Morphology and Ontogeny of *Bathyconchoecia septemspinosa* Angel, 1970 (Ostracoda: Halocyprididae)

LOUIS S. KORNICKER
and
MARTIN V. ANGEL

SMITHSONIAN CONTRIBUTIONS TO ZOOLOGY · NUMBER 195

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ABSTRACT

Kornicker, Louis S., and Martin V. Angel. Morphology and Ontogeny of *Bathyconchoecia septemspinosa* Angel, 1970 (Ostracoda: Halocyprididae). *Smithsonian Contributions to Zoology*, number 195, 21 pages, 14 figures, 2 tables. 1975.—Appendages and carapaces of the A-1 and A-2 male and female instars and the A-4 instar (sex indeterminate) of *Bathyconchoecia septemspinosa* Angel, 1970, are described and illustrated. The ontogenetic development of the species from the A-4 to A-1 instar is discussed.

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Morphology and Ontogeny of *Bathyconchoecia septemspinosa* Angel, 1970 (Ostracoda: Halocyprididae)

Louis S. Kornicker and Martin V. Angel

Introduction

Kornicker (1969) described a new species, *Bathyconchoecia deeveyae*, ornamented with seven long spines. The description was based on a single juvenile collected in the Peru-Chile Trench System. Since that time two additional spinous specimens of *Bathyconchoecia* have been reported: a single juvenile of a new species, *Bathyconchoecia septemspinosa*, from the Eastern Atlantic by Angel (1970), and an adult male of *B. deeveyae* from the Indian Ocean by George (1972). A collection from three stations of 24 specimens of the Eastern Atlantic species, *B. septemspinosa* Angel, 1970, provided an opportunity to study its ontogeny and to examine the shell using the Scanning Electron Microscope.

We wish to thank Dr. Thomas E. Bowman for reviewing the manuscript, Mrs. Carolyn Bartlett Gast for the shaded rendering of the ostracode carapace in Figure 3, and Mr. Paul Mazer for final preparation of appendage illustrations from camera lucida drawings by the senior author. The assistance of Mr. Walter R. Brown and Miss Mary Mann, who operated the Scanning Electron Microscope at the National Museum of Natural History, is appreciated.

DISPOSITION OF SPECIMENS.—Thirteen specimens have been deposited at the British Museum (Natural History) and eleven specimens at the National Museum of Natural History, Smithsonian Institution.

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Station Data

Atlantis II, Cruise 42

(Collected by Dr. Howard Sanders and Dr. Robert Hessler)

Station 203, 23 May 1968; 8°48′S, 12°52′E; 527–542 m; epibenthic trawl.

Bathyconchoecia septemspinosa Angel, 1970: 1 A-2 ♀.

R.R.S. *Discovery*

(Collected by Dr. Martin V. Angel)

Station 7816 (5), 4 March 1972; 10°44′12″N, 17°23′18″W; 271–320 m; 0318–0405 hours; 2.4 m (width at mouth) experimental benthic trawl; foraminiferal substrate; *Bathyconchoecia subrufa* Angel, 1970, also present in sample.

Bathyconchoecia septemspinosa Angel, 1970: 21 specimens (1 A-1 ♀, 4 A-1 ♂, 2 A-1 sex unknown, 13 A-2 sex unknown, 1 A-4 sex unknown).

Station 7822 (7), 5 March 1972; 8°59′06″N, 20°16′12″W; 1203–1203 m; 1737–1818 hours; 2.4 m (width at mouth) experimental benthic trawl; foraminiferal substrate; *Bathyconchoecia subrufa* Angel, 1970, also present in sample.

Bathyconchoecia septemspinosa Angel, 1970: 1 A-1 sex unknown, 1 A-2 sex unknown.

Genus *Bathyconchoecia* Deevey, 1968

TYPE-SPECIES.—*Bathyconchoecia paulula* Deevey, 1968.

DISTRIBUTION.—Poulsen (1972:446) observed that the regional distribution of species in the genus *Bathyconchoecia*, with two exceptions, is almost exclusively tropical. A third species, *Bathyconchoecia arctica* Angel, in press, is present in high Arctic latitudes (Angel, in press). The spinous forms have a narrow latitudinal range of about 12 degrees north and south of the equator (Figure 1); no doubt additional collections will increase the range. Nonspinous species of *Bathyconchoecia* have been collected between depths of 130 to 3165 m (Poulsen, 1972:446). The shallowest depths at which spinous forms have been collected are from 271 to 320 m; the deepest depths are 3600 to 1800 m. It may be concluded that both the spinous and nonspinous forms are generally restricted to bathyal (200–2000 m) and abyssal (more than 2000 m) depths.

SYSTEMATICS.—The systematics of the spinous species of *Bathyconchoecia* is not without uncertainties. For example, the A–1? female of *B. deeveyae* described by Kornicker (1969) is pigmented in the vicinity of the head and proximal part of the 1st antenna, whereas, the adult male of that species described by George (1971) is unpigmented (George, 1974, in litt.). George (1974, in litt.) attributed the lack of pigmentation in his specimen to the length of time it was preserved in formalin. Also, the A-3 female of *B. septemspinosa* described by Angel (1970) is about the same size as the A-2 instars of that species in the present

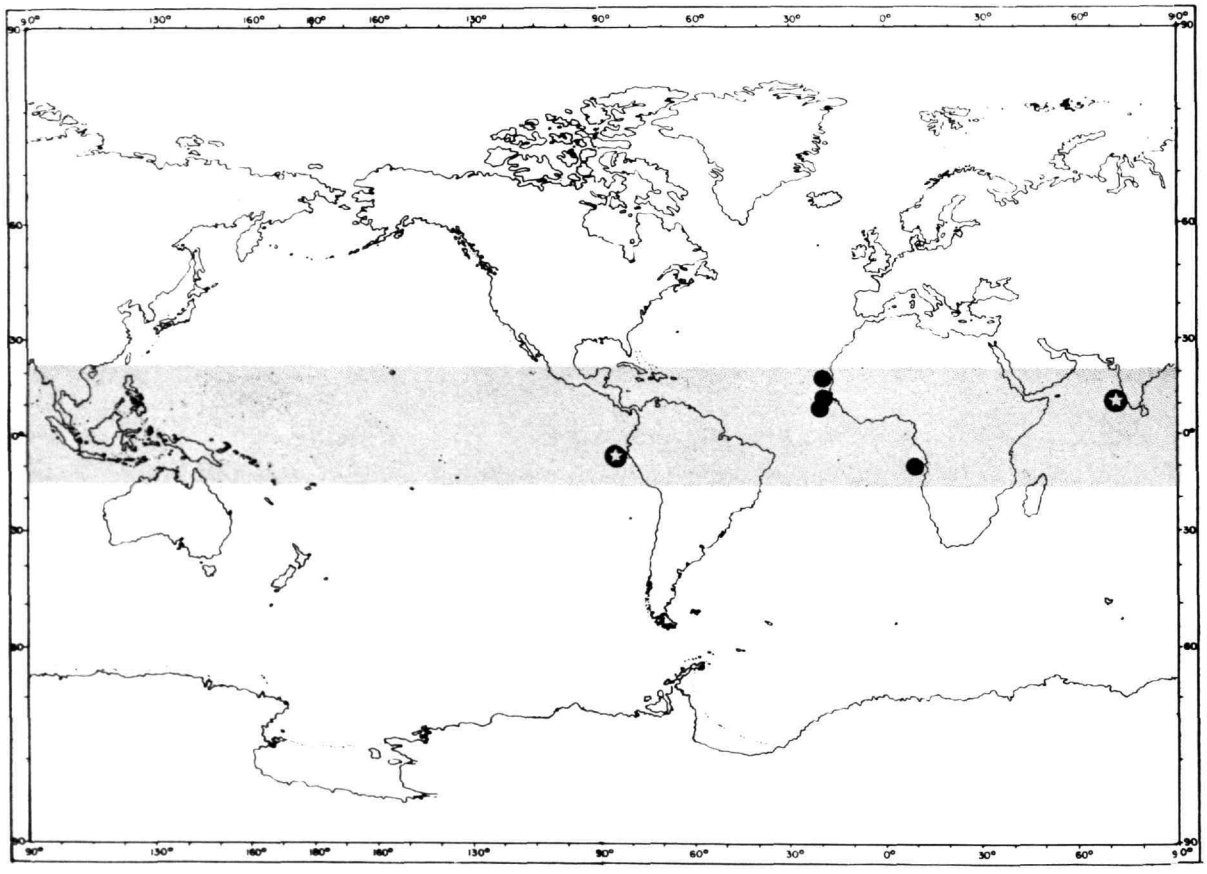

FIGURE 1.—Distribution of spinous *Bathyconchoecia*. (Stars = *B. deeveyae* Kornicker, 1969; discs = *B. septemspinosa* Angel, 1970.)

collection. Although the absence of serrated frills between fossae of *B. deeveyae* and their presence on *B. septemspinosa* seems to be a valid criterion for distinguishing the two species, their presence or absence is difficult to ascertain on decalcified specimens, and the present study indicates that they may be absent on some early juveniles of *B. septemspinosa.* The absence of pigment in *B. septemspinosa* and its presence in *B. deeveyae* was considered by Angel (1970) to be a way of distinguishing the two species. However, the present study suggests that early juveniles of *B. septemspinosa* may be without pigment, and the suggestion of George (1974, in litt.) that pigment is affected by the length of time the specimen is preserved in formalin cannot be ignored. Possibly, the two species may be separated by the number of claws on the furca: 7 on the adult *B. deeveyae* and 8 on the adult *B. septemspinosa.* Clearly, additional work is required before these problems with identification and taxonomy are resolved. For the purpose of this paper we have assumed that the known spinous forms comprise two species: *B. deeveyae,* a Pacific-Indian Ocean form, and *B. septemspinosa,* an east Atlantic form, and that the size range of similar age groups of each species is quite variable.

NOTE ON *B. deeveyae.*—While reexamining the carapace of the holotype of *B. deeveyae,* it was observed that when the carapace was transferred from alcohol to a dished slide containing a drop of glycerine, the surface of the carapace appeared distinctly punctate, but after the surface became completely wetted by glycerine, the punctae were no longer visible. The punctae became invisible after a few seconds to three minutes from the time it was transferred to glycerine. They remained visible longer when an air bubble was present inside the carapace. The same phenomenon was observed when the specimen was transferred from alcohol to immersion oil.

Bathyconchoecia septemspinosa Angel

FIGURES 2–14

Bathyconchoecia septemspinosa Angel, 1970:192, figures 7, 8.—Poulsen, 1972:453 [key].

HOLOTYPE.—Unique specimen; juvenile female; British Museum (Natural History) No. 1969.2.6.3.

TYPE-LOCALITY.—*Discovery* Station 6665, haul 38, 10°11′N, 19°38′W, depth 3600–1800 m, sounding 4800 m, 26 February 1968 (Angel, 1970:192).

