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VARGULA MORINI, A NEW SPECIES OF BIOLUMINESCENT OSTRACODE (MYODOCOPIDA: CYPRIDINIDAE) FROM BELIZE AND AN ASSOCIATED COPEPOD (COPEPODA: SIPHONOSTOMATOIDA: NICOTHOIDAE)

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A B S T R A C T

A new species of bioluminescent ostracode, *Vargula morini* from Carrie Bow Cay, Belize, is described on the basis of morphology and mating displays. Every night, males of *V. morini* produce an elaborate species-specific bioluminescent courtship display in order to attract females. These displays occur over coral or coral rubble, beginning near the sea surface and continuing as a series of rapid flashes produced in a downward direction. A nicothoid copepod was found living within the posterodorsal area of the valves of some *V. morini*. Scanning electron micrographs of these minute ostracode parasites are presented here for the first time.

Males of many species of bioluminescent cypridinid ostracodes produce nightly bioluminescent displays to attract females. These displays are species specific, and usually begin about an hour postsunset (Morin and Cohen, 1988; Cohen and Morin, 1993). Over 60 species of luminescent cypridinids that engage in luminescent courtship behavior have been discovered in the Caribbean (Cohen and Morin, 1986, 1989; Morin and Cohen, 1991). These ostracodes produce their own luciferin and luciferase in separate glands in the light organ, and secrete these molecules from a series of nozzles on the upper lip (Huvard, 1993). Upon contact with the sea water, a bright blue luminescence is produced. Details of the behavioral displays and a taxonomic description of a new species, *Vargula morini*, from Belize are given here. Females that were collected at a different time in the same locality, but not during displays, and are morphologically similar to *V. morini* males, are tentatively placed in this species and herein described. A nicothoid copepod was found living within the posterodorsal area of the valves of some *V. morini*. Scanning electron micrographs of these minute ostracode parasites are presented here for the first time.

Materials and Methods

Methods for observing, recording and collecting the specimens were similar to those previously described (Cohen and Morin, 1986, 1989, 1993; Morin and Cohen, 1988). Specimens were collected directly from their bioluminescent courtship display in either discrete or sweep nets, or from sand samples. Light amplified videos (Morin and Cohen, 1988) of the luminescent displays were simultaneously (or independently) recorded during the displays. The videos were analyzed on a frame by frame basis (see Morin and Cohen, 1988, for details) and processed using APL/Statgraphics computer programs. Relative distances between pulses recorded on the video were converted into absolute distances based on *in situ* measurements. The temporal data represent the lower limits of the actual duration of the pulses (Cohen and Morin, 1989). The lowest temporal resolution is 33 ms (1 video frame). The captured specimens were measured, fixed, preserved, and microscopically analyzed (by both light and scanning electron microscopy) according to the methods of Cohen and Morin (1986). The SEM observations were carried out on a Cambridge 360 scanning electron microscope at the University of Southern California (see Cohen and Morin, 1997).

Holotypes and paratypes are deposited in the Natural History Museum of Los Angeles County, California (LACM). The SEM material are deposited in the Smithsonian Institution, Washington, D. C. (USNM). All materials are in alcohol except for limb and SEM (dry) slides as listed under type material. Abbreviations listed under type material are: discretes = samples from single displays collected in individually numbered velcro-sealed discrete nets; sweeps = samples collected with hand net from several displays; traps = baited tube traps; [VV] = paratypes which are voucher specimens of the video recordings of specific displays.

Glossary of Terms

General.—L = length, Ht = height, D = dorsal, V = ventral, M = medial, Lat = lateral, RT = right, LT = left, W = width; additional terms as in Morin and Cohen (1988) and Cohen and Morin (1989, 1993), and designation of setae by letters and numbers shown in figures. Terms describing the copulatory (eighth) limb are as described in Cohen and Morin (1993). Nozzles of the upper lip are the same as the glandular pegs or processes of Kornicker (1975: 111). Measurements are taken as in Cohen and Morin (1993). Copepod terminology is that recommended by Boxshall (personal communication, 1996).

Vargula morini, new species

Vargula new species M, in Cohen 1989: 326.
F-Group species VFF, in Cohen and Morin, 1993: 57.

Morphological Diagnosis

Valve Size.—Relatively large: Male L = 1.88–2.02 mm, mean = 1.96 ± 0.02 mm, Ht = 1.16–1.26 mm, mean = 1.20 ± 0.02 mm, ratio of L:Ht = 1.57–1.67, mean = 1.61 ± 0.02 mm, (n = 55); female paratypes: L = 2.28–2.32 mm, Ht = ~1.43–1.56 mm, ratio of L:Ht = 1.47–about 1.59 [n = 3]. *Valve shape* (Figs. 1A, B, 2A, B). Rather boxy oval, high, posterodorsal margin sloped, but more steeply than anterodorsal margin, males with low rather pointed projecting keel. *Infold*. Males: Rostral row with 27–39 setae [5–8 along incisur] plus 0–9 anterior and 1–8 setae posterior to row [n = 16]; anteroventral row with 51–67 setae [5–11 along incisur] plus 0–3 anterior and 3–20 posterior to row [n = 13];

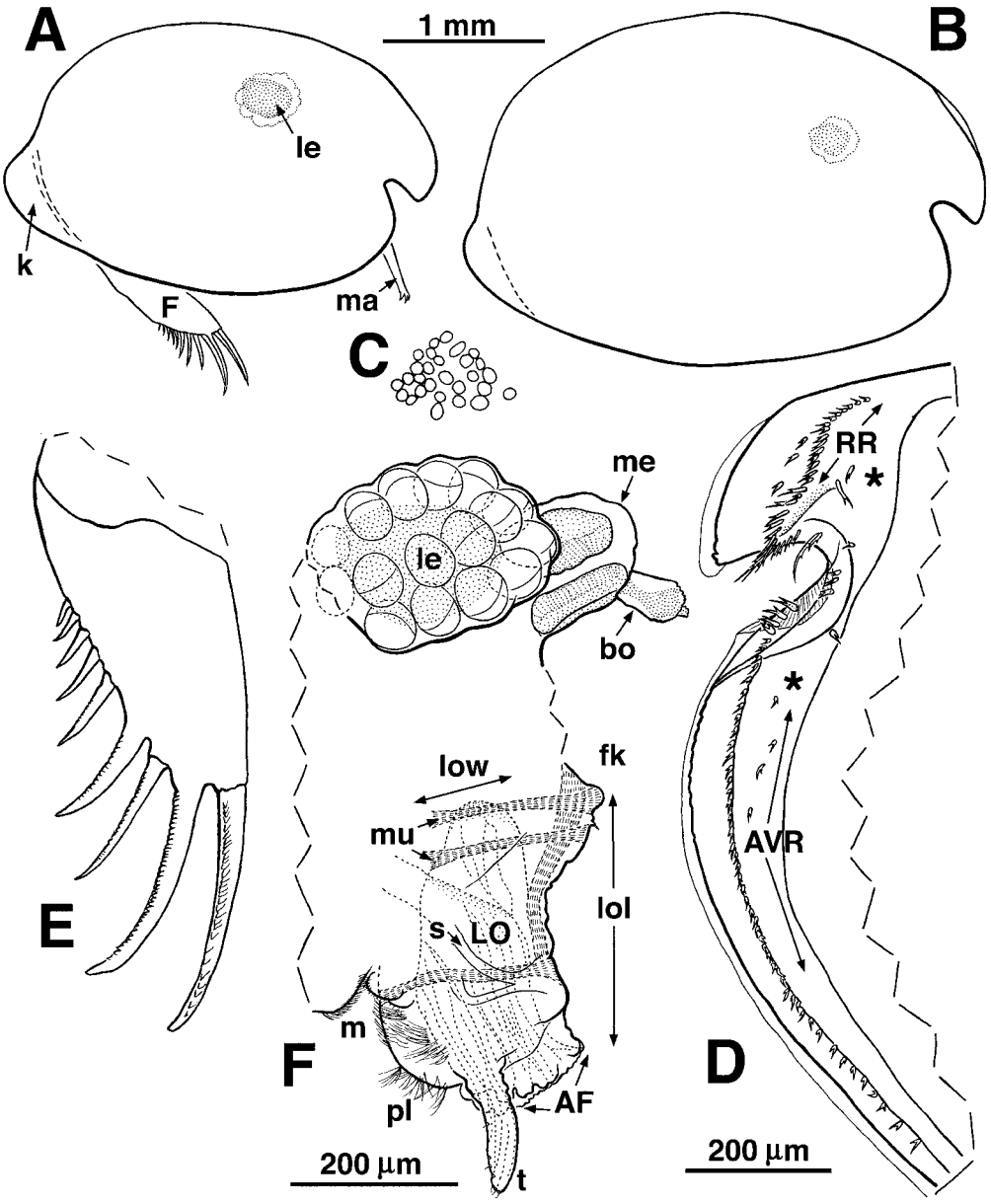

Fig. 1. *Vargula morini*: A, valve of male, BZ02078.3-A: Rt Lat exterior view of complete specimen showing caudal list (dotted line), keel, lateral eye, furca, and mandible; B, female, BZ04078.17-A: Rt Lat view of complete specimen showing lateral eye and caudal list; C, male, USNM 157161: interior view of muscle scars; D, male, BZ02078.3-B: Infold of Rt valve, M view; E, furca of male BZ11078-2-A; F, female, BZ11078.2-A: Rt view of anterior of body showing lateral eye, medial eye, Bellonci organ, frontal knob, and upper lip (pigmented areas stippled). AF = anterior field, AVR = anteroventral row of setae, bo = Bellonci organ, fk = frontal knob, k = keel, le = lateral eye, LO = light organ, m = mouth, ma = mandible, me = medial eye, mu = muscle, pl = posterior lobe, RR = rostral row of setae, t = tusk, * = diagnostic character.

