee, 1995: fig. 3A (Lex), B (Rex); and (6) *B. bamfieldensis* in Ooishi, 2000: fig. 3a (Rex), b (Lex).

As seen in Table 2, the ratio Psp : Dsp = 1:0.77 for *B. sarsi* indicates that the proximalmost spine (Psp) is slightly longer than the distalmost spine (Dsp). The slightly longer proximalmost spine is somewhat similar to the one in *B. koreensis* (1:0.75), *B. bergensis* (1:0.80), and *B. abbotti* (1:0.86). In *B. bamfieldensis*, the ratio (1:1.40) is reversed, because the proximalmost spine is obviously shorter than the distalmost spine.

In left leg 1 exopod, the ratio Pse : Dse = 1:1.26 for *B. sarsi* (Fig. 4b) indicates that the distalmost setiform element (Dse) is not markedly longer than the proximalmost element (Pse). In other species, however, the distalmost element is much longer (*B. koreensis* [1:1.66]) or very much longer (*B. abbotti* [1:3.16], *B. bamfieldensis* [1:3.16]) than the proximalmost element. In *B. inaequipes*, both elements were shown to be similar in length. It is apparent that this was inadequately illustrated (see Ooishi, 2002), because the distalmost element has been recognized as the longest of all setiform elements in four known species (*B. bergensis* [not illustrated], *B. abboti*, *B. koreensis*, and *B. bamfieldensis* [illustrated]).

Table 2. Comparative lengths of armature elements on exopods of right and left leg 1 in *Botryllophilus sarsi* and its five congeners of subgroup 1. In right leg 1 exopod, "Psp : Dsp" shows a ratio of the length of the proximalmost spine (Psp) to that of the distalmost spine (Dsp). In left leg 1 exopod, "Pse : Dse" shows a ratio of the length of the proximalmost setiform element (Pse) to that of the distalmost setiform element (Dse).

Species	Right leg 1 exopod Psp : Dsp	Left leg 1 exopod Pse : Dse
B. sarsi	1:0.77	1:1.26
B. bergensis	1:0.80	unknown
B. inaequipes	unknown	1:?1.0
B. abbotti	1:0.86	1:3.16
B. koreensis	1:0.75	1:1.66
B. bamfieldensis	1:1.40	1:3.16

Therefore, a combination of the length ratios for armature elements on the exopods of right and left leg 1 of *B. sarsi* evidently differs from that of any of the last three species mentioned above. These three species can also be distinguished from each other on the same basis (see Table 2). Specific features may be found in the remaining armature elements on exopods of leg 1 or other legs.

Based on the description presented here and the above-mentioned comparative lengths of leg armature elements, *B. sarsi* can be characterized by a combination of many minor features as follows: (1) cephalosome with anteriorly rounded margin, and metasome unsegmented; (2) in antennule, first segment with relatively short major setae on distal margin and one very short independent seta at anterodistal corner; (3) paragnaths large, rounded; (4) in right leg 1 exopod, proximalmost spine slightly longer than distalmost spine, and in left leg 1 exopod, distalmost setiform element not markedly longer than proximalmost element; (5) spine protruding from posterior side of right

leg 1 exopod directed mediodistally; (6) right leg 2 endopod with 3 spiniform elements and 4 pointed long setae; (7) right leg 4 endopod with 2 spiniform elements and 3 blunt long setae; (8) gonoporal apparatus including 5 small sclerites internally; and (9) transverse slit for genital atrium not very close to anterior margin of genital segment.

The rather slender spine (Fig. 4a, V1) protruding from the posterior side of right leg 1 exopod and directed mediodistally appears to be specific for *B. sarsi*. It is stout and directed distally in *B. abbotti*, *B. koreensis*, *B. bamfieldensis*, and probably in *B. inaequipes*. In *B. bergensis*, this spine was overlooked in the original description (see Ooishi, 2000: 586), so it is not available for comparison.

The original description of *B. bergensis* lacks many other morphological details, but it is possible to include this species, for the time being, in a key to species of subgroup 1 of type A. Morphological features of *B. inaequipes* in the key are based on the description by Hansen (1923) as well as a redescription by Ooishi (2002).