DISTRIBUTION.—Eastern Atlantic between 10°44′N–8°48′S and 12°52′E–20°16′12″W. The exact depth range is uncertain because some specimens were collected in nets that traversed a wide range of depths. The shallowest depths at which the species was collected are from 271 to 320 m, the deepest depth is from 3600 to 1800 m.

ONTOGENY.—The stage of development of specimens was determined by the number of claws on the caudal furca (Table 1), which increases by one at each stage in the interval between the A-4 to A-1 instars, the range of ages in our collections. Neither fossae nor frills between fossae were perceived on the single A-4 instar nor on 11 of 15 of the A-2 instars. They were observed on a single A-3 instar (Angel, 1970:194), on 4 of the 15 A-2 instars, and on all of the 7 A-1 instars. The frills when present are more widely distributed on some specimens than on others. When restricted, the frills are generally on the ventral part of the valve. The average growth factor of length between the A-2 (15 specimens) and A-1 instars (7 specimens) is 1.43, of height 1.37. This suggests that the growth factor between these two stages is about 1.4. The distribution of instars in the present collection according to length and height of carapaces is shown in Figure 2; selected morphogical characters of the carapace and appendages of instars are listed in Table 1.

All appendages were present on the instars studied; however, the 7th limb of the A-4 instar consisted of only 1 fuzzy bristle. The two individual bristles interpreted to be 7th limbs (Figure 14*j,k*) were observed on the slide after the specimen was dissected, not in place on the undissected specimen. The bristles were interpreted to be 7th limbs because of the stout base, but it is possible that the interpretation is in error. Angel (1970) did not report the presence of a 7th limb on the A-3 female he studied.

The setation of the 1st antenna is similar in the A-4 to A-1 instars. The number of dorsal bristles on the 1st endopodial segment of the 2nd antenna increases from 1 on the A-4 and A-3 instars to 2 on the A-2 and A-1 instars, otherwise the limb is similar on all instars.

The number of stout terminal teeth of the mandibular coxa increases from 4 on the A-4 and A-3

instars to 5 on the A-2 and A-1 instars. The exact number of list teeth on the coxa is difficult to ascertain because of their small size and close proximity. The total number of list teeth increases from about 14 on the A-4 instar to 23–39 on the A-1 instar. The number of list teeth varies on specimens at the same developmental stage, and also on the left and right mandibles of the same specimen. The number of ventral bristles on the 1st endopodial segment of the mandible increases from 0 on the A-4 and A-3 instars to 2 on the A-2 instar, and to 3 on the A-1 instar. On the 2nd endopodial segment, the number of ventral bristles increases from 0 on the A-4 instar to 1 on the A-3 to A-1 instars; the number of dorsal bristles increases from 2 on the A-4 and A-3 instars to 3 on the A-2 and A-1 instars; the number of terminal bristles increases from 4 on the A-4 instar to 6 on the A-3 instar and 7 on the A-2 and A-1 instars.

The number of claws on each furcal lamella increases from 4 on the A-4 instar to 5 on the A-3 instar, 6 on the A-2 instar, and 7 on the A-1 instar.

Pigmentation was not observed in the vicinity of the head and in the proximal part of the 1st antenna on the A-4 and A-3 instars, but was observed on the A-2 and A-1 instars.

Description of Juvenile A-2 Female (Figures 3–6).—Carapace with linear dorsal margin except for slight bulge near middle and at posterior corner of each valve in vicinity of glands (Figures

Table 1.—*Stages in the development of* Bathyconchoecia septemspinosa *and comparison of characters with* B. deeveyae *arranged according to stage of development* (character present indicated by "P," absent by "A")

Character	*B. septemspinosa*							*B. deeveyae*	
	USNM 149322 A-4	Angel, 1970 A-3 ♀[1]	USNM 144009 A-2 ♀	USNM 149320B A-2 ♀	USNM 149316 A-1 ♀	USNM 149321 A-1 ♂	USNM 149324 A-1 ♂	Kornicker, 1969 A-1? ♀	George, 1971 Adult ♂
Carapace									
Length without spines, mm	0.65	1.2	1.09	1.22	1.62	1.77	1.65	1.12	1.28
Frills between fossae	A	P	P	P	P	P	P	A	A
First antenna: terminal bristles	4	4	4	4	4	4	4	4[2]	4
Second antenna: dorsal bristles on 1st endopodial	1	1	2	2	2	2	2	2	2
Mandible									
Coxa:									
Stout terminal teeth	4	4	5	5	5	5	5	5	5
Proximal list teeth	6	9	12	14	11–17	20	12–19	4–5	9
Distal list teeth	8	14	17	15	12–16	19	13–20	8–9	14
Total list teeth	14	23	29	29	23–33	39	25–39	12–14	23
Spiny bristle on anteroventral corner	P	A	P	P	P	P	P	P	P
Endopodite:									
1st, ventral bristles	0	0	2	2	3	3	3	3	3
2nd, ventral/dorsal bristles	0/2	1/2	1/3	1/3	1/3	1/3	1/3	1/3	1/2
Terminal bristles	4	6	7	7	7	7	7	7	7
Furca, claws	4	5	6	6	7	7	7	6	7
Pigmentation in proximal part of 1st antenna and extending into head region	A[3]	A	P	P	P	P	P	P	A[4]

[1] Angel (1970:197) considered this specimen to be an A-2 ♀ based on the ovarian development. It is considered here to be an A-3 ♀ because of the number of furcal claws and sparsity of bristles on appendages.

[2] Kornicker (1969:405) incorrectly gave the number of terminal bristles as "3," but illustrated the correct number "4" (1969: 406, figure 1*e,f*).

[3] The region of the head and proximal part of the 1st antenna appeared brown when viewed through the shell, but pigment spots were not visible on the extracted specimen.

[4] George (1974, in litt.).

3, 5*a*); anterodorsal corner evenly rounded except for spine on right valve (Figure 5*f*); rostrum with pointed tip and long spine pointing forward and outward (Figure 5*c*); outer surface of carapace continues onto medial side of rostrum (Figure 5*e*); incisur with continuous margin and slightly curved at inner end (Figure 5*c,e*); anteroventral, ventral, and posteroventral margins evenly rounded (Figure 5*a*); posterior margin very slightly convex (Figure 5*f*); carapace widest anterior to middle, with slight indentation slightly behind middle.

Ornamentation (Figures 3, 5*c,d*): Spines vary somewhat in length; the following measurements are for USNM 144009: rostral spines about 30 percent of carapace length; posterior spine on right valve only, parallel to dorsal margin and flush with inner edge of valve (Figure 5*f*), length about 36 percent of carapace length (Figure 3); dorsal spines just anterior to valve middle pointing upward, backward, and outward, length about 40 percent of carapace length (Figure 5*a*); spines hollow, and tapering from broad base to pointed tip, with faint elongate ribs (Figure 5*c*). Carapace punctate; anterior ventral surface near margin with slightly arcuate more-or-less radially oriented minute ridges between punctae (Figures 3, 5*c,d*); minute ribs project past edge of rostrum and anteroventral part of each valve below incisur (Figure 5*c,e*); valves sufficiently translucent to see pigmented areas in proximal part of 1st antennae and glands in posterodorsal corner of each valve (Figure 5*a*).

Central muscle scar: Located in middle of each

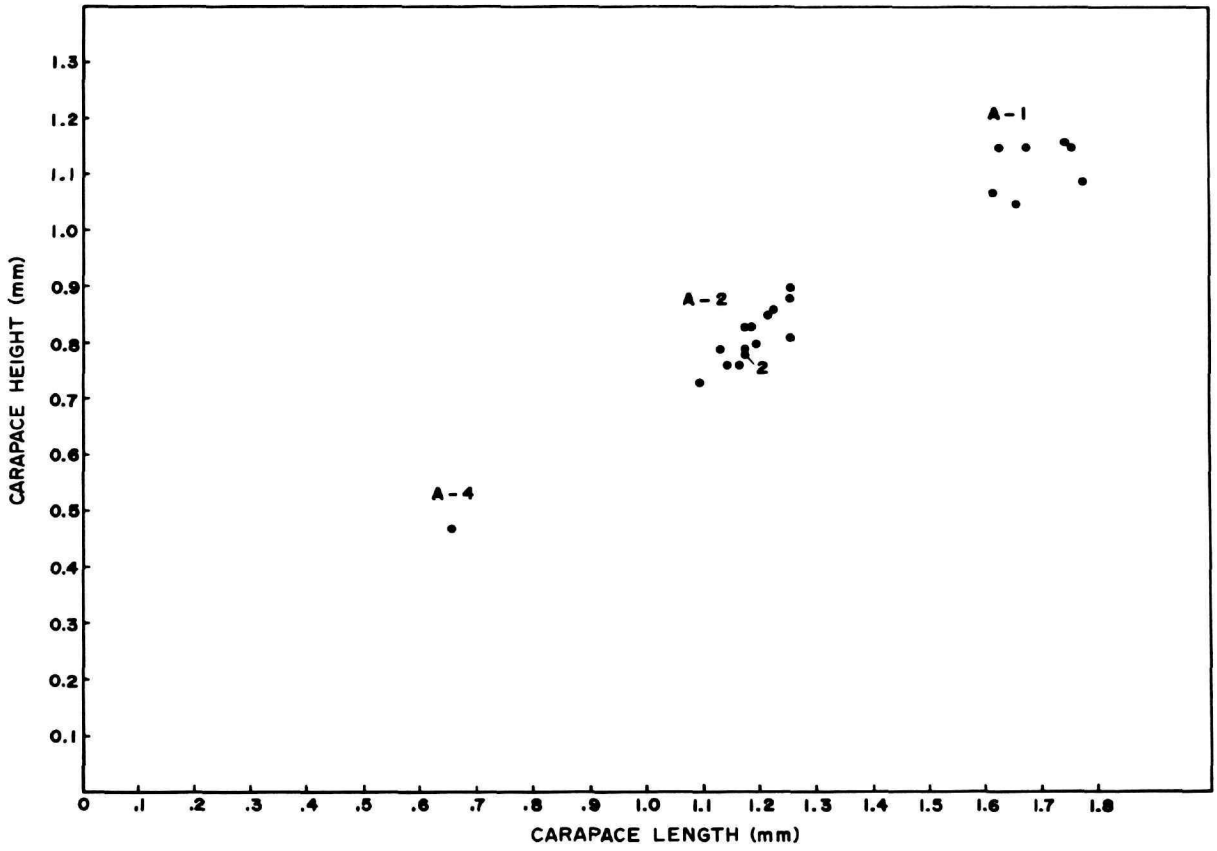

FIGURE 2.—Comparison of relationship between shell length and height of instars of *Bathyconchoecia septemspinosa* in the present collections.