L ventral infold with 3–6 and posteroventral infold with 0 setae (Fig. 1D). Females: Rostral row with 30–42 setae [7–10 along incisur] plus 2–6 anterior and 6–15 posterior to row [$n = 5$]; anteroventral row with 65–78 setae [4–10 along incisur] plus 0–4 setae anterior and 10–34 posterior to row [$n = 7$]. *Furca* (Figs. 1A, E, 2A–C). Second and fourth claws without suture. *Upper lip* (Figs. 1F, 3A–D). Central row of anterior field (Fig. 3A–C) with total of about 15–17 nozzles, raised lateral ridges and pegs with about 24–32 nozzles. Ventral pair of long tusks (Figs. 1F, 3A, B) with posterior and terminal nozzles. Dorsal lateral field near mouth (Fig. 3A, D) with about 13–16 nozzles. *Male first antenna* (Figs. 2A, B, 4A). Ventral seta of article 4 L = 0.05–0.06% of Valve L, total small suckers on b- and c-setae = 20–23 [includes 5–6 on proximal c-seta, $n = 5$]. *Second antenna* (Figs. 2A, 4B). Number of tooth-like spines on seta of second exopodial article in males = 5–6 [mean = 5.4 ± 0.5, $n = 5$] in females 4–7 [$n = 3$]. *Mandible* (Figs. 1A, 2A, B, 3E, 4C, D). D d-setae of end article not extending to third article; terminal article with all claws moderately curved [tips rather bent], V claws slightly more curved, VM claw about 81–88% L of D Lat claw [mean = 86 ± 3%, $n = 4$]; tip of d-seta similar to that of b- and c-setae [tapered to narrow tube-tip], d-seta L about 63–73% D

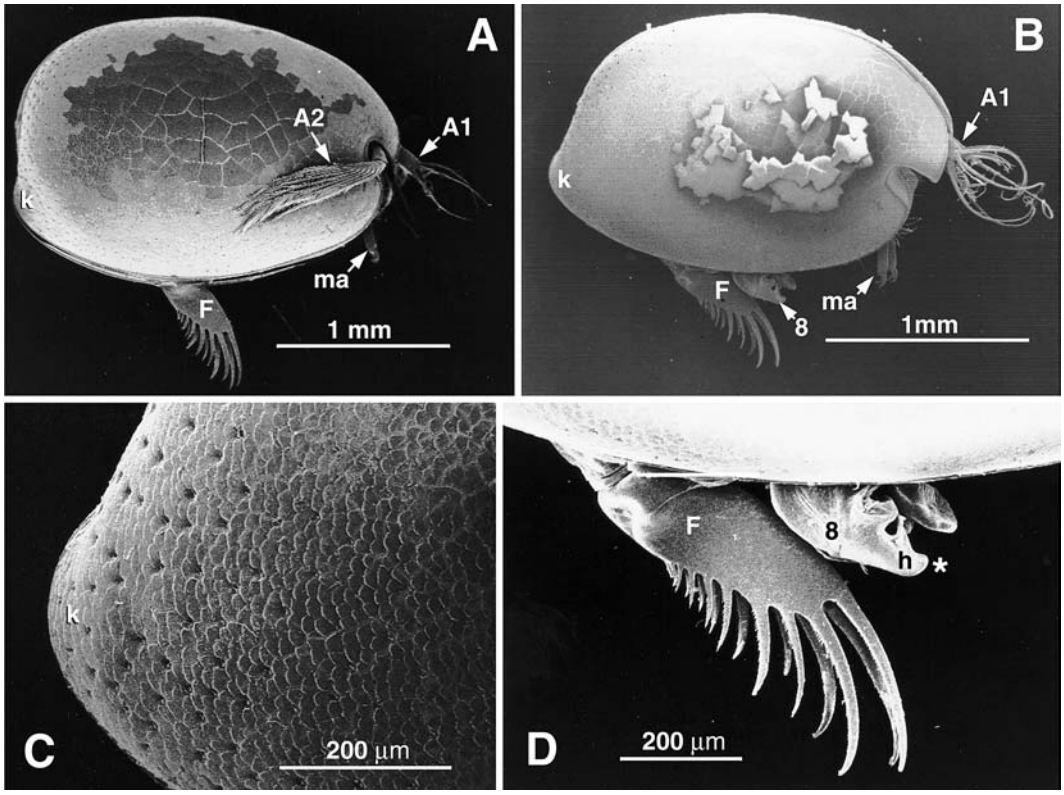

Fig. 2. *Vargula morini*: A, female, BZ04078.17-A: Rt external view showing first and second antennae, mandible, and furca; valve shows cracks as artifacts; B, male, BZ02078.6-A: external view, showing first antenna, mandible, copulatory organ and furca (central region shows artifact from surface breakage); C, posterior valve surface, showing exterior ornamentation, pores and setae of RT keel; D, furca and copulatory (eighth) limb. A1 = first antenna, A2 = second antenna, h = hood, f = furca, ma = mandible, 8 = copulatory organ, * = diagnostic character.

claw L [mean = 66 ± 4%, n = 5] in males, similar in females [n = 2], c-seta about 56–68% L of VM claw [mean = 62 ± 7%, n = 4]. *Fourth limb* (Figs. 3F, 4E). All 4 lateral a-setae of second endopodial article with similar tips (very pointed with minute subterminal papillae); d-1 claw about 70–80% L of d-3 seta (n = 5); smallest c-seta (c-1) without teeth (n = 7). *Fifth limb* (Fig. 3F). L of posteriormost seta of endite III about 2.2–2.3 X L of smallest seta [= second posterior most seta and with few long proximal spines, n = 4]; longest a-claw on second article about 0.4% of valve L [n = 4]; inner corner of fifth article with group of small spines on small projecting process [n = 5, not projecting in 1]. *Seventh limb* (Fig. 5B, C). Total setae in males = 9–13 [includes 2–4 (usually 3) terminal peg setae, n = 4]. *Male copulatory [eighth] limb* (Figs. 2B, C, 5D–F, 6A–D). Outer lobe: Hood with medium-sized, rather triangular lobe-like central peak and thinned weak rather triangular or blunt flap-like tip; 3 ringed, bare thumb setae at base of hood next to prominent long stout thumb-like sclerotized thumb; 2 or 3 more proximal ringed, bare setae. Inner lobe: distal cleft area with small bare triangular tooth [on finger branch] and much longer, basally bent, rather straight bare claw [on setal branch, claw = about 1.0–1.4% of valve L], about 6 ringed bare setae. Central lobe: stout, posterior, with 3 or 4 stout slightly ringed, spinous setae. *Eye size* (Fig. 1F). Lateral eye male: diameter = 0.30–0.34 mm, mean = 0.32 ± 0.01 mm; ratio of lateral eye diameter : valve L = 0.15–0.18 mm, mean = 0.16 ± 0.01 mm [n = 16]; medial eye male: L = 0.17–0.20 mm [n = 3].

Types and Etymology

Holotype.—LACM cat. no. CR 1988-153.1, male, L = 1.96 mm, limbs on slide, rest in alcohol; sample no. BZ02078.3, specimen B; collected at northern end of back reef, NW of Carrie Bow Cay, Belize; 2 July 1988; caught by A. Cohen from display above patch reef of 2.4–3 m depth; reef with some *Acropora palmata*, *Montastrea annularis*, variety of gorgonians and small corals; collected at night by discrete trap net through typical downward flashing display of *V. morini*, which was videotaped.

Paratypes.—All Belize. Habitats, depths, and displays as indicated under General Biology. Carrie Bow Cay (all 1988). Males: Back reef discretes: BZ02078.3, 2 July, A. Cohen, n = 1 (limb slide a with paratype ostracode limbs, plus B copepodite of Nicothoidae sp.) [VV], LACM cat. no. CR 1988-153.2. Back reef discretes and sweeps: BZ02078.6, 2 July, A. Cohen, n = 3 (SEM mounts a, b, c), USNM. Shallow fore-reef sweeps: BZ04078.17, 4 July, B. Bingham, n = 5 (limb slide dd), LACM cat. no. CR 1988-154.1; n = 5 (SEM mounts c, d, e, f), USNM, alcohol spec. E SEM remains, LACM cat. no. CR 1988-154.1. Females: Shallow fore-reef sweeps: BZ04078.17, 4 July, B. Bingham, n = 2 (limb slides aa, g), LACM cat. no. CR 1988-154.2; n = 2 (SEM mounts a, b), USNM. Glovers Reef discretes. Males: BZ11078.2, 11 July, 1988, A. Cohen and J. G. Morin, n = 2 (limb slide a), LACM cat. no. CR 1988-157.1.