Key to Species (Females) of *Botryllophilus* (subgroup 1 of type A species)

1. Metasome distinctly or weakly segmented; left legs with exopods rhomboid or sickle-shaped 2
– Metasome unsegmented; left legs with exopods rhomboid 3
2. Metasome distinctly segmented; left legs with exopods rhomboid; antennule without setal variation on first and second segments; leg 5 with conspicuous gap between 2 short distal setae . . . . . *B. inaequipes* Hansen, 1923
– Metasome weakly segmented; left legs with exopods sickle-shaped; antennule with setal variation on first and second segments; leg 5 without conspicuous gap between 2 short distal setae . . . . . *B. bamfieldensis* Ooishi, 2000
3. Leg armature formula with slight deviation from pattern I (5, 4, 4, 4, for exopods of left legs 1–4) . . . . . *B. bergensis* Schellenberg, 1921
– Leg armature formula without deviation from pattern I (5, 4, 4, 3, for exopods of left legs 1–4) 4
4. Mandibular coxa with modified gnathobasic portion; antennule with 1 long independent seta at anterodistal corner of first segment . . . . . *B. abbotti* Ooishi and Illg, 1989
– Mandibular coxa with unmodified gnathobasic portion; antennule with 1 short independent seta at anterodistal corner 5
5. Cephalosome triangular (anterior margin pointed); spine from posterior side of right leg 1 exopod directed distally; right leg 2 endopod with 4 spiniform elements and 3 pointed long setae . . . . . *B. koreensis* Seo and Lee, 1995
– Cephalosome subtriangular (anterior margin rounded); spine from posterior side of right leg 1 exopod directed mediodistally; right leg 2 endopod with 3 spiniform elements and 4 pointed long setae . . . . . *B. sarsi* Ooishi, new species

Comparison of *B. sarsi* with Similar Botryllophilins, and Consideration of Their Ascidian Hosts

The present study of *B. sarsi* makes it possible to compare this species with two unnamed North Pacific botryllophilins (MB2, ZB1). As a result, it has been found that MB2, which lives in *Aplidium solidum* (Ritter and Forsyth), more closely resembles *B. sarsi* than ZB1, which lives in *Aplidium sagamiense* (Tokioka). ZB1 can be distinguished from *B. sarsi* because the first antennular segment has longer major setae and some additional independent short setae, and the right leg 4 endopod has sharply pointed, long setae, beside spiniform elements. In MB2, these features are like those of *B. sarsi*. However, these unnamed botryllophilins can be distinguished from *B. sarsi* by the shape and position of the spine protruding from the posterior side of the exopod of right leg 1. Further detailed comparative studies will be needed to describe or identify these botryllophilins.

There is a problem with respect to the ascidian host of *B. brevipes* Sars, stated to be *Botryllus* sp. (stolidobranch), because the ascidian host for *B. sarsi* is *Polycitor vitreus* (aplousobranch). The localities, Espevær (59°35′N, 5°9′E, for *B. brevipes* Sars) and Molldøra (for *B. sarsi*), are both on the west coast of Norway.

Botryllus schlosseri and *Botrylloides leachi* (Botryllidae) are known to harbor *Botryllophilus ruber* Hesse and/or *Mychophilus roseus* Hesse at Strangford Lough (Gotto, 1954). From the west coast of Sweden, *B. ruber* has been reported by Bresciani and Lützen (1962) as an associate of *Botrylloides leachi*. However, the occurrence of *B. brevipes* Sars, together with *B. ruber* or by itself, in these botryllids has not been reported by these authors. These facts have been reconfirmed by personal communications (2001) with both Drs. Gotto and Bresciani.

I had examined many colonies of various botryllids at Roscoff where I was collecting specimens of *B. ruber* or *M. roseus* in 1992 and 1996. However, I have never found botryllophilins other than *B. ruber* in these botryllids.

The above-mentioned facts may lead us to question whether the host for *B. brevipes* Sars is

a botryllid. The ascidian hosts for the two botryllophilins (MB2, ZB1) from the North Pacific Ocean, which resemble *B. sarsi*, and for *Botryllophilus* sp. from the northwestern Atlantic Ocean, which was thought by Dudley and Illg (1991) to resemble *B. brevipes* Sars, are also aplousobranchs, as in the case of *B. sarsi*.

Acknowledgements

I am grateful to Marit Christiansen, Zoological Museum of University of Oslo (ZMO), for making it possible for me to study the specimens of *B. sarsi* from the west coast of Norway and for biographies of two scientists who collected or identified the material as *B. brevipes* Sars. I am indebted to Lutz Bachmann (ZMO) for the catalog numbers of type specimens of the new species. Åse Wilhelmsen (ZMO) helped me at the Museum and in reconfirming the data of the specimens. Dag GammelsÊter (ZMO) provided supplementary information for the localities. I thank Vivian Gotto, Queen's University of Belfast (QUB), Geoff Boxshall, Natural History Museum, London, and an anonymous reviewer for comments on the manuscript. Appreciation is extended to Gotto (QUB) and José Bresciani, Royal Veterinary and Agricultural University, for information about the occurrence of *B. brevipes* Sars in European seas, and to Edward Ruppert, Clemson University, for the data on a botryllophilin from the southeastern United States. Mark Holmes, National Museum of Ireland, shared a technique for making permanent slides. Dennis Willows, Friday Harbor Laboratories (FHL), University of Washington, provided facilities and equipment. Eugene Kozloff (FHL) helped in preparation of the manuscript.

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Received: 2 October 2001.
Accepted: 3 April 2002.