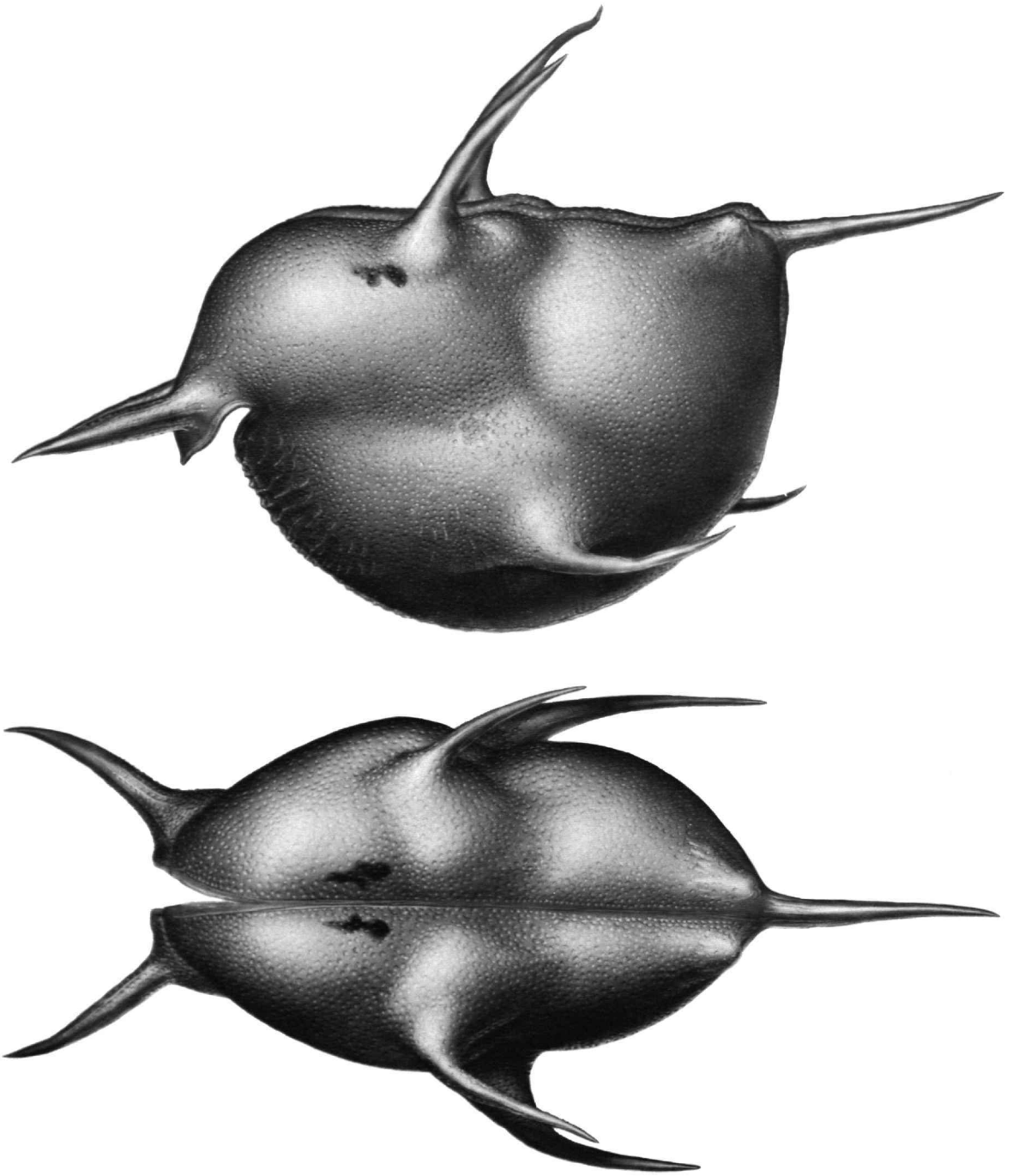

FIGURE 3.—*Bathyconchoecia septemspinosa* Angel, A-2 female, USNM 144009, length excluding spines 1.09 mm: lateral and dorsal views.

valve, indistinct, but appears to consist of small, oval, individual scars (Figure 5*a,b*).

Glands: Symmetrically located in posterodorsal corner of each valve; opening at apex of small mound (Figure 5*a,f*).

Infold: Broad behind rostrum and along anteroventral and ventral margins (Figure 5*e*), narrower along posteroventral and dorsal margins; thin list extending along middle of infold from anteroventral margin to posteroventral corner, fringed from about middle of ventral margin to middle of dorsal margin (Figure 5*g*); anteroventral, ventral, and posteroventral infold between list and valve edge with about 22 raised medial pores forming row (Figure 5*g*); a similar pore, but larger, observed behind rostrum of left valve; right valve with sclerotized crescent-shaped ridge near base of posterodorsal spine (Figure 5*f*).

Bristles: Slender bristles emerging from closed pores sparse on valve surface (Figure 5*d*), a few minute hairs present along valve margins.

Pores: Radial pores on minute protuberances sparsely distributed along valve margins (Figure 5*f*).

Micromorphology of left valve based on scanning electron photomicrographs (valve distorted during freeze-dry procedure) (Figure 4): Surface pits appear as flat-bottomed fossae with discontinuous rim (Figure 4*d–f*); thin bare ridges between punctae on anterior and ventral parts of carapace not clearly discernible, but appearing as white lines in Figure 4*d–f*.

Size: USNM 144009, length including spines 1.74 mm, length excluding spines 1.09 mm, height including spines 0.96 mm, height excluding spines 0.73 mm.

Slender sparse bristles emerge from pores without visible openings around base (Figure 4*g*). Pores present between selvage and anteroventral, ventral, and posteroventral valve edge (Figure 4*j–l*). Outer margin of list with toothlike fringe (Figure 4*h,i*).

First antenna (Figure 5*i*): Shaft short with indistinct segmentation. Brushlike structure with about 189 filaments in about 9 rows, each with about 21 filaments. Dorsal bristle on segment following brushlike structure stout, spinous, about three-fourths length of brushlike filaments. Terminal segment with 4 bristles; 3 slightly longer than bristle on previous joint, 1 much longer, reaching well past brushlike filaments and with widely scattered marginal spines. Proximal part of limb with centers of black pigment.

Second antenna (Figure 5*j–l*): Protopodite bare. Endopodite 2-segmented (Figure 5*j*): 1st segment with 2 spinous bristles; 2nd segment with 3 medium length bristles on proximal part and 2 long terminal bristles on small pedestal, all bristles on 2nd segment with widely scattered marginal spines. Exopodite 9-segmented (Figure 5*k–l*): segment 1 with minute faint teeth along ventral margin and short medial bristle extending past distal margin of 2nd segment; segments 2 to 8 with long bristles with natatory hairs; 9th segment with 4 bristles (Figure 5*l*), 1 long, 1 medium, 1 short bristle with widely scattered marginal spines, and 1 very short bristle with few marginal spines; distal margins of joints 2 to 8 with minute, very faint spines forming row.

Mandible (Figure 6*a–e*): Ventral margin or coxa divided in posterior part with teeth and anterior part with spines (Figure 6*c–e*); posterior part consisting of lateral and medial sections; lateral section with triangular anterior part with pointed tip and posterior part with serrate posterior margin and 5 terminal teeth decreasing in size anteriorly; medial section with anterior (proximal list) and posterior (distal list) groups of teeth along ventral margin; anterior group with teeth forming V-shaped row with apex of V pointing anteriorly and 6 teeth (including apical tooth) along medial arm of V, and 5 and 6 teeth (excluding apical tooth) along lateral arm of V; posterior group with teeth forming roughly 4 rows: medial row with 2 teeth, rows lateral to medial row with 4, 3, and 5 teeth; part of an additional 5th row with 3 teeth present lateral to anterior teeth of 4th row; anterior spined part of coxa with long ventral spines divided roughly into 5 groups; anterior ventral corner anterior to spines with short stout bristle similar to that illustrated by Kornicker (1969) for *B. deeveyae* (Figure 6*e*) (bristle broken off right limb of USNM 144009). A few minute spines present on medial side of coxa proximal to teeth and long spines.

Basis with 5 triangular teeth on ventral margin, each with about 10 minute secondary teeth along sides except at tip (Figure 5*a,b*); one posterior tooth on posterior margin proximal to 5 ventrally located teeth; 1 tubelike bristle and 1 short stout toothlike bristle on posterior margin proximal to