Additional material from Carrie Bow Cay. Males: Shallow fore-reef sand sample: ac-cbc-69, 25 May, 1976, A. Cohen, n = 1 (6 limb slides), USNM157161. South Water Cut rubble wash, Child 152, 1 Feb., 1978, C. Child, n = 1 (2 limb slides a), USNM. Females: South Water Cut rubble wash, Child 152, 1 Feb., 1978, C. Child, n = 1 (limb slide b), USNM. Slope of outer reef sand and rubble, K-36, 5 April, 1979, B. Kensley, n = 1 (limb slide), USNM. Lagoon patch reef SW of Cay sand samples: ac-cbc-38, 18

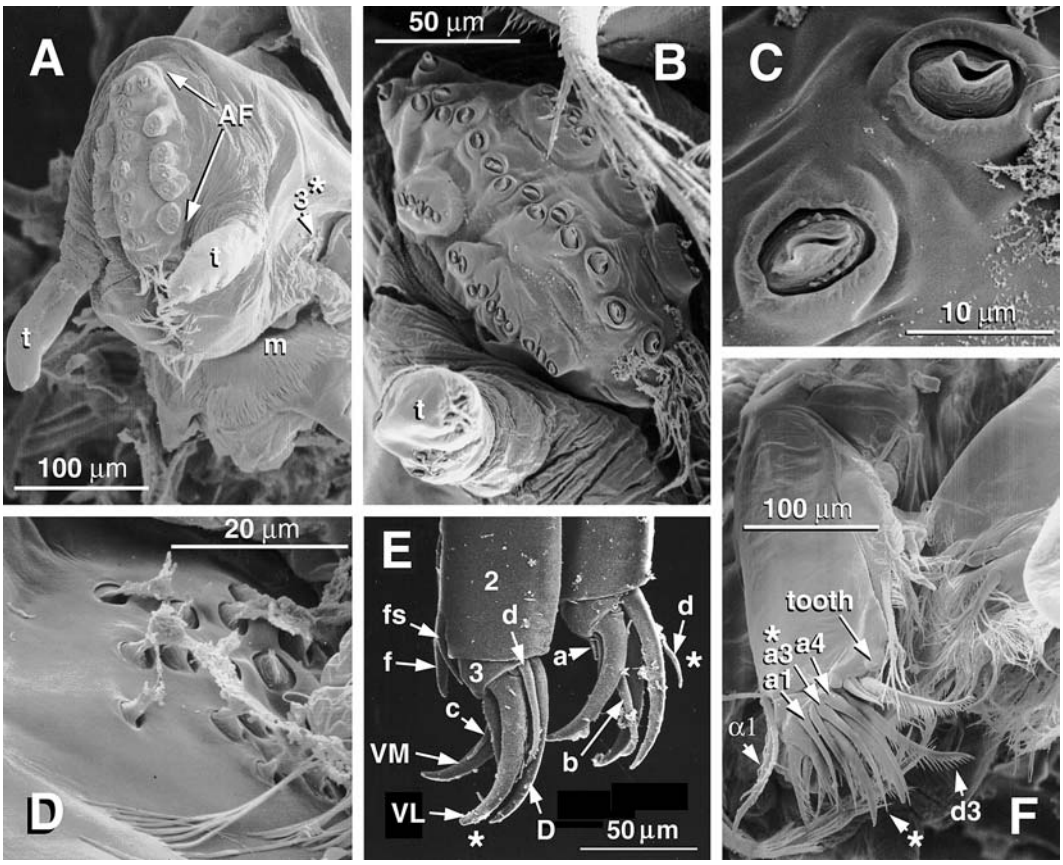

Fig. 3. *Vargula morini*: Male, BZ04078.17-F: A, upper lip, showing anterior field, tusks, dorsal lateral field, and mouth. AF = anterior field, m = mouth, t = tusk, 3 = dorsal lateral field; B, anterior field and Rt tusk. t = tusk; C, nozzles of the central anterior field; D, nozzles of the dorsal lateral field (shows probable secretory material being extracted when fixed); E, male, BZ02078.6-A: third and distal second endopodial articles of mandibles (anterior to Rt). D = dorsal claw, f = finger, FS = finger seta, VL = ventral lateral claw, VM = ventral medial claw, mandible setae labeled a-d, articles numbered; F, male, BZ04078.17-D: Lat LT fourth limb and partial fifth limb, distal setae lettered and numbered, * = diagnostic character.

May, 1976, A. Cohen, $n = 1$, USNM; ac-cbc-56, 19 May, 1976, G. Bretschko, $n = 1$, USNM. Deep fore–reef discrete: BZ08078.12, 8 July, 1988, J. Morin, $n = 3$, LACM.

Additional material from Middle Cay at Glover's Reef (all 2000). Males: sweeps: 00BZ0711.23, 7 July, E. Torres, D. G. Valdez, A. Cohen, $n = 9$ (limb slide b), Juvenile 00BZ0711.23, 7 July, E. Torres, D. G. Valdez, A. Cohen, $n = 1$, LACM.

Etymology.—The species is named in honor of Dr. James G. Morin, our collaborator and mentor, for his contributions to research in bioluminescent ostracodes and bioluminescence in general.

General Biology

Geographical Distribution.—*Vargula morini* is known from the reefs of Carrie Bow Cay (16°80′N, 88°08′W) and from Glover's Reef (about 16°45′N, 87°45′W).

Habitat.—*Vargula morini* occurs in reef habitats including shallow fore-reefs (at about 3–4 m), and back reefs with considerable water flow (5–6 m). Males display over low mixed coral mounds of *Montastrea annularis*, *Siderastrea* rubble, over *Acropora cervicornis* thickets, and occasionally over *A. palmata*. They display most commonly along flanks of fore-reef above isolated coral mounds that are interspersed with sand. It is presumed, but unknown, that they occupy reef habitats below the display areas during the day.

Additional specimens (display unknown and listed as additional material herein) have been collected from a daytime sand sample (surface scoop of sand) from a groove of the spur and groove formation of the shallow fore reef (9 m), an area where nighttime displays have been observed. Others were collected in the vicinity of Carrie Bow Cay from daytime bottom samples of sand from within a patch reef SW of the Cay (4.5–5 m), and from coral rubble on the outer reef slope (30 m) and in South Water Cut (6 m).

Additional material from 18–20 m on the deep fore-reef of Carrie Bow Cay was collected from upward displays over coral (particularly coral edges) and may be conspecific (see Discussion).

Bioluminescent Display, Behavior and Ecology.—The typical display of *Vargula morini* is a distinctive very rapid, strobe-like downward display usually consisting of about 10–20 flashes per train; this number is sometimes less in shallower water. Train lengths range between about 1 m to more than 2 m, and their swim speed is rapid. Pulses are swift with about a 50 msec duration. While pulses appear to have the same duration throughout a train, the final few are usually dimmer than the first series. The first two pulses may occur in

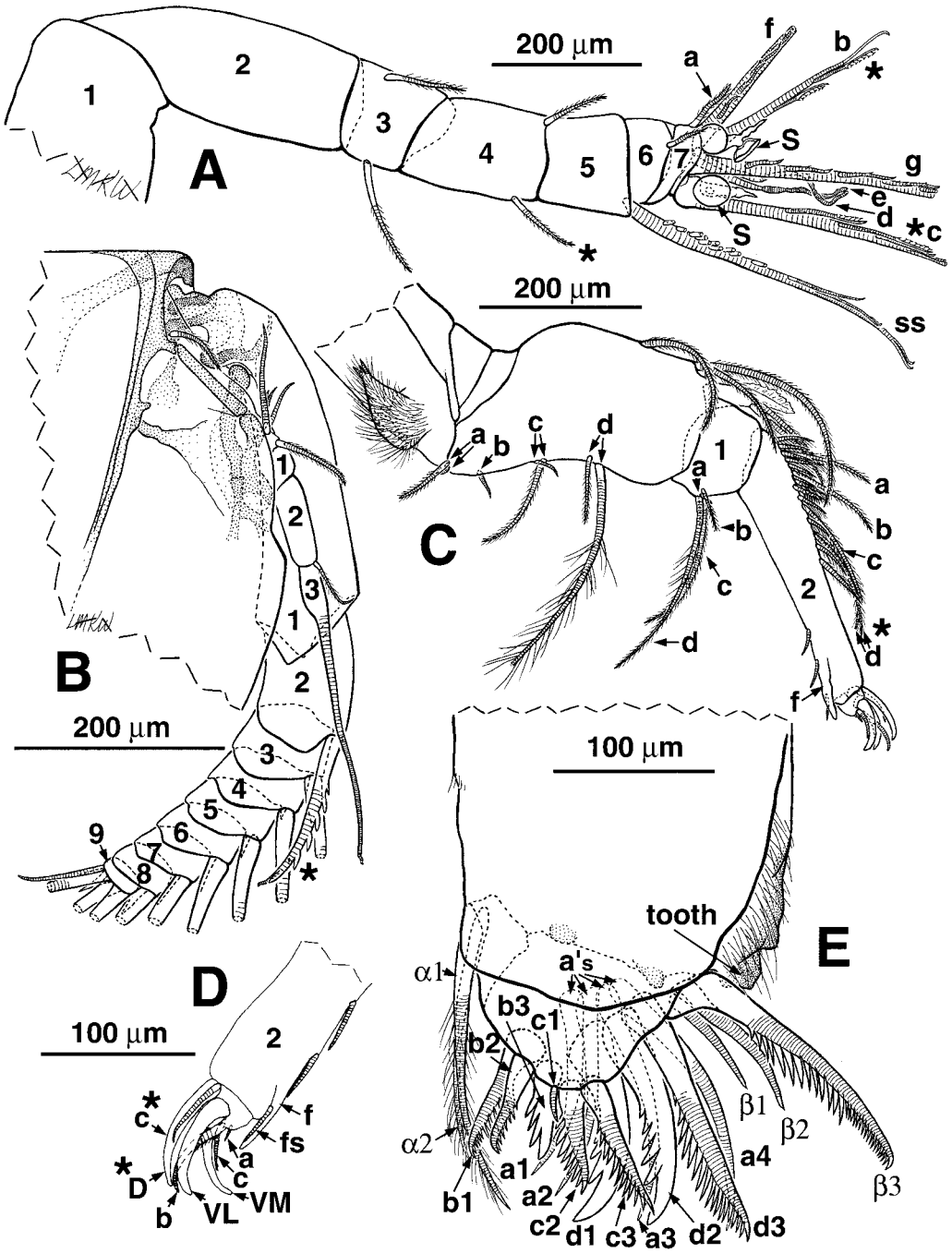

Fig. 4. *Vargula morini*: male, BZ11078.2-A: A, first antenna. Articles numbered, distal setae lettered, S = sucker, ss = sensory seta (only bases of longer filaments shown); B, male, BZ02078.3-A: second antenna with articles numbered (only endopod, exopod, distal protopod, proximal parts of exopodial setae 3–9 shown); C, male, BZ02078.3-B: Lt mandible, V setae of basis lettered, first two endopodial articles numbered; D, male, USNM 157161: endopod of mandible, only third and distal second article shown. D = dorsal lateral claw, f = finger of ventral article, fs = finger seta, VL = ventral lateral claw, VM = ventral medial claw, setae of end article indicated by lower case letters; E, male, BZ11078.2-A: endopod of Rt M fourth limb, only second and distal first article shown, distal setae lettered and numbered, * = diagnostic character.