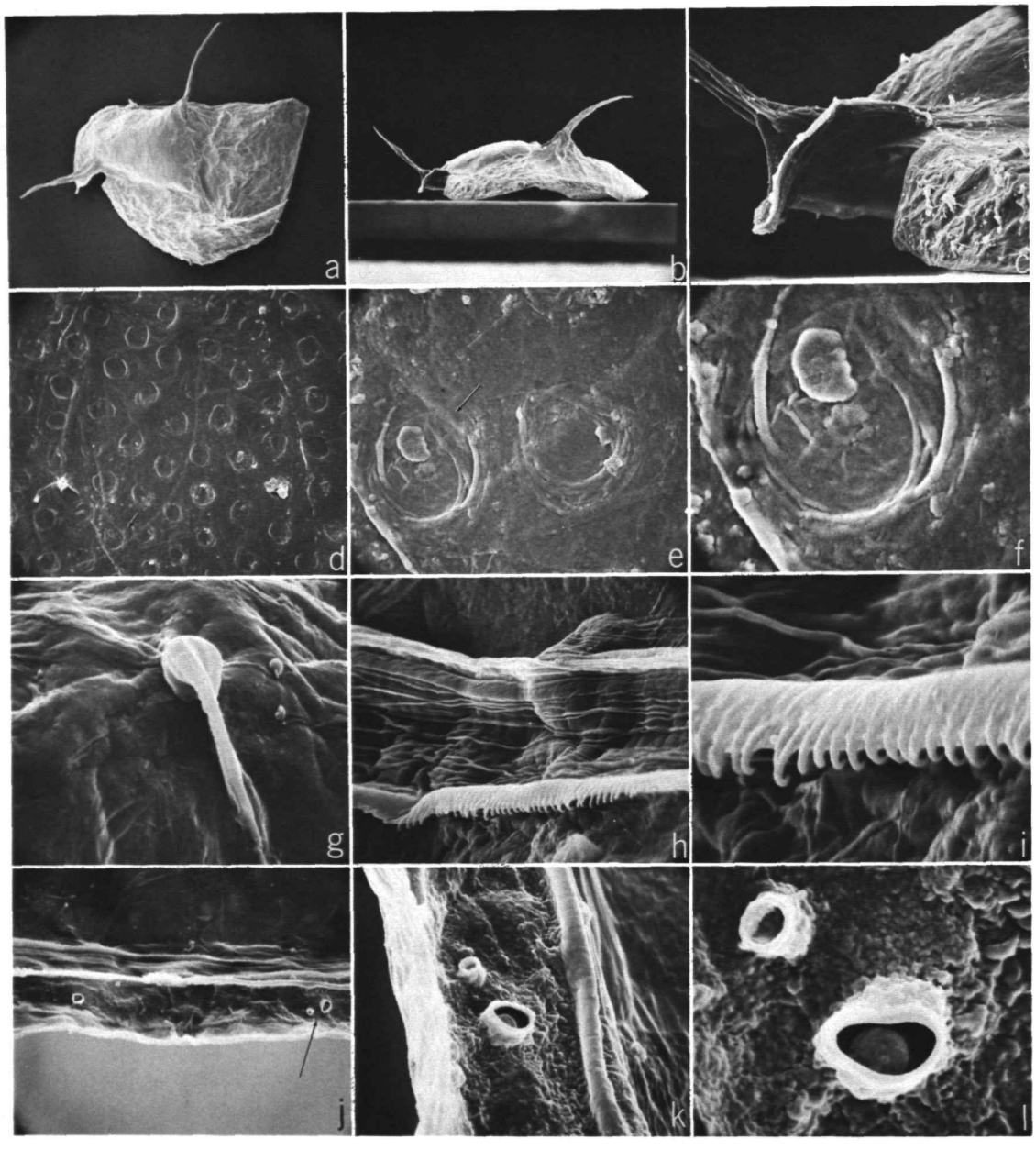

FIGURE 4.—*Bathyconchoecia septemspinosa* Angel, A-2 female, USNM 144009, left valve: *a*, lateral view (valve distorted during freeze-drying operation in preparation for use with the Scanning Electron Microscope), × 70; *b*, same, ventral view, × 70; *c*, ventral view of anterior part of valve showing incisur, × 1400; *d*, fossae on lateral surface of valve, × 1000; *e*, detail of fossae shown in *d* (see arrow in *d*), × 5000; *f*, fossae from *e* (see arrow in *e*), × 10,000; *g*, rare surface hair, × 7000; *h*, ventral margin from inside showing serrate list, × 3600; *i*, detail of list shown in *h*, × 11,000; *j*, ventral margin from inside showing pores ventral to serrate list, × 900; *k*, detail of 2 pores shown in *j* (see arrow in *j*), × 3600; *l*, same pores shown in *k*, × 9000. (Figures reduced to 52% for publication.)

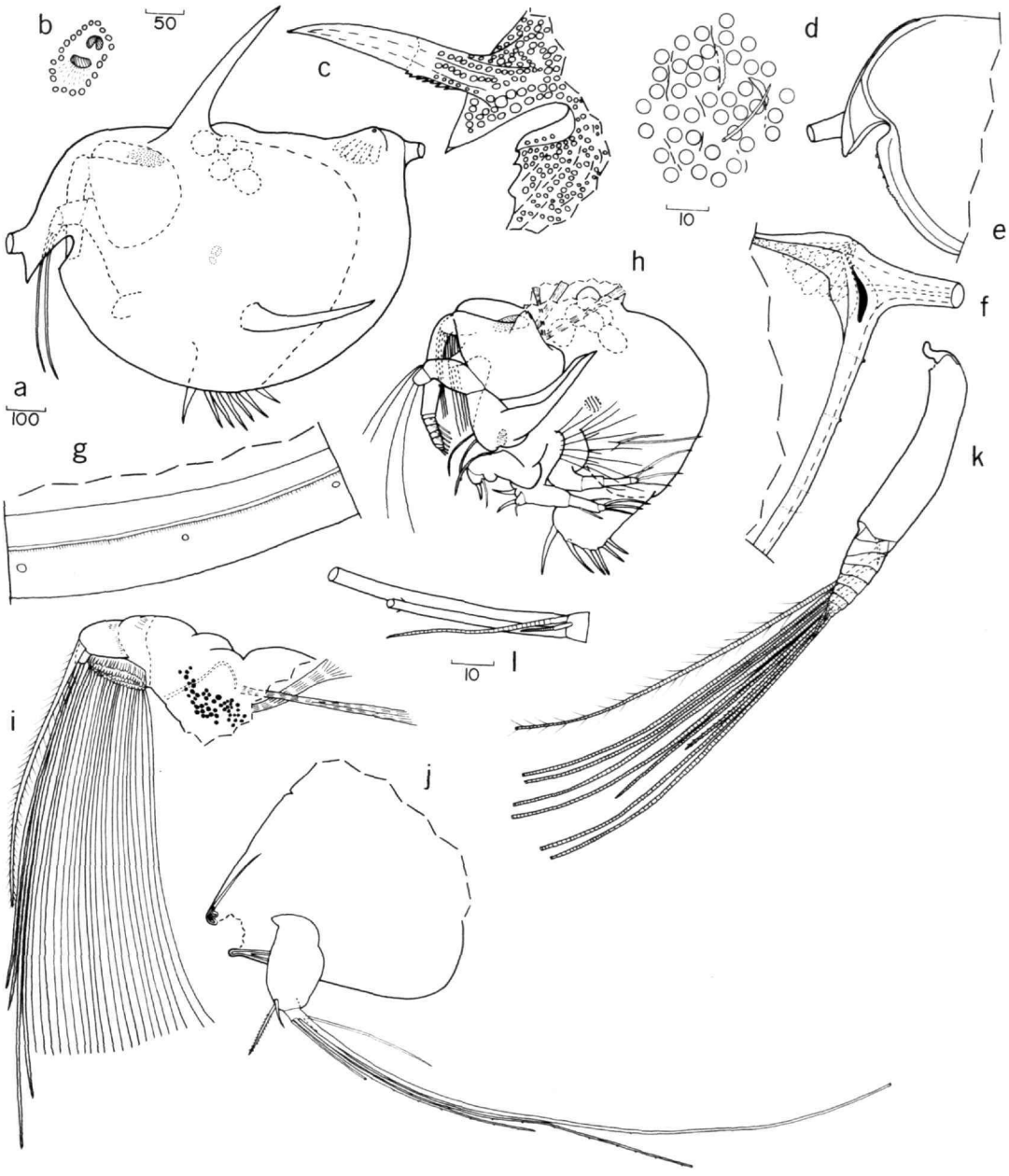

FIGURE 5.—*Bathyconchoecia septemspinosa* Angel, A-2 female, USNM 144009: *a*, complete specimen, left side; *b*, adductor muscle attachment scars (crosshatched) on left valve with surrounding fossae, anterior to left; *c*, anterior of left valve; *d*, detail of surface showing fossae, a few frills between fossae, and a single hair; *e*, anterior of right valve from inside; *f*, posterior of right valve from inside; *g*, ventral margin of right valve from inside; *h*, animal with shell removed, only left appendages shown (not all bristles on appendages shown); *i*, left 1st antenna, lateral view; *j*, protopodite and endopodite of right 2nd antenna, medial view (all natatory hairs not shown); *k*, exopodite of right 2nd antenna, lateral view; *l*, 9th joint of exopodite shown in *k* (marginal spines not shown). (Same magnification in microns: *a,e,h; b,c,f,i-k; d,g.*)

FIGURE 6.—*Bathyconchoecia septemspinosa* Angel, A-2 female, USNM 144009: *a*, basis and endopodite of right mandible, medial view; *b*, tip of basis shown in *a*; *c*, coxa of right mandible, medial view; *d*, tip of coxa shown in *c*; *e*, spinous bristle on anteroventral corner of coxa of left mandible, medial view; *f*, maxilla; *g*, 5th limb; *h*, 2 bristles of epipodite of 5th limb; *i*, 6th limb; *j*, left lamella of furca; *k*, head region showing rod-shaped organ (arrow). (Same magnification in microns: *a,j,k; c,f,g,i; b,d,e*.)

posterior tooth; anterior margin of basale with 1 long bristle with faint short marginal spines; lateral side of basis proximal to teeth with 3 long stout bristles with short marginal spines (Figure 5*a*); medial side of basis with 2 long proximal bristles (1 of these near dorsal margin) with long marginal hairs (Figure 5*a*).

Endopodite 3-segmented (Figure 6*a*): 1st segment with long hairs on medial and lateral surfaces and 3 bristles: 1 terminal dorsal bristle with short distinct marginal spines, 2 ventral bristles near distal margin (1 lateral with short marginal spines, 1 medial with few spines near tip). Second segment with few medial spines forming 1 or 2 rows, and 3 terminal bristles, 1 ventral with few spines near tip, 3 dorsal (2 long, 1 short, all with short marginal spines); end segment with 4 ventral bristles (1 of these with base on lateral side) with short faint marginal spines, and 3 terminal bristles (of these, ventral bristle very long, unringed, claw-like with short distinct spines on both margins, remaining 2 bristles much shorter, ringed, and also with short distinct marginal spines); medial surface of end joint with tightly packed long hairs forming cluster near middle.

Maxilla (Figure 6*f*): Endite of precoxa with 2 short slender bristles, 3 short stout faintly pectinate ventral bristles followed by 2 stout, longer ventral bristles with long marginal spines; endite of coxa with 6 short, stout, faintly pectinate, unringed bristles, 2 slightly longer, pectinate, ringed bristles, and 3 short slender bristles. Basis with 2 long stout hirsute bristles, 1 dorsal, 1 lateral (this bristle could be on 1st endopodial segment); small lobe with short stout bristle present on lateral side of basis (could be on proximal end of 1st endopodial joint) near dorsal margin (exopodite?). Endopodite: dorsal margin of 1st joint with long hairs and 3 bristles, 2 proximal with few long proximal hairs and closely packed short distal hairs, 1 distal with few long proximal hairs and widely spaced short distal spines; ventral margin with 3 bristles (inner 2 of these with bases actually on medial surface), outer bristle with short marginal spines, middle bristle with few long proximal hairs and short distal spines, inner bristle about one-half length other bristles and with short marginal spines located in distal ventral corner near the 3 posterior and medial bristles; lateral surface also with short spines near ventral margin. End segment with 2 terminal claws (1 short, ventral, very faintly pectinate and 1 longer, dorsal, also very faintly pectinate) and 4 slender bristles between the claws, 2 medial, 2 lateral, all bare, or with few faint

TABLE 2.—*Morphological characters of A-2 instars observed without opening carapace and determining sex* (last specimen in list, USNM 149320B, from *Discovery* station 7822/7, remaining specimens from *Discovery* station 7816/5)

Length excluding spines (mm)	*Height measured from straight dorsal margin (mm)*	*Color of pigment in area of head region and base of 1st antenna*	*Fossae and frills on carapace surface*
1.16	0.81	brown	not visible
1.21	0.90	brown	not visible
1.25	0.90	brown	not visible
1.17	0.78	brown	not visible
1.19	0.80	brown	not visible
1.17	0.78	amber	not visible
1.25	0.88	amber	not visible
1.17	0.79	amber	not visible
1.18	0.83	amber	not visible
1.17	0.84	amber	not visible
1.12 (shell torn)	0.79	amber	not visible
1.25 (shell distorted)	0.81	brown	fossae and frills visible; frills ventral only
1.14 (shell torn)	0.76	no data	fossae and frills visible
1.22	0.86	brown	fossae and frills all over shell

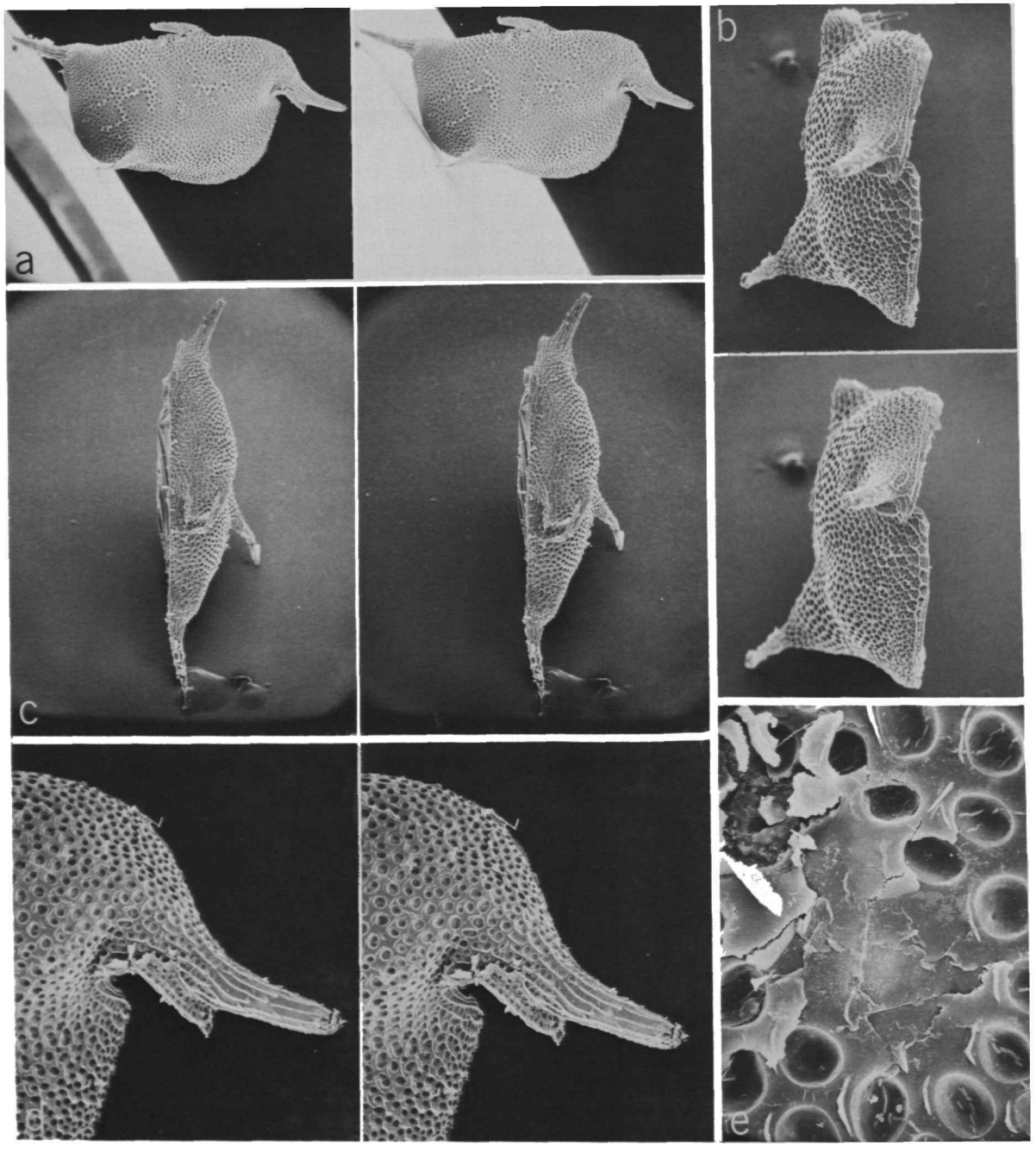

FIGURE 7.—*Bathyconchoecia septemspinosa* Angel, right valve of A-1 female, USNM 149316: *a*, stereo pair of valve from outside, × 36; *b*, stereo pair of valve from anterior, × 70; *c*, stereo pair of valve, dorsal view, × 40; *d*, stereo pair of anterior, × 125; *e*, smooth outside surface in vicinity of adductor muscle attachment, anterior to right, × 660. (Figure reduced to 68% for publication.)

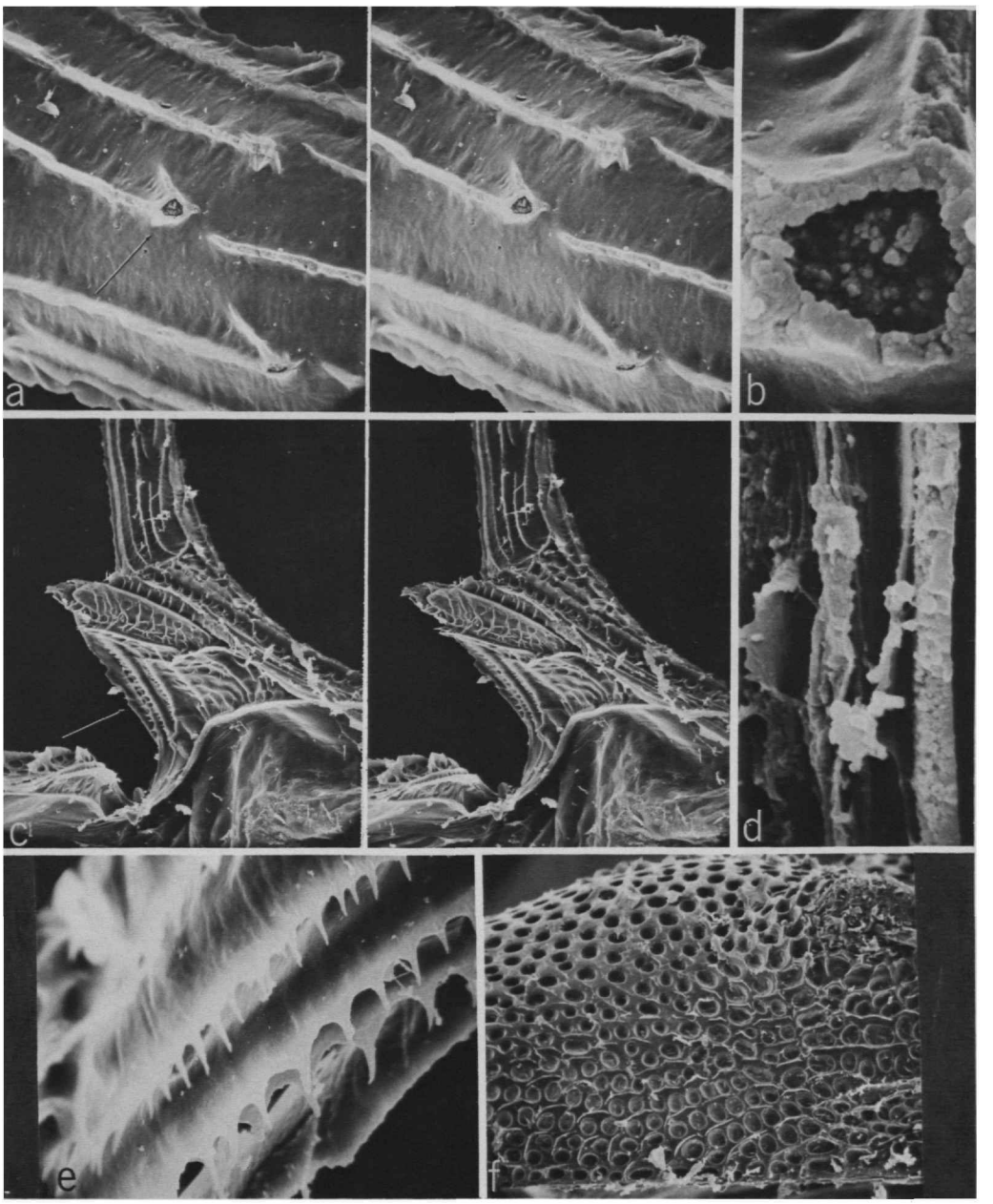

FIGURE 8.—*Bathyconchoecia septemspinosa* Angel, right valve of A-1 female, USNM 149316: *a*, stereo pair of part of anterior spine near base, × 1250; *b*, detail of remnant of broken tip of rib on anterior spine (for location see arrow in *a*), × 10,200; *c*, stereo pair of anterior of valve from inside, anterior of valve toward top, × 260; *d*, cross section of dorsal margin of valve from inside, dorsal margin of valve to right, × 7500; *e*, serrated frills along inner ventral margin of rostrum, ventral margin toward bottom (for location see arrow in *c*), × 1950; *f*, dorsal view of part of valve shown in Figure 6*c*, note base of dorsal spine at upper left, × 190. (Figures reduced to 62% for publication.)