about the same location before the rapid vertical downward component commences, and then the final three to four pulses sometimes, but not always, also appear almost stationary. The vertical section is composed of pulses that progressively are spaced closer together, with the initial gaps being about 15–25 cm and the final series of pulses have gaps of about 5 cm. Interpulse intervals are short. The displays commence about 4 m above the substrate, or within 0.5 to 1.5 m of the sea surface where the water is shallower than about 5 m. Displays terminate within 30–150 cm of the reef. The displays begin at about 55 (to 60) minutes postsunset [+ 2.32–2.5 crep (Nielson, 1963)]($n = 7$) and continue for about 1 h ($\sim + 5$ crep). Densities of displays are often high, especially above the shallow fore-reef, where they may occur only 20–50 cm

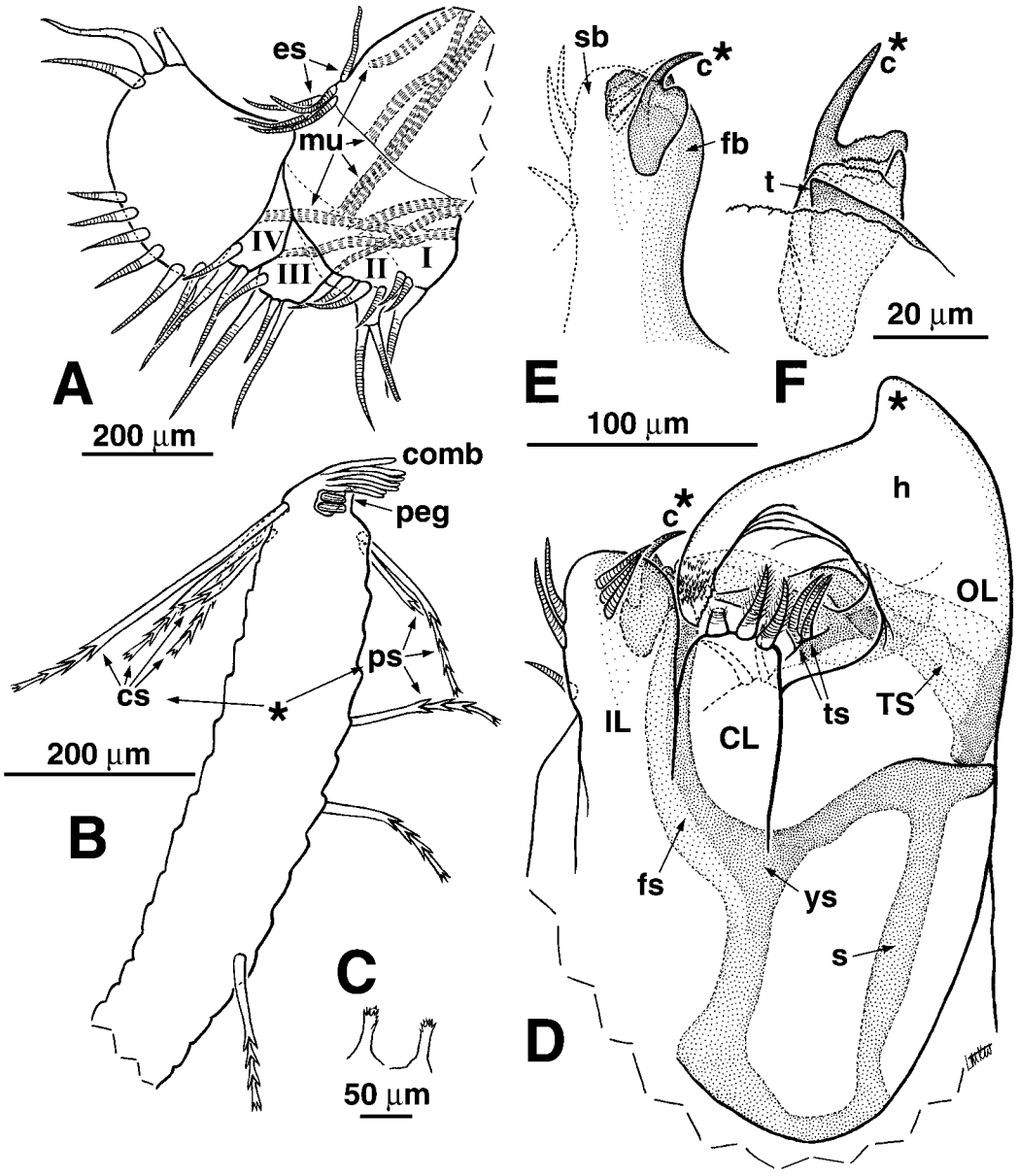

Fig. 5. *Vargula morini*: A, male, BZ02078.3-B: Lat RT sixth limb (setal ornamentation not shown; endites I–IV labeled); B, seventh limb; C, pegs of seventh limbs. Male, BZ02078.3-A: D, posterior view of male copulatory (8th) limb; E, tip of inner lobe of copulatory limb; F, male, BZ11078.2-A: tooth and claw of inner lobe of copulatory limb. c = claw, CL = central lobe, cs = comb setae, es = epipodial setae, fb = finger branch, fs = finger sclerite, h = hood, IL = inner lobe, mu = muscle, OL = outer lobe, ps = peg setae, s = strut, sb = setal branch, t = thumb, ts = thumb setae, TS = thumb sclerite, ys = Y-sclerite, * = diagnostic character.

apart. While neighboring individuals do not show synchrony of signaling, there is distinct surging of displays during periods of about a minute or so, followed by an ebbing of displays. A similar pattern can be observed spatially with one area being more active at one time and another at another time. Where densities are highest, these patterns are less clear because of the intense activity. Displays both pick up and diminish rapidly at the beginning and end of the display period respectively. Four H-Group species (designated MWU [upward display], SZU [upward display], MSH [lateral display], and BSD [downward display], and one other F-Group (= Phot-Group of Cohen and Morin, 2003) species (designated LSU [upward display]), as well as *Kornickeria hastingsi carriebowae* (Cohen and Morin, 1993) (designated RFU [upward display]) signal in the vicinity of *V. morini* but usually not in the identical microhabitat. Species *K. hastingsi* (Cohen and Morin, 1993), MWU, RFU, SZU commence signaling before *V. morini*, MSH starts only a short period before [minutes], while BSD and LSU begin their signals after *V. morini*. However, all overlap in displays during the peak display period. Single flashers apparently attract silent satellite males to them during their displays. Based on discrete sampling, a mean of 2.97 males per display ($n = 35$) was observed, with a maximum of 17 males collected in a single sample.

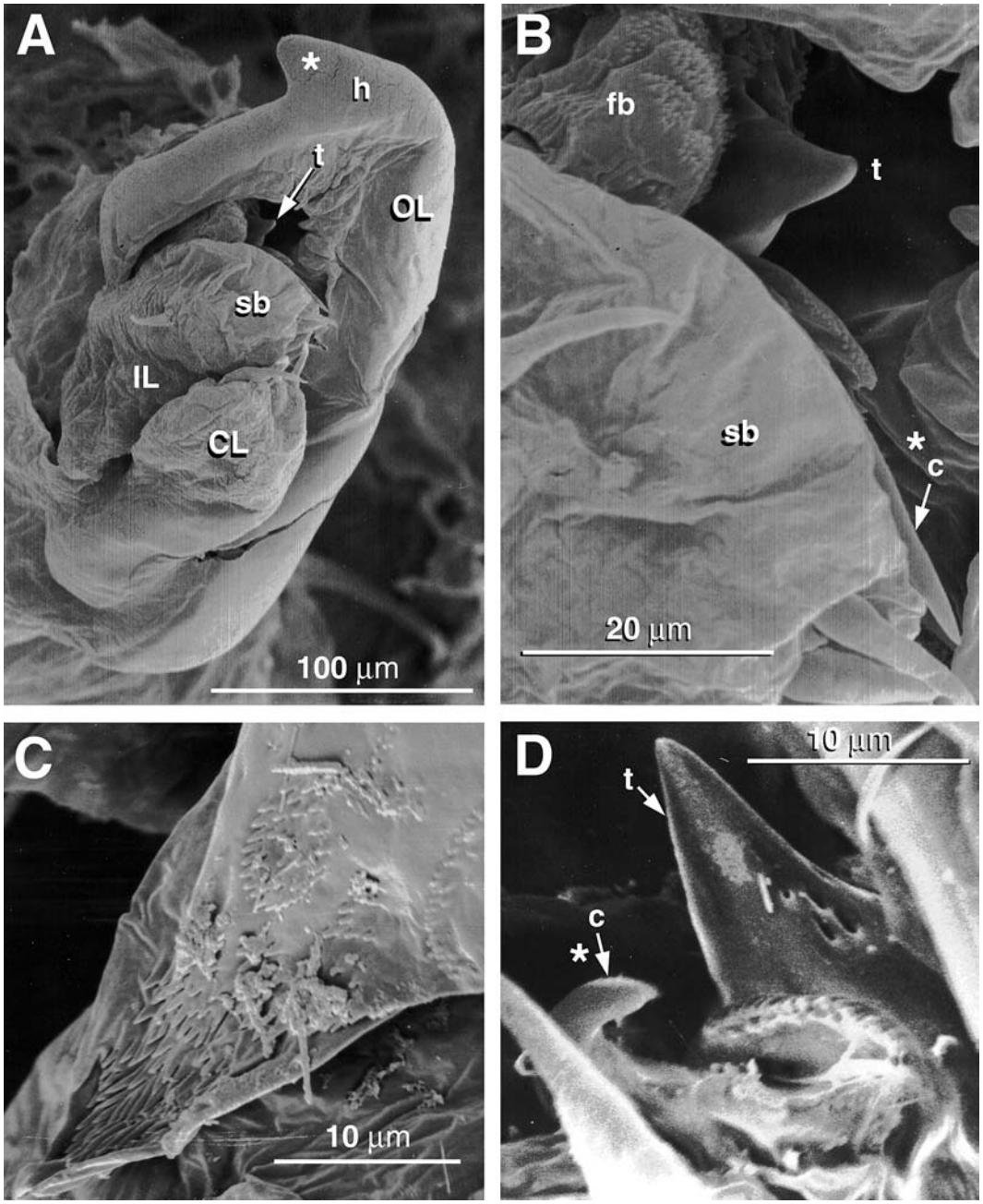

Fig. 6. *Vargula morini*: male BZ04078.17-F copulatory limb: A, Rt limb, posterior view; B, inner lobe showing tooth and tip of claw, some setae of inner lobe; C, hood tip; D, tooth, claw and basal fringe of claw. CL = central lobe, c = claw, f = fringe, fb = finger branch, h = hood, IL = inner lobe, OL = outer lobe, sb = setal branch, t = thumb, * = diagnostic character.

Color of Living Ostracodes.—*Vargula morini* show a little dark reddish pigmentation below the eye. The gut is army-green to light brown, sometimes chalky-white above. The eyes are maroon-black, and the curved rectangular light organ is light yellow.

Light Organ Size from Field Data.—Light organ L = 0.13 ± 0.01 mm [range = 0.10–0.16, n = 18], light organ Ht = 0.32 ± 0.03 mm [range = 0.28–0.36, n = 18]. Ratio of light organ L : Valve L = 0.07 ± 0.01 mm [range = 0.05–0.08, n = 16].

Parasites and Commensals.—Some specimens with ciliates attached to infold posterior to caudal list. Some with nicothoid copepods (Fig. 7) within valves, usually in posterodorsal area [further remarks in Discussion section].

Description of Adult Male Characters

Carapace (Figs. 1A, 2B).—Oval with deep incisur and protruding keel; margins rounded, posterodorsal margin sloped more steeply than anterodorsal margin. Keel large, joined by dorsal concave curve to posterior margin of valve

below midheight of valve; incisur at about midheight of valve. D edge of incisur slightly overlapping V edge at inner end. Rostrum with few small bumps on anterior tip. Valve surface (Fig. 2C, D) with vein-like or scale-like pattern visible on margins at 100 ×, and on valve surface with SEMs; also scattered setae (longer setae emerging from pores with raised rim and knob; shorter setae from depressions in valve, conspicuous on posterior viewed with SEM [Fig. 2D]). About 14–18 (many small ones fused together) muscle scars arranged in irregular inverted "V" with 2–4 smaller scars inside "V" (Fig. 1C).

Infold (Fig. 1D).—Infold posterior to rostral margin with row of 27–39 [$n = 17$] double setae parallel to rostral margin (5–8 along incisur), 1–8 double setae posterior to row, and 0–9 setae anterior to row; 2 very unequal double setae near posterodorsal edge of incisur and 1 minute double seta posterior to D inner corner of incisur; sclerotized ridge (list) at angle D to incisur. Anteroventral infold with 3–4 short double setae near inner corner of incisur and 1 double seta near posterior edge of infold; row of 51–67 double setae parallel to margin (5–11 along incisur); usually with few setae (0–3) anterior to row, and 3–20 setae posterior to row [$n = 13$]. LT valve with 3–6 widely spaced setae on V margin and 0–2 on posteroventral infold. List becoming broader in vicinity of keel, forming ridge. Ridge in LT valve straight, with dorsal bend and ending dorsally in knob, in RT valve slightly curved, with slight bend near middle and posterior thin, transparent fringe of tiny irregular teeth or spines and ending dorsally with bar.

Selvage.—Lamellar prolongation of selvage broad along rostrum, broad and striated along lower margin of incisur, narrower and with fainter striations along V margin, terminating on V margin of keel.

Size.—Valve size: Fairly large for Phot-Group (F-Group). L = 1.88–2.02 mm, mean = 1.96 mm ± 0.02 mm; Ht = 1.16–1.26 mm, mean = 1.20 mm ± 0.02 mm; ratio of L:Ht = 1.57–1.67, mean = 1.61 ± 0.02 [$n = 55$].

Eyes.—Medial eye (Fig. 1F) small (0.17–0.20 mm), with band of pigment. Lateral eye (Fig. 1A, B, F) larger, about 0.32–0.34 mm, mean = 0.32 mm ± 0.01 mm [$n = 18$] and about 15% of valve L (mean = 16% ± 0.7%, $n = 18$), with 16 ommatidia. Eye pigment dark brown in reflected light, maroon brown in transmitted light.

Bellonci Organ (Fig. 1F).—Small, about 0.08 mm, about half L of medial eye ($n = 3$), L usually cylindrical and tapering distally (shape variable, often slightly wider before tapering distally, sometimes round, cylindrical, triangular, pear-shaped or oval and sometimes with distinct tip), without pigment, attached to V cup of medial eye.

Upper Lip (Figs. 1F, 3A–D).—Ventral anterior field (Figs. 1F, 3A–C) consisting of few rows of nozzles: a single (slightly staggered) central row bordered on each side by a raised row of pegs and/or a ridge. Central row with about 15–17 (anterior 2–3 together) nozzles, pegs, and ridges with about 24–32 (3–10/peg) nozzles. Ventral pair of long tusks (Figs. 1F, 3A, B) lateral and posterior to anterior field, tusks tapering only near tip, tusks smooth, with some proximal horizontal lines (wrinkles) and rows of short lateral and terminal hairs, about 5–6 posterior nozzles and about 2–3 terminal nozzles. Ventral posterior part of upper lip hirsute (Figs. 1F, 3A). Paired, more dorsal lateral field (Fig. 3A, D) of about 13–16 nozzles anterior to mouth. Small lobe (or bifid lobe) (Fig. 1F) lateral to mouth, mouth with short spines. Upper lip sometimes with proximal pigment in preserved specimens.

Anterior of Body (Fig. 1F).—Single small, rounded frontal knob with 2–4 smaller triangular teeth ventral to knob.

Posterior of Body.—Smooth, with about 35 narrow D muscle bands.

First Antenna (Figs. 2A, B, 4A).—First article bare. Second article with M spines forming rows and spines near and on D and V margins. Third article short with M spines forming rows. Setae of third and fourth articles with short spines. Third article with 1 D seta just proximal to middle and 1 longer V seta near middle. Fourth article with 1 terminal D seta shorter than that of third article and 1 distal V seta (shorter than that of third article). Sensory seta of fifth article with 10 long bare proximal and 2 distinctly more slender and shorter distal filaments and bifurcate tip. Sixth article with short apparently bare M seta near D margin. Seventh article: a-seta longer than seta of sixth article; b-seta with stout proximal filament with bulbous base followed by large sucker and small distal process and pointed tip, 2 distal slender filaments each bearing proximal tiny bump and 5 or 6 small suckers ($n = 5$) (distal filament extending to about tip of seta); c-seta similar to b-seta but about twice as long, with slightly larger basal filament and sucker, with 2 more distal filaments each bearing proximal tiny bump and 5–6 ($n = 5$) small suckers, with 5 or 6 more distal bare filaments (first filament adjacent to distal sucker-bearing filament). Eighth article: d- and e-setae longer than b-seta, bare, filamentous; long f- and g-setae with slender filaments (f-with 9, g-seta with 10) increasing in L distally, some with a few spines. C-, f-, and g-setae tapering, becoming filamentous distally, longer (g-seta longest) than sensory seta; each of these 3 setae with bifurcate tips (distal part of these 3 setae not shown in Fig. 4A).

Second antenna (Figs. 2A, 4B).—Protopod with short bare seta with minute spines. Endopod 3-jointed (Fig. 4B): First article with 4 proximal setae (1 long and about twice L of 3 shorter setae) and 1 long distal spinous seta (about same L and extending to near middle of second article); Second article elongate, with 1 short terminal seta usually extending to end of third article; third article about 1/2 to 2/3 L of second article, with long terminal filament. Exopod (Fig. 4B): second article with seta with tip reaching to about sixth or seventh article, with 5–6 V spines (mean = 5.4 ± 0.5, $n = 5$); articles 3–8 with basal spines becoming longer distally (basal spines often with thin distal spinelet) and with setae with natatory hairs (only basal part of setae shown in Fig. 4B); Lat spine of ninth article about same size as spine of eighth article; ninth article with 4 setae (3 long with natatory hairs, 1 shorter with few short spines or bare).

Mandible (Figs. 1A, 2A, B, 3E, 4C, D).—Coxal endite spinous, with ringed seta near base, endite tip with bare peg between 2 longer stouter spines (one or both slightly ringed). Basis: 7 ringed setae on proximal 2/3 of V margin: 1 medium long spinous and 1 short bare (about 1/3 L of longer seta) M a-setae, 1 short bare Lat b-seta close to a-setae, 1 long spinous and 1 short bare c-setae and 2 d-setae (c-setae not close to d-setae; shortest a-, b- and c-setae all about same L; proximal d-seta medium long with short spines, distal d-seta very long and hirsute with short distal spines); distal (less than half) of D margin with 3 long setae with short spines (1 distal and 2 longer, unequal, subterminal, M seta proximally unringed). Exopod: extending just beyond end of first endopodial article, with M wrinkled or hirsute D process extending to pointed tip and 2 V setae (longer proximal seta with short spines, distal seta with inconspicuous spines). Endopod: first endopodial article with 4 ringed V setae (1 minute bare a-seta, 1 medium short b-seta with short spines, and 2 unequally long c- and d-setae [c-seta with short spines, longer Lat d-seta with about 9–15 long hairs or spines near middle and distal short spines]). Second endopodial article (Fig. 4C, D): D margin with about 17 setae: 1 a-, 1 b-, 1 c-, 2 d-setae (long, ringed with short spines, d-setae longest and do not extend to 3rd article), 9–10 DM whisk setae with fine hairs, one short stout unringed M seta with short spines, 2–3 setae distal to d-setae (2 ringed with short spines and 0–1 whisk). V margin with 2 short single setae proximal to finger (setae sometimes overlapping), and 1 about equally long finger seta with base on Lat side of subterminal finger; finger (Figs. 3E, 4C, D) long stout sclerotized straight unringed with rounded pointed tip. End article (Figs. 3E, 4C, D) with 3 long moderately curved claws; all claws with tips curved and bearing few small proximal M teeth; V Lat claws stouter and more curved than D Lat claw. D-Lat claw, thinner than V Lat claws, with tip less bent (Figs. 3E, 4C, D), slightly longer but not extending beyond V Lat claws; 4 ringed setae: 1 long VM c-seta, 1 longer V Lat b-seta without bulbous base but stout and extending beyond claws, 1 very short bare VM a-seta, and 1 D Lat bare d-seta extending to about distal 2/3–3/4 L of D Lat claw. End of d-seta with narrow tube tip similar to that of a-, b- and c-setae; b- and c-setae with proximal short spines.

Fourth Limb (Figs. 3F, 4E).—Endite setae (not shown): I = 11 long stout with long spines or hairs (most setae unringed, 1–3 distally ringed with bare pointed or bifid tip); II = 5–6 long, distally ringed with few proximal hairs and slender pectination or long spines, and 1 shorter with proximal hairs and spines; III = 5 long, distally ringed, with long spines. Coxa: hirsute lobe and stout hirsute D seta. Basis with 2 long thin bare Lat setae (one near base of exopod and longer than exopodial setae) and 1 distal M setae (one may be on first endopodial article). Exopod (Figs. 3F, 4E) hirsute, with 1 long hirsute proximal seta and 2 long terminal setae (hirsute outer seta with distal short spines and slightly longer than inner seta (with short spines, but not hirsute). Endopod: first article rectangular (Figs. 3F, 4E): Subterminal cutting tooth big, squarish, with 2 blunt points, ventrally projected; 2 smaller terminal teeth (1 near beta- and 1 near alpha-setae), 2 alpha-setae (alpha 1 longer and hirsute, alpha 2 with few short hairs), 3 ringed beta-setae, stouter and longer outer beta-3-seta shorter than alpha-seta and with row of about 29–31 long teeth (distal teeth decrease in size gradually), beta-1 bare, beta-2-seta bare (or with few inconspicuous teeth); first article with rows of M hairs; second article narrower than first endopodial article, with 4 ringed a-setae (all with threadlike tips, a-3- and a-4-setae with few small teeth near middle); 3 stout pectinate b-setae, b-1 and b-2 finely pectinate (b-1 with 8–13 and b-2 with about 6–7 larger teeth), b-3 shorter, unringed, claw-like, straight and tapering, with about 2–4 medium-sized teeth (usually only on anterior outer side), b2-seta L = 70–80% b1-seta L; 3 ringed c-setae, c1-seta short, slender, c2- and c3-setae long, stout, pectinate, c-2 with 7–9 and c-3 with 11–13 teeth, L c1- = about 30–60% L b3-seta; 3 long, stout, pectinate d-setae (d1- and d2-setae shorter, unringed, claw-like, with 3–5 teeth each, d-3 ringed with 17–18 (males) or 14–15 (females) teeth. Aberration: BZ11078.2-A with 4 a-setae on one limb and 5 on the other, and b-3 very slightly ringed.

Fifth Limb (Fig. 3F).—Epopodial setae: 43–46 [$n = 2$]. Protopod with long, rather straight anterior distal tooth with expanded round tip and very small bump near middle (Fig. 3F). Endite setae: I = 6–7 stout, tapered, unequal, with long stout hairs or spines (all or most distally ringed with bare pointed tips); II = 6 stout unequal, with most distally ringed with long hairs or spines, some distally pectinate; III = 7 (inner [posterior] seta [#1] stoutest, long, with proximal hairs, distally pectinate; adjacent 2–3 setae [#2–3 or 4] usually unringed, pointed, rather claw-like [sometimes with distal teeth], #2 seta very small, unringed, triangular, with few long proximal spines; last [anterior] seta [#3] longest, with proximal hairs, distally ringed, with short spines; last 2 anterior setae usually similar). Exopod with 2 prominent sclerites; first article sclerite rather "L"-shaped (shorter, broader part of "L" underlying 6 teeth of article, longer part of "L" underlying anterior setal row); second article sclerite large, irregular, occupying outer half of article. First expodial article: Posterior row of 6 pectinate claw-like teeth, 1 proximal smooth triangular peg with tiny terminal teeth or spines, and 1 large stout distally ringed peg-seta (with about 2–4 long, spiny, proximal filaments and 1–3 short, stout teeth) proximal to peg; peg-seta shorter than longest tooth, peg shorter than shortest tooth, shortest tooth with total of 4–7 small cusps (variable, stout, distal cusp smallest, tooth tip stout and pointed); anterior row of 3 setae (1 short-medium long hirsute and often very faint [with distal short spines in some specimens], 2 very long with long proximal stout hairs or spines and distal rings and pectination [stouter pectination on marginal seta]), and fourth anterior seta (on proximal margin of article over sclerite, may be on protopod) faint, short-medium long and hirsute (with distal short spines in some). Second exopodial article with total of 13 setae: 4 stout unringed anterior a-claws with distal teeth, 7 long to medium-long ringed pectinate b-setae (posterior row of 3 b′-setae, anterior row of 4 longer b″-setae), 1 proximally hirsute posterior c-seta with distal rings and short spines, and 1 hirsute anterior d-seta with distal rings and short spines. Inner lobe of third exopodial article with 3 ringed setae (shorter more proximal one with long proximal hairs and distal short spines,

subterminal seta longest, distally ringed with short spines, terminal seta slightly ringed with few short spines); outer lobe hirsute with 1 terminal (slightly stouter) ringed seta with proximal hairs and distal short spines and 1 subterminal ringed seta on inner side of lobe (inner seta bearing short spines and with abruptly narrowed tip). Fourth exopodial article hirsute with 3–4 ringed setae (most with short spines, spines slightly larger on proximal seta). Fifth exopodial article hirsute, with 2 subequal ringed terminal setae with short spines, posterior seta usually longer than anterior seta; small spinous process present terminally on inner corner.

Sixth Limb (Fig. 5A; hairs and spines not shown).—End article basally separated by suture or groove from rest of limb, rather stubby or boxy, not very extended posteriorly, ventral margin curved or irregularly curved (with corner near anterior end of gap between setae); 4 or 5 bare ringed epipodial setae. Endites separated from each other and rest of limb by grooves or sutures. Endites with M hairs. Endite setae: I = 3 ringed (1 long terminal seta with long spines or stout hairs and unringed, 2 short proximal setae with long spines or hairs); II = 5 (2 long terminal setae with long mid spines or hairs and distal rings and short spines, 3 short unringed proximal setae with long hairs); III = 4 (2 terminal setae with long proximal [or middle] stout hairs or spines, and distal rings and short spines; 2 setae [1 terminal, 1 distal] shorter, hirsute, often ringed, with distal short spines); IV = 3 ringed (2 terminal long setae with long proximal or middle stout hairs or spines and distal short spines, 1 distal, shorter seta with long hairs). End article with long fine hairs on M surface, Lat surface with distal stouter long hairs, terminal (V) margin usually with slight irregularity in convex curve (slightly angled within setal gap), with total of 9–11 (usually 10) [n = 5] V terminal setae: 1 shorter, thinner, spinous lateral seta usually with none or few long proximal spines, 5–6 short to medium-long anterior setae with long proximal and medium-short distal spines (distally ringed), followed by long space (gap = about 45% V L of end article), between anterior setae and 3 posterior setae (shorter most anterior of the posterior setae with long midhairs and short distal spines and usually ringed, 2 most posterior setae unequally longer and hirsute, unringed). Aberrant specimens: BZ02078.3-B with 1 limb with 2 setae of endite II joined.

Seventh Limb (Fig. 5B, C).—Limbs slightly expanded in distal setal area. Total of 9–13 setae (n = 5). Comb side with 0–2 (usually 1) nonterminal (each with 3 bells) and 4 terminal setae (each with 3–4 bells; bells consist of encircling fringe); peg side with 2–4 nonterminal setae (usually 3)[each with 2–4 bells], and 2–4 terminal setae (usually 3)[each with 2–5 bells]. Comb of 7 long, tapered, minutely fringed ''teeth'' with rounded tips (middle tooth shorter than those on either side of it; Fig. 5B arrow) and 4–6 short blunt teeth (2–3 on each side), short teeth grooved or brush-like. Single sclerotized peg (straight, thin, shorter than short comb teeth, with about 8–9 minute pointed terminal or lateral teeth (Fig. 5C), base of peg slightly recessed from outer limb edge.

Copulatory (Eighth) Limb (Figs. 2B, C, 5D–F, 6A–D).—Basal part of first article with prominent Y-sclerite with a strut so that the sclerite forms an irregularly rectangular loop (Fig. 5D) with a M distal inner extension (finger) terminating near the distal tip of the finger branch of the inner lobe (Fig. 5D); loop slightly broader distally and slightly elongated at outer distal corner. Inner lobe with 2 branches, finger branch and setal branch, separated by terminal cleft (Figs. 5D, 6A). Finger branch (Figs. 5D, F, 6A–D): tip with numerous minute triangular or knobby teeth (more prominent within cleft) and prominent triangular tooth on cleft edge near end of finger sclerite, tooth with basal pores (Fig. 6D). Setal branch: cleft region with prominent terminal rather long and curved claw (Figs. 5D–F, 6A, C, D) (much longer than tooth, base of claw at least sometimes with tiny teeth associated with basal fringes), and on its external surface 5–7 ringed bare nonterminal setae with tapered bases (Figs. 5D, E, 6B). Outer lobe (second article, possibly an exopod): with thumb sclerite articulating with distal corner of strut of Y-sclerite of first article (see Fig. 5D), distally, sclerite associated with exposed long, bare, extended sclerotized thumb emerging at inner D base of hood (thumb extending nearly to tip of hood); 3 ringed, bare, thumb setae [n = 5] are grouped near and proximal to thumb base (Fig. 5D), 2–3 proximal anterior ringed setae (Fig. 5D) and numerous anterior proximal rows of tiny scales or papillae. Hood (distal extension of second article): usually folded over the distal inner lobe in preserved specimens (probably retracted position); tip of hood (Figs. 5D, 6A, B) bears subterminal minute scales, teeth or papillae (proximal teeth slightly smaller than distal teeth) (tip is thin flap-like lobe, can be wrinkled or folded in slide mounts); apex of hood peaked (forming rather triangular projecting lobe) (Figs. 5D, 6A). Central lobe (third lobe) (Figs. 5D, 6A): lies posterior and M to inner and outer lobes, rather central on limb; appears to be attached to basal part of first article just proximal to origin of finger sclerite extension; bears 3–4 ringed terminal setae with short spines.

Furca (Figs. 1A, E, 2A–C).—Each lamella with 8 or 9 claws [n = 9]; claws 2 and 4 fused to lamella; claw 3 more slender than, but longer than claw 4; all claws with 2 rows of posterior teeth (1 M row, 1 Lat row) and larger claws with row of flat anterior teeth. Anterior lamella with few tiny spines; margin posterior to claws with several groups of spines; area D and posterior to lamella with slightly indented rounded area with about 6 pads of short spines. Claw L ratios: first : second = 1.1–1.2, second : third = 1.5–1.8, third : fourth = 1.1–1.2, fourth : fifth = 1.4–1.5 (n = 4 or 5).

Description of Adult Female Characters

Description of adult female characters is based upon females assigned to *Vargula morini* (not designated as types because they were not collected from mating displays).

Carapace.—Shape of carapace more rounded and keel smaller than in males (Figs. 1B, 2A).

Infold.—Rostral row with about 30–42 setae (7–10 along incisur) plus 2–6 anterior and 6–15 posterior to row [n = 5]; anteroventral row with about 65–78 setae [4–10 along incisur] plus 0–4 anterior and 10–34 posterior to row [n = 7].

Size.—Larger than males. L = 2.28–2.47 mm, Ht = 1.43–1.60 mm [$n = 7$], ratio of L:Ht = 1.44–1.63, mean = 1.54 mm [$n = 6$].

Eyes.—Lateral eye: Smaller than in males; L = 0.25–0.28 mm, 0.11–0.12% of valve L [$n = 2$].

Upper Lip.—Observed only with light microscope, and no difference from males detected.

First Antenna.—Fourth article with distal V seta about 0.4% of valve L ($n = 3$). Seventh article lacks suckers; b-seta has 3 filaments and is longer than a-seta and shorter than d-seta.

Second Antenna.—Exopod with 4–7 V spines on seta of second article [$n = 2$].

Mandible.—V margin of second endopodial article with 2 short single setae proximal to finger, with space sometimes greater between the setae of females; and finger shorter and thinner (slightly shorter than finger seta) than in males. Aberrations: Rt limb of K-36 very stunted at tip, missing many setae on second and third articles; one limb of BZ04078.17-A with very short b-seta on D second article.

Seventh Limb.—Total of 15–18 setae [$n = 3$]; comb side with 3–4 (usually 3) nonterminal and 4–5 terminal setae (each with 3–4 bells), peg side with 4–5 nonterminal (each with 4 bells) and 3–4 (usually 4) terminal (2–4 bells). Comb of 7 long teeth and 6 short lateral teeth (3/side).

Genital Lobe (Eighth Limb).—Much smaller than in males and unjointed. Low, irregularly tubular medial ridge terminating laterally in prominent round knob; medial ridge with attached irregularly rounded spermatophore in BZ04078.17-A. Setose openings (Cohen and Morin, 1997) not observed (but not examined with SEM).

Discussion

Vargula morini.—*Vargula morini* is sympatric with two other F-Group (=Phot-Group of Cohen and Morin, 2003) species of *Vargula* and several other cypridinids, but is the only species in its geographical locality with a rapid flashing downward bioluminescent mating display. Although the other two F-Group species of *Vargula* also produce vertical shortening displays (Cohen and Morin, 1993), their displays are distinctly different (e.g., both are directed upward).

A new Belizean species of *Vargula* (Torres and Morin, unpublished manuscript) also has a flashing display, but can be distinguished from *V. morini* by its morphology, bioluminescent display and habitat. This new species of *Vargula* displays only over seagrass beds and *V. morini* displays only over reef habitats. The display of *Vargula* n. sp. is not downward, but a series of rapid flashes in an upward direction. *Vargula* n. sp differs morphologically from *V. morini* in carapace shape (a more sloping oval) and size (male: L = 1.56–1.70 mm, mean = 1.62 ± 0.03 mm, Ht = 0.98–1.04 mm, mean = 1.02 ± 0.02 mm, ratio of L:Ht = 1.56–1.65, mean = 1.60 [$n = 45$]; female L = 2.05 mm, Ht = 1.41 mm, ratio of L:Ht = 1.45 [$n = 1$]); number of infold setae (male: rostral row with 13–20 plus 0–1 anterior and 1–5 posterior to row; anteroventral row with 22–27 (2–4 along incisur) plus 0 anterior and 2–11 posterior to row; female: anteroventral row with about 39 plus about 2 anterior and 14–15 posterior to row), shape of the mandibular claws (less curved) and copulatory limb (hood with smaller peak, inner lobe with smaller straighter claw), and other details.

Vargula morini displays in the same habitat as an undescribed species of F-Group *Vargula* designated LSU, but the two species can be distinguished by display and morphology. The display of LSU is not a series of downward rapid flashes, but a slow pulsed, vertical shortening display in an upward direction. The two species are similar in valve shape and size, but can be easily distinguished by a few morphological characters, particularly the number of infold setae. On the anteroventral infold, *V. morini* males have a row of 51–67 setae [$n = 13$] and females a row of 65–78 [$n = 7$], whereas LSU males have a row of 30–47 [$n = 4$] and females a row of 35–39 [$n = 1$]. On the mandible of *V. morini*, the terminal VM claw is 81–88% of the length of the dorsal claw [$n = 5$ males, 2 females], but is 89–97% in LSU [$n = 5$ males, 1 female]. The terminal d-seta of the mandible is 63–73% of the dorsal claw length in *V. morini*, but 67–80% in LSU.

Vargula morini is also sympatric and displays in the same habitat with some other bioluminescent cypridinid genera (e.g., *Kornickeria hastingsi* Cohen and Morin, 1993), but differs morphologically from all of those species in generic characters (e.g., valve higher, less elongate) and in display (flashes, not longer lasting light spots). One other cypridinid, *Skogsbergia lerneri* (Kornicker, 1958) occurs with *V. morini*, but *S. lerneri* lacks a luminescent display and differs from *Vargula* in numerous morphological characters (e.g., upper lip without tusk, furca with fourth claw shorter than fifth and only second claw without a suture, male first antenna with abundant long filaments on some terminal setae, endopod of second antenna with only 1 article, lateral eye with about 30 ommatidia).

Most male specimens of bioluminescent cypridinid ostracodes have been caught from their mating displays in the water column; the displays last for only about one hour each night. Females and juveniles are only rarely captured in the water column. Although all females, juveniles and males produce a bright unpatterned luminescence to deter predators, only males perform patterned displays (Morin, 1986; Morin and Cohen, 1991; Cohen and Morin, 1993). Males cement a spermatophore to the female genital opening (e.g., Cohen and Morin, 1997), and probably females swim to a male display, mate only once, then return to their benthic habitat where they can produce several broods fertilized by the stored sperm (e.g., Cohen, 1983).

It has been presumed that the ostracodes with bioluminescent mating displays dwell for most of their time (and life history) in the benthic substrate below the displays. Several daytime benthic samples made by the second author and colleagues at the Smithsonian Institution support this assumption. These benthic samples of coral rubble, or of a few cm of the benthic sand surface, contained ostracodes identifiable by their morphology as *Vargula morini*. Their identity seems certain, but because they were not captured from a *V. morini* display and some were from localities not studied at night, we have listed them as additional material of this species. The daytime samples, which also included

some juveniles, do indicate that *V. morini* dwells in sand and coral rubble on the bottom of various reef areas during the day, including the spur and groove of the fore-reef (where *V. morini* has also been captured from nighttime displays), the edge of an adjacent cut through the barrier reef, the slope of the barrier outer reef ridge, and a patch reef in the lagoon west of the barrier reef. It is likely that nighttime mating displays occur over each of these benthic habitats.

Three specimens from deeper reefs (about 18 m) at Carrie Bow Cay were collected in discrete nets, from upward flashing displays, and are included as additional material because the males display in an upward direction, rather than downward, and show some morphological differences, particularly in the number of infold setae. On the anteroventral infold, deeper water males have a row of 28–32 setae plus 0 anterior and 0 posterior [$n = 2$], whereas shallower specimens have a row of 51–67 setae plus 0–3 anterior and 3–20 posterior [$n = 13$]. On the rostral infold, deeper water males have a row of 17–20 setae plus 0 anterior and 1 posterior to row [$n = 2$], whereas shallower males have 28–39 plus 0–8 anterior and 1–8 posterior to row [$n = 16$]. Deeper males also differ from shallower males in having slightly longer valves (2.03–2.07 mm, not 1.88–2.02 mm), and the total number of suckers on the b- and c-seta of the first antenna. Deeper males had 17 suckers [$n = 2$], whereas the shallower males had a total of 20–23 small suckers on the b- and c-setae [$n = 5$]. On the mandible, deeper males have a VM claw about 90.8% L of the D Lat claw rather than 81–88% as in the shallower males. On the fourth limb, the d1 claw is about 66% L of the d-3 seta, rather than 70–80% as in the shallower males, and the alpha seta is the same length or shorter than the beta seta. On the fifth limb, the second seta on endite III has hairs (as in the shallower specimens) but is slightly shorter. The longest a-claw on second article is about 0.53% of valve L, not about 0.4 as in the shallower specimens. Due to the variation in direction of displays and some morphological characters, these deeper specimens are listed as additional material and are only tentatively assigned to this species. DNA comparisons of shallow and deep specimens would aid in measuring their taxonomic affinities, but no deep samples have yet been collected for that purpose.

Because both upward and some more typical *V. morini* downward displays were observed together over the deep reef (only), molecular comparisons might help test for incipient speciation in that population. Females may be using display direction (up or down) as a basis for choosing male mates in the deeper reef area, causing total or partial reproductive isolation between upward and downward displaying *V. morini* there.

Nicothoid Copepod.—The copepodite found within the valves of some *V. morini* appears to be an undescribed species perhaps of the genus *Sphaeronella* (Order Siphonostomatoida, Nicothoidae). We had considered ostracodes to be small, until we found ourselves challenged in trying to discern the anatomical details of their parasites. We were unable to resolve questions regarding the correct interpretation of some of the copepod's anatomy. Therefore, we have decided to illustrate the copepod with SEMs, but leave it in open nomenclature as Nicothoidae sp. A. In labeling the nicothoid SEM illustrations, we have followed herein an interpretation of G. Boxshall, who in 1996 kindly reviewed our manuscript (Boxshall, personal communication, 1996). The SEM illustrations (Fig. 7) are the first to be published of these ostracode parasites, and we hope that they will inspire a renewed interest in the taxonomy of this group. Because of host specificity, comparison of the phylogenies of parasites and hosts might clarify evolution of both groups. The 19 nicothoid copepod species that have been described previously from ostracode hosts are all parasites of the ostracode order Myodocopida (Bradford 1975, 1980; Yoo and Lim, 1996); seven of these were reported from the family Cypridinidae. Each has been found on a single host species, usually within the posterodorsal region of the ostracode valves.

Only three genera of copepods have been described as parasites of ostracodes. *Sphaeronella* differs from *Sphaeronelloides* in having: (1) unfused urosomal segments one and two (these segments are completely fused in *Sphaeronelloides*), and (2) biramous trunk limbs (rami reduced in *Sphaeronelloides*). *Sphaeronella* differs from *Sphaeronellopsis* in lacking a genital flap and fused caudal rami (Bradford,1975). We think that Nicothoidae sp. A may belong to *Sphaeronella*, because Nicothoidae sp. A appears to exhibit the characters just enumerated for that genus (Fig. 7). We have labelled the three separate narrower segments extending posteriorly from the cephalothorax as urosomites following Boxshall's suggestion; Boxshall noted that the first two urosomal segments "are probably 'thoracic' not abdominal in origin" (Boxshall, personal communication, 1996). Three segments are visible in the SEM (Fig. 7C), but the terminal (third) one is obscured by setae from the swimming legs; the third segment is clearer in specimens viewed by light microscopy and is apparently fused with the caudal ramus (Boxshall, personal communication, 1996).

As an anonymous reviewer has noted, the dorsal view (Fig. 7A) seems to indicate that the cephalothorax has a posterior division (arrow in Fig. 7A), and that "one free pedigerous segment in addition to the cephalothorax is a common feature of *Sphaeronella*." As the division is not apparent in that position ventrally (Fig. 7B), we remain uncertain.

The copepodites of Nicothoidae sp. A differ morphologically from illustrations of all other nicothoid copepodites described from ostracode hosts. Nicothoidae sp. A has a uniquely shaped cephalothorax (the cephalosome is oval-rectangular, much longer than wide, with one small frontal-lateral point on each side) (Fig. 7A, B), and an apparently unique maxilla (fifth limb). The maxilla most closely resembles that of *Sphaeronella dikrothrix* (Bowman and Kornicker, 1969) found on the cypridinid host *Metavargula ampla* (almost always in posterodorsal part of valves). Unlike the two Nicothoidae females illustrated from *Vargula graminicola* and another undescribed species of *Vargula* (Torres and Morin, unpublished manuscript), the frontal margin of Nicothoidae sp. A is bare. The copepodites of *Sphaeronella rugosidoloria* (Bradford, 1975), *S. siphonostrae* (Bradford, 1975), *S. dikrothrix* (Bowman and Kornicker, 1969), *S. metavargulae* (Bradford, 1975), and *S. squamosa*

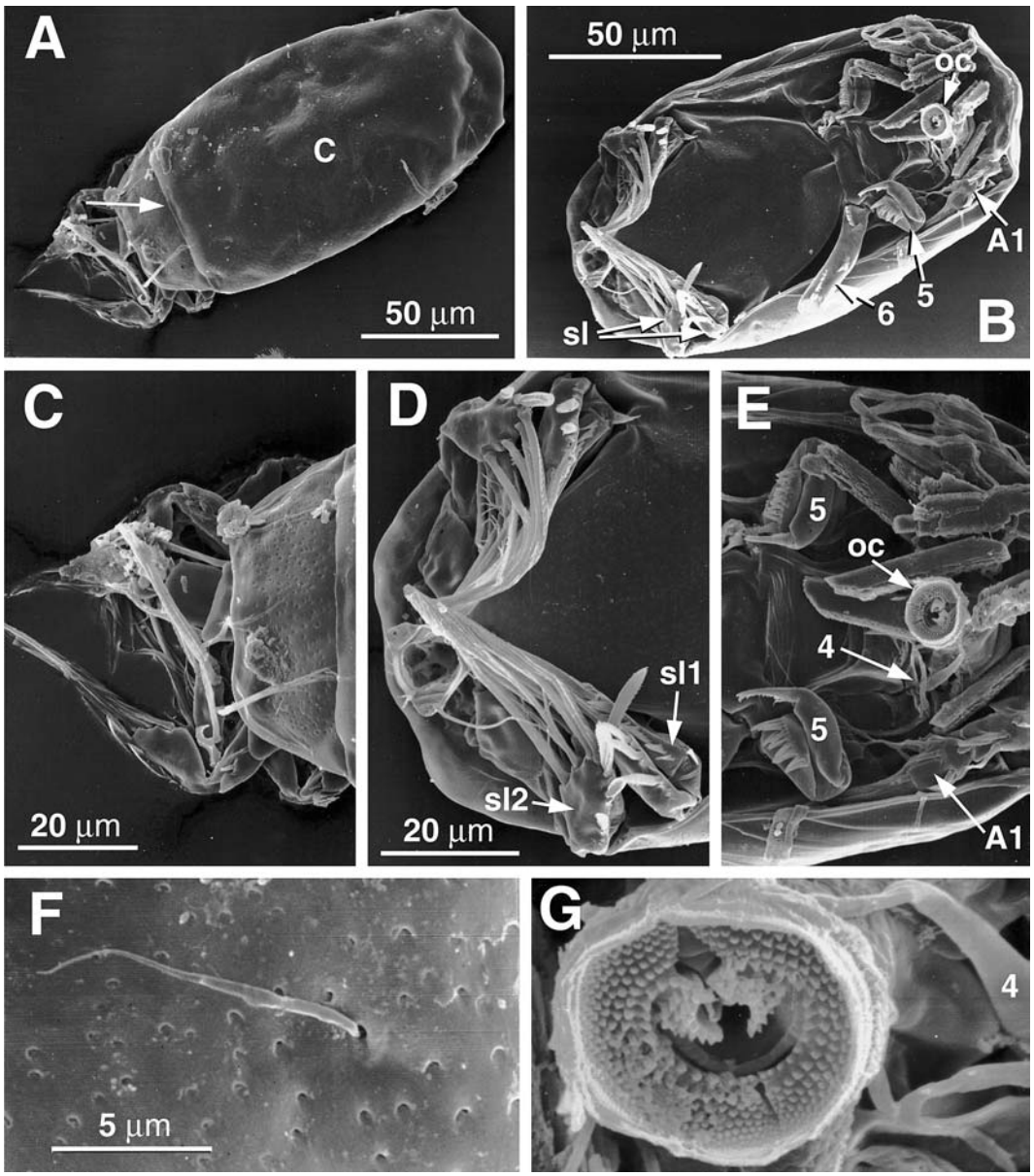

Fig. 7. Nicothoidae sp. A copepodite: BZ04078.17-B: A, dorsal view of whole animal (arrow indicates dorsal division). BZ04078.17-G: B, ventral view of whole animal. BZ04078.17-B: C, posterior dorsal region. BZ04078.17-G: D, posterior ventral region (urosomite 2 and caudal rami missing). E, anterior ventral region. BZ04078.17-B: F, external surface of carapace (showing pores and seta). BZ04078.17-G: G, oral cone. A1 = antennule, 4 = maxillule, 5 = maxilla, 6 = maxilliped, oc = oral cone, sl = swimming legs, u = urosome, c = cephalothorax.

(Yoo and Lim, 1996), all found on cypridinid hosts (but not F-Group *Vargula*), are unknown.

Bradford (1975: 8) noted that "among those parasites found on certain families of ostracodes, common characters are found," and that all six species found on cypridinid hosts have a maxillule (fourth limb) with three branches. Nicothoidae sp. A appears to have three on that limb. Bradford assigned no polarity to this character and it is also present in nicothoids found on amphipod, isopod, cumacean and two other ostracode families (*S. antarctica* and *S. synasterope* on Cylindroleberididae hosts, and *S. sarsiellae* on Sarsiellidae host). Nicothoidae sp. A copepodites apparently have three branches, although it was difficult to be certain. Bradford also found different characters in common among nicothoids found respectively on hosts of the myodocopid families Philomedidae and Sarsiellidae, but not Cylindroleberididae, although the character given for parasites of the Philomedidae was not unique.

In Bradford's (1975) diagnostic list of nicothoid species, those from cypridinid hosts were separated into two groups: (1) those having a first antenna with one segment (*Sphaeronella rugosidoloriae* and *S. siphonostrae*, a character also shared with *S. parasteropeae* from a cylindroleberid host), or (2) those having a first antenna with two segments (character also shared with *S. sarsiellae* from a sarsiellid host and *S. synasteropeae* from a cylindroleberid host). Both of these nicothoid groups were