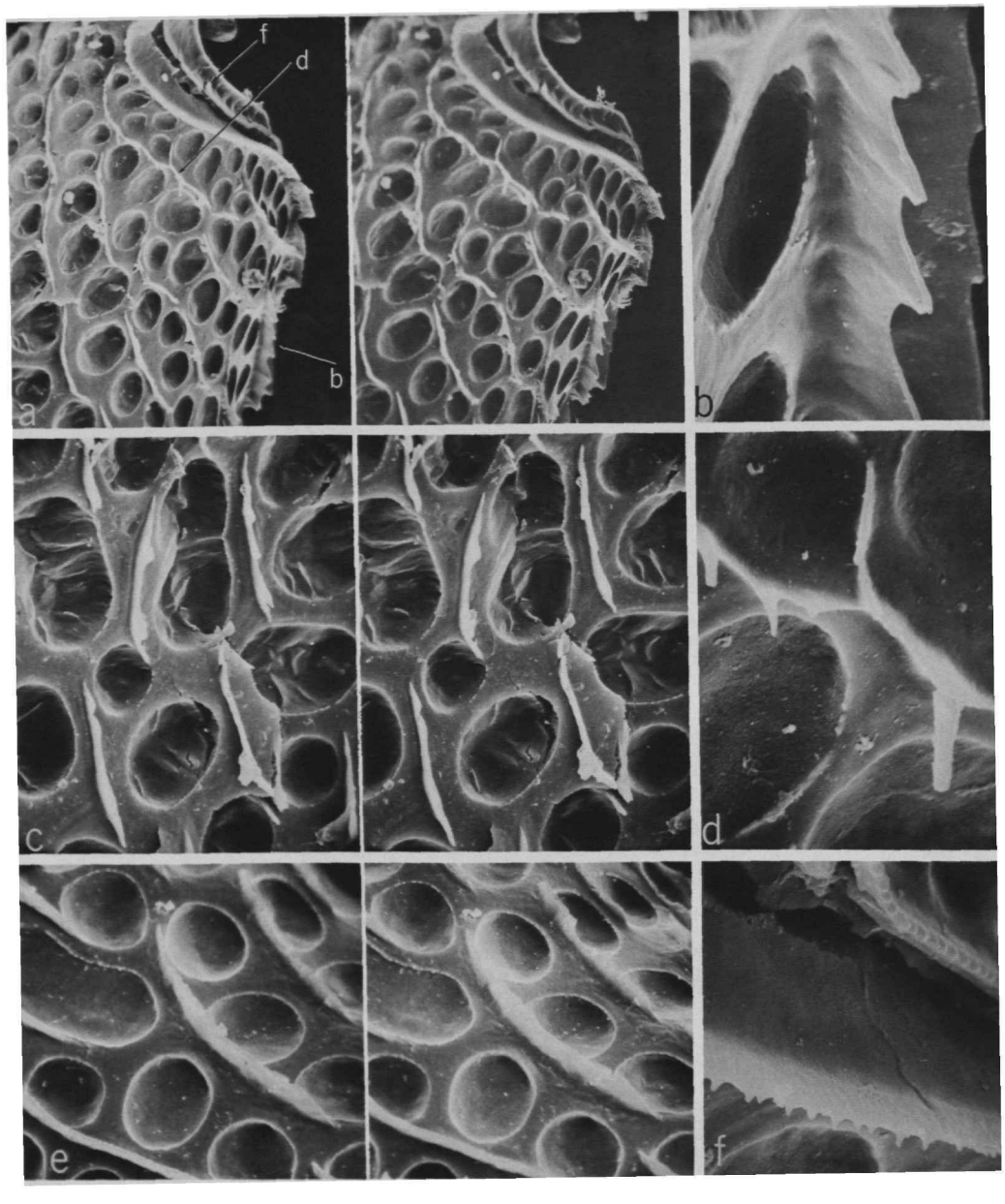

FIGURE 9.—*Bathyconchoecia septemspinosa* Angel, right valve of A-1 female, USNM 149316: *a*, stereo pair of anterior part of valve below incisur, outside view, × 650; *b*, detail of fossae and serrate frill near anteroventral margin of valve (for location see arrow in *a*), × 4220; *c*, stereo pair of fossae and frills on outer surface of valve, × 1250; *d*, detail of serrate margin of frill (for location see arrow in *a*), × 4030; *e*, stereo pair of fossae and frills on anterior spine near base, × 1250; *f*, ridges along ventral margin of incisur, note papillate edge of upper ridge and serrate margin of lower ridge (for location see arrow in *a*). (Figures reduced to 62% for publication.)

marginal spines; abundant short spines present on surface of segment ventral to short claw.

Fifth limb (Figure 6*g,h*): Exopodite 3-segmented: 1st segment with 1 very long, stout, subterminal dorsal bristle with widely spaced short marginal spines, 2 ventral bristles (1 proximal, 1 distal, both with short marginal spines), and 3 or 4 lateral or medial bristles; 2nd segment with 2 ventral bristles near middle and 1 subterminal dorsal bristle, all with short marginal spines. End segment with 3 bristles: ventral bristle slender with marginal spines; middle bristle stout, faintly pectinate; dorsal bristle longer than middle bristle, faintly pectinate.

Sixth limb (Figure 6*i*): Protopodite with 1 terminal dorsal bristle with long marginal spines. Exopodite 4-segmented: 1st segment with 2 spinous ventral bristles (1 near middle, 1 terminal), 1 lateral bristle, and 1 very long terminal dorsal bristle with short marginal spines; 2nd segment with 1 slender terminal ventral bristle; 3rd segment with 1 ventral bristle and 1 dorsal bristle with location

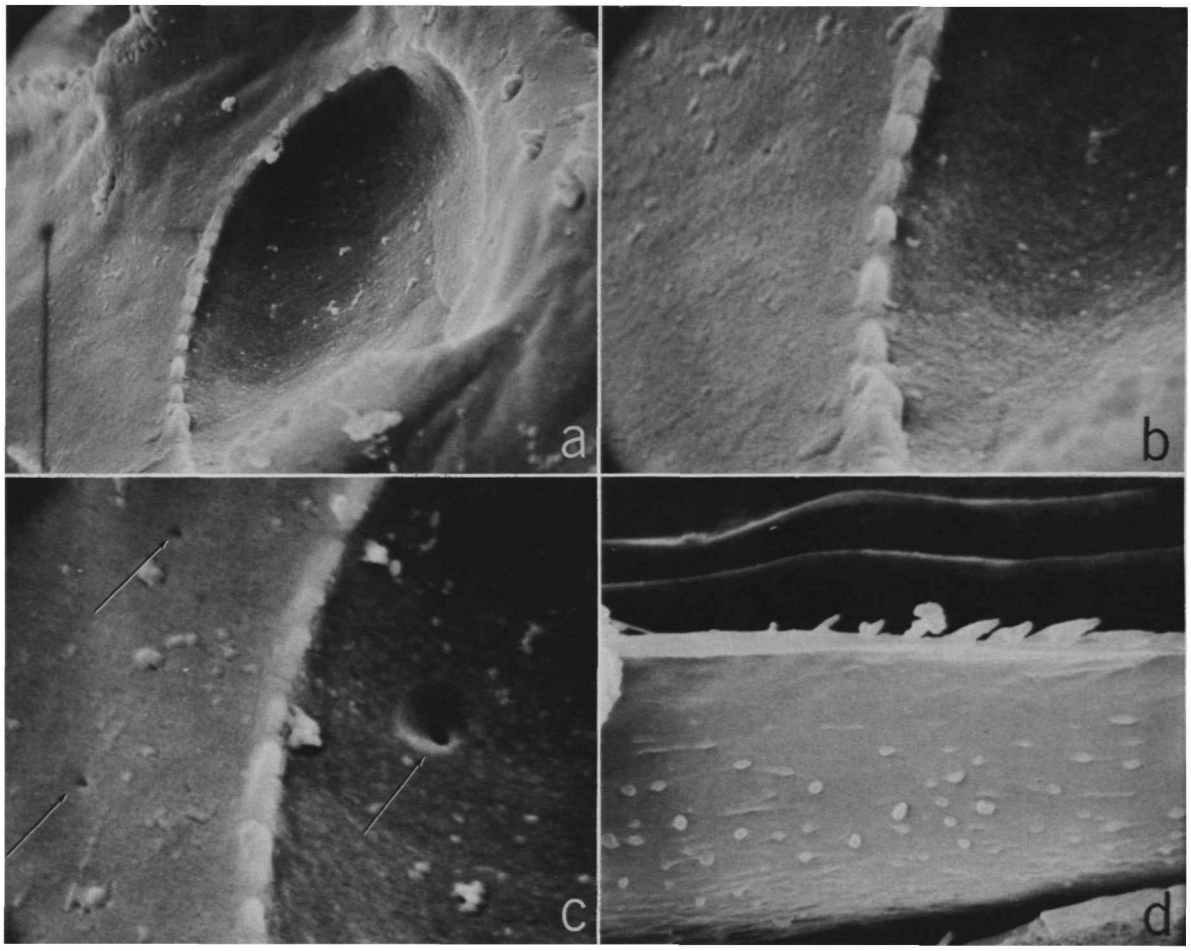

FIGURE 10.—*Bathyconchoecia septemspinosa* Angel, right valve of A-1 female, USNM 149316: *a*, fossae showing papillate border, × 5300; *b*, detail of papillate border shown in *a*, × 10,000; *c*, detail showing pore in fossae (arrow) and 2 smaller pores on surface between fossae (arrows), × 12,000; *d*, serrated list near ventral margin of valve, ventral margin of valve toward bottom, inside view, × 8500. (Figures reduced to 81% for publication.)

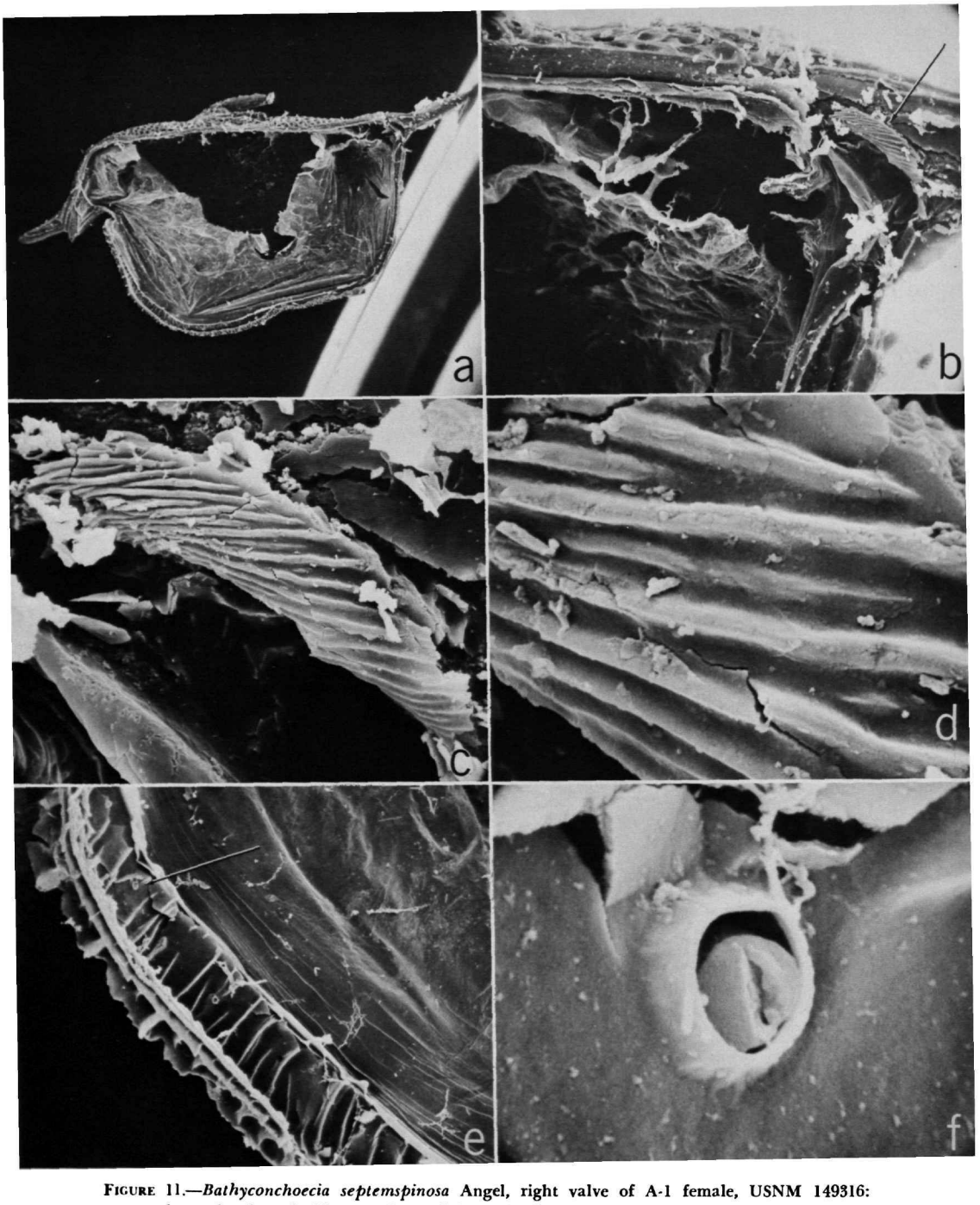

FIGURE 11.—*Bathyconchoecia septemspinosa* Angel, right valve of A-1 female, USNM 149316: *a*, complete valve from inside, anterior to left, × 45; *b*, posterodorsal corner, × 320; *c*, dentate structure in posterodorsal corner of valve (for location see arrow in *b*), × 1500; *d*, detail of dentate structure shown in *c*, × 6500; *e*, anteroventral margin of valve from inside, × 390; *f*, pore shown in *e* (for location see arrow in *e*), × 10,000. (Figures reduced to 77% for publication.)

of base about one-fourth length of segment measured from distal margin; end segment with 3 subequal bristles.

Seventh limb: Consisting of 2 bristles on broad base (Figure 5*h*).

Furca (Figure 6*j*): Each lamella with 6 claws followed by low triangular process; all claws with teeth along posterior margins; a spinous bristle following triangular process on left lamella.

Rod-shaped organ: A small knob (Figure 6*k*) between the 1st antennae may represent the rod-shaped organ.

DESCRIPTION OF A-2 INSTARS (sex undetermined).—Carapace similar to that of A-2 female described above except as noted in Table 2.

DESCRIPTION OF A-1 FEMALE (Figures 7–12).—Carapace similar to that of A-2 female except fossae more distinct and serrate frills between fossae more abundant (Figures 7–11, 12*a–d*).

Micromorphology of right valve based on scanning electron photomicrographs: Surface fossae appear as dished round-to-elongate-oval fossae, each with a continuous rim formed of papillae (Figure 10*a–c*); short serrate ridges present between fossae on all parts of valve (Figures 7, 8*f*, 9*a,c,e*); serrate ridges forming parallel rows on medial side of rostrum (Figure 8*c–e*); ridges also present on spines, some with knobbed and hooked ends (Figure 8*a,b*). Area of central muscle attachments free of fossae (Figure 7*e*). Minute pores sparsely scattered over valve surface and some occur in fossae (Figure 10*c*). Outer margin of list with toothlike fringe (Figure 10*d*). Pores present between selvage and valve edge (Figure 11*e,f*). Posterodorsal corner of each valve with dentition consisting of pad with about 25 irregular ridges (Figure 11*b–d*).

Size: USNM 149316, length with spines 2.37 mm, length without spines 1.62 mm, height with dorsal

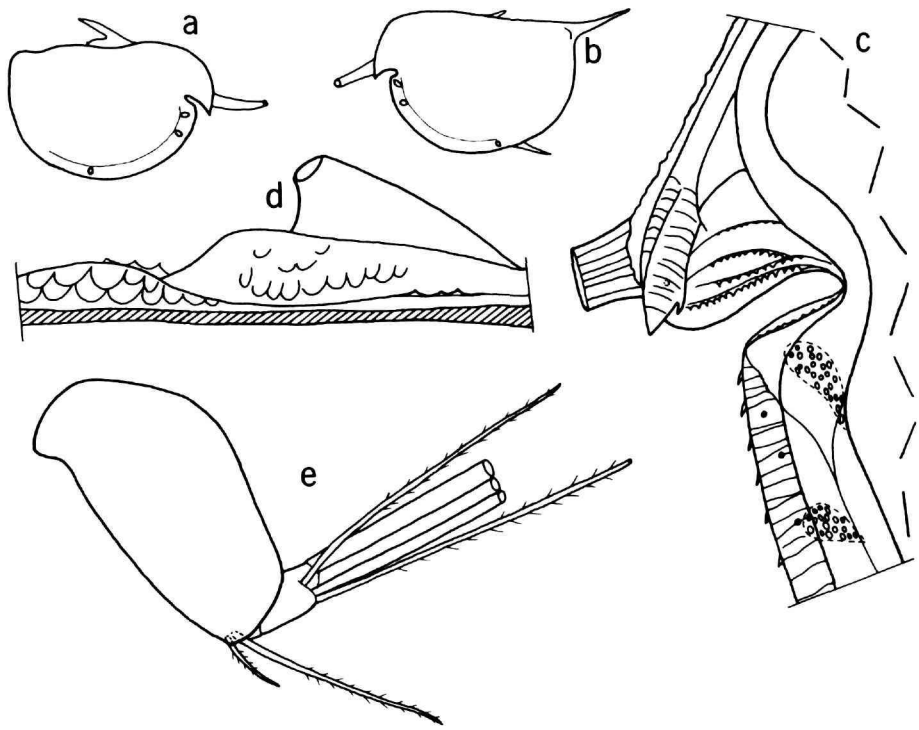

FIGURE 12.—*Bathyconchoecia septemspinosa* Angel, A-1 female, USNM 149316, length excluding spines 1.65 mm: *a*, left valve from inside; *b*, right valve from inside; *c*, anterior of right valve from inside; *d*, part of dorsal margin of left valve, dorsal view; *e*, endopodite of right 2nd antenna, medial view.

FIGURE 13.—*Bathyconchoecia septemspinosa* Angel, A-1 male: *a*, posterodorsal margin of right valve from inside; *b*, posterodorsal corner of left valve from outside (drawn with transmitted light); *c*, posterodorsal corners of left and right valves spread under cover slip, inside view; *d*, endopodite of left 2nd antenna, medial view; *e*, tip of coxa of right mandible, medial view; *f*, same, left mandible, medial view; *g*, list teeth of left mandible, medial view; *h*, left furcal lamella and distal part of copulatory organ (details of tip of styliform lobe not shown); *i*, claw 1 of right furcal lamella showing sutures; *j*, tip of anterior lobe of copulatory organ shown in *h*; *k*, styliform lobe of copulatory organ shown in *h*. (*a,b* from USNM 149323; *c,e,g* from USNM 149324; *d,f,h-k* from USNM 149321.) (Same magnification in microns: *a,b,h; c,d,i-k; e-g*.)

spine 1.62 mm, height measured from straight dorsal hinge 1.15 mm, height measured from dorsal bulge 1.22 mm, width excluding spines 0.90 mm.

First antenna, second antenna (Figure 12*e*), *fifth, sixth, seventh limbs, rod-shaped organ*: Similar to those on A-2 female.

Mandible: 1st endopodial segment with 3 ventral bristles; 2nd endopodial segment with 7 terminal bristles; limb otherwise similar to those of A-2 female.

Furca: Each lamella with 7 claws.

Pigmentation: Similar to that of A-2 female.

Description of A-1 Male (Figure 13).—Carapace similar to that of A-1 female (Figure 13*a–c*).

Size: USNM 149323, length excluding spines 1.74 mm, height measured from straight dorsal hinge 1.16 mm; USNM 149328, length excluding spines 1.75 mm, height measured from straight dorsal hinge 1.15 mm; USNM 149321, length excluding spines 1.77 mm, height measured from straight dorsal hinge 1.09 mm; USNM 149324, length excluding spines 1.65 mm, height measured from straight dorsal hinge 1.05 mm.

First antenna: Similar to that of A-2 female.

Second antenna: Protopodite bare. Endopodite 3-segmented (Figure 13*d*): 1st segment with 2 spinous distodorsal bristles, 1 short, 1 long; 2nd joint with 2 long bristles with widely spaced marginal spines; 3rd segment with 3 bristles, all with marginal spines, middle bristle longer than others; 3rd joint positioned medially of 2nd joint and similar in size on both limbs. Exopodite similar to that on A-2 female except 9th joint bears 4 bristles, 2 short and 1 medium length with spines, 1 long with natatory hairs.

Mandible (Figure 13*e–g*): Coxale with 12–20 teeth on proximal list and 13–20 teeth in distal list (Figure 13*e–g*), otherwise similar to that on A-2 female. Basis similar to that on A-2 female. Endopodite 3-segmented: 1st segment with 4 bristles, 3 ventral, 1 dorsal; 2nd segment with 4 bristles, 1 ventral, 3 dorsal; limb otherwise similar to that of A-2 female.

Maxilla: Similar to that of A-2 female.

Fifth limb: Exopodite similar to that of A-3 female except 2nd segment with additional ventral bristle (3 total).

Sixth limb, seventh limb: Similar to those of A-2 female.

Furca (Figure 13*h,i*): Similar to that of A-2 female except for having 7 claws; subdued triangular process following claw 7. Claws with lateral and medial teeth forming 2 rows along concave margin; claw 1 with faint dorsal hairs near distal end; 4 or 5 faint sutures visible on claw 1 of right lamella (Figure 13*i*) when observed under high magnification (× 400) (other claws not examined under high magnification).

Rod-shaped organ: Small knob present similar to that of A-2 female.

Copulatory organ (Figure 13*h,j,k*): Consisting of large anterior lobe with few minute serrations along ventral edge (Figure 13*j*) and posterior styliform lobe with 2 spines at tip (Figure 13*k*).

Description of A-1 Instars (sex not determined).—Two specimens with carapaces similar to that of A-1 ♀; brown pigment observed through shell in area of head and anterior part of 1st antennae; fossae and frills observed all over surface of each valve.

Size: USNM 149320A, length excluding spines 1.61 mm, height measured from straight dorsal margin 1.07 mm; British Museum specimen, length excluding spines 1.67 mm, height measured from straight dorsal margin 1.15 mm. (USNM 149320A with 7 furcal claws.)

Description of A-4 Instar, USNM 149322 (sex indeterminate) (Figure 14).—Carapace (Figure 14*a–c*) decalcified; similar to carapace of A-2 female except no fossae or frills visible. (Although the region of the head and proximal part of the 1st antenna appeared brown when viewed through shell, no pigment was visible in those areas on animal when removed from shell.)

Size: Length excluding spines 0.65 mm, height measured from straight dorsal hinge 0.47 mm.

First antenna: Similar to that of A-2 female, except without pigment.

Second antenna: Protopodite bare. Endopodite 2-segmented (Figure 14*d,e*): 1st segment with 1 spinous bristle; 2nd segment weakly divided into dorsal and ventral parts having 3 bristles on dorsal part and 2 on ventral part. Exopodite similar to that of A-2 female except 9th joint with 3 bristles, 1 long with natatory hairs, 1 medium with marginal spines, and 1 short bristle; only 8 segments were observed on exopodite of right limb, the only one examined in detail.

Mandible (Figure 14*f–i*): Only single list present on coxa, but this consisting of about 14 teeth form-

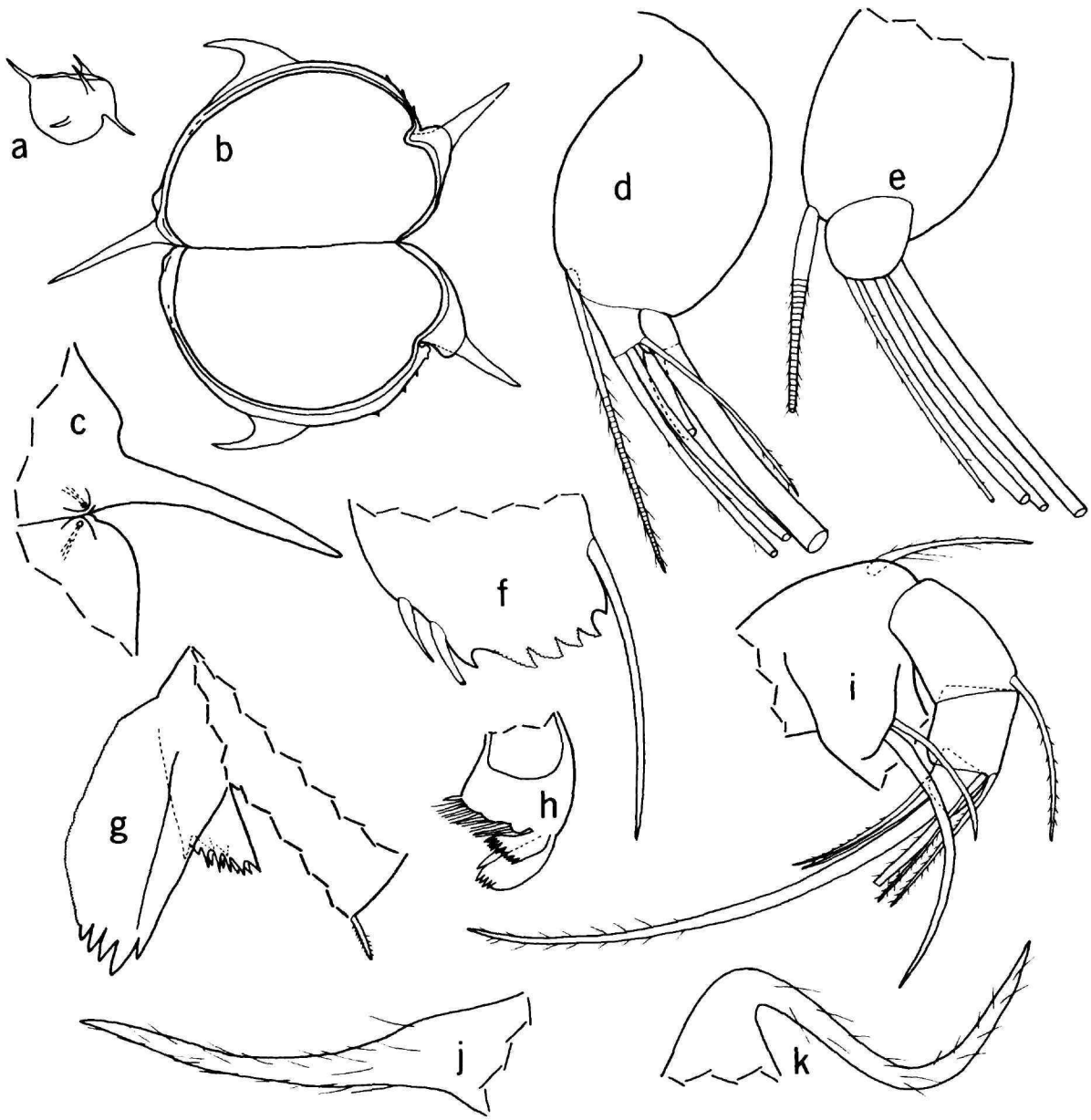

FIGURE 14.—*Bathyconchoecia septemspinosa* Angel, A-4 instar, USNM 149322B, length excluding spines 0.65 mm: *a*, lateral view from right of complete specimen; *b*, inside view of both valves spread under cover slip; *c*, outside view of spread valves showing location of glands in postero-dorsal corner of each valve; *d*, endopodite of right 2nd antenna, medial view; *e*, same of left 2nd antenna, lateral view; *f*, tip of basis of right mandible, lateral view; *g*, tip of coxa of right mandible, lateral view; *h*, same, medial view; *i*, proximal part of basis and endopodite of right mandible, lateral view; *j*, *k*, 7th? limbs. (Same magnification in microns: *h*,*i*; *d*-*g*, *j*,*k*.)

ing 2 rows probably equivalent to proximal and distal lists (Figure 14*g,h*): proximal list (lateral row) with about 6 teeth, distal list (medial row) with about 8 teeth. Basis: lateral side with 2 long bristles (Figure 14*i*); medial side with 1 spinous bristle near dorsal margin (Figure 14*i*). Endopodite (Figure 14*i*): 1st segment with terminal spinous dorsal bristle; 2nd segment with 2 terminal spinous dorsal bristles; end segment with 4 bristles, one of these long, clawlike. Limb otherwise similar to that of A-2 female.

Maxilla: Well developed.

Fifth and sixth limbs: Present.

Seventh limb: Consisting of single fuzzy bristle (see discussion of this limb under "Ontogeny").

Furca: Each lamella with 4 claws followed by a triangular process; a long bristle following triangular process on left lamella.

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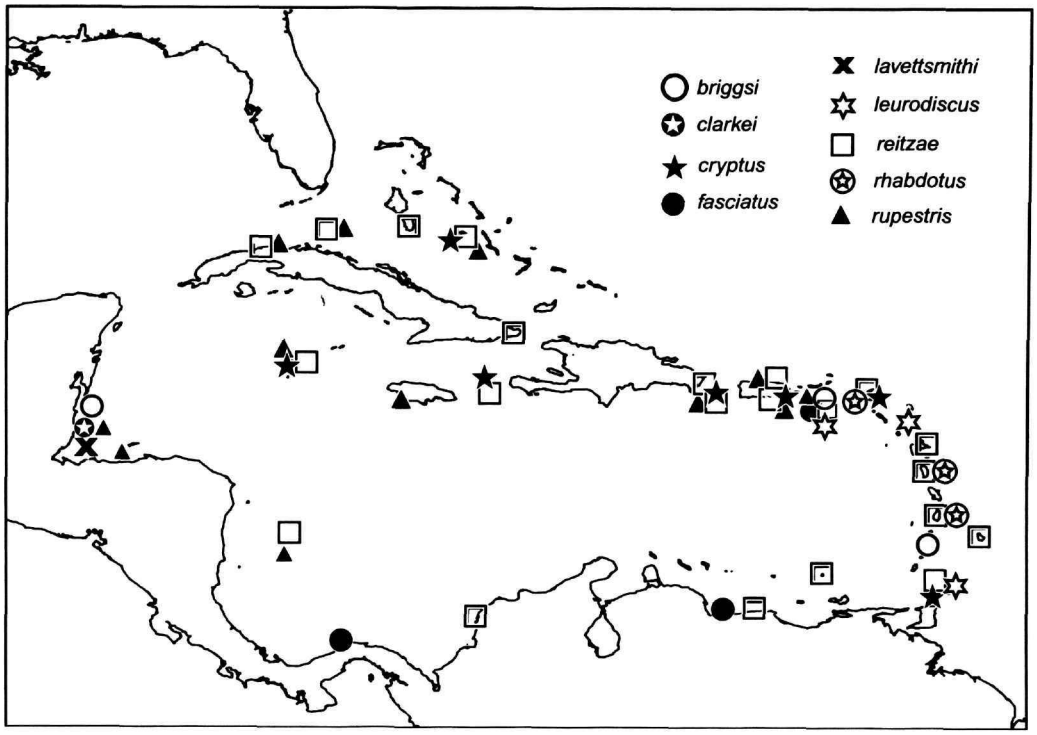

FIGURE 13.—Geographic distribution of examined specimens of the nine species of genus *Tomicodon* known from the Caribbean Sea. The distribution of *T. australis*, known only from the southeastern coast of Brazil, is not shown.

of 25 mm SL or greater (*T. fasciatus, T. reitzae, T. rhabdotus, T. rupestris*) tend to be geographically widespread, whereas species with a maximum size less than 20 mm SL (*T. clarkei, T. leurodiscus*) tend to have more narrowly restricted geographic distributions. The exceptions among species of larger size are *T. lavettsmithi*, which is known only from Belize, and *T. australis*, which is known only from southeastern Brazil. The exception among species of smaller size are *T. briggsi*, which has a wide but disjunct distribution, and *T. cryptus*, which has a relatively widespread distribution from Tobago, through the Antilles, to the Cayman Islands.

As a result of the widespread distributions discussed above, there are numerous instances of sympatry between two or sometimes three species at certain localities. *Tomicodon reitzae* occurs sympatrically at one or more localities with *T. fasciatus, T. rhabdotus, T. briggsi, T. leurodiscus, T. cryptus*, and *T. rupestris*. *Tomicodon reitzae* is absent from Central American coastal areas and Belize, where *T. clarkei* and *T. lavettsmithi* occur. *Tomicodon reitzae* also is absent from southeastern Brazil where *T. australis* occurs. We have found three localities where three *Tomicodon* species have been taken in the same collecting station. At St. Barthélemy, *T. rhabdotus, T. cryptus*, and *T. reitzae* occur together. At Mona Island, a single station contained specimens of *T. rupestris, T. cryptus*, and *T. reitzae*. At Tobago, *T. cryptus* and *T. reitzae* were taken in the same collecting station near Mt. Irvine, and *T. leurodiscus* was taken at the southeastern end of the island.

Although *T. clarkei* and *T. lavettsmithi* occur sympatrically off the coast of Belize, they are allotopically distributed in different habitats that may be separated by only a few kilometers. The *T. clarkei* specimen was found in the high-energy spur-and-groove habitat of the fore reef, whereas *T. lavettsmithi* is known only from the quieter waters of lagoonal islands.

Of potential biogeographic interest are the distribution patterns of *T. rupestris* and *T. fasciatus*. *Tomicodon rupestris* is endemic to the northern Caribbean, occurring from San Andrés Island, Belize, Honduras, Cuba, and the Bahamas through the Greater Antilles to Mona Island, Puerto Rico. By contrast, *T. fasciatus* occurs from St. Croix and Venezuela westward to Panama. The significance of these patterns will remain unknown until a phylogeny of these taxa is hypothesized.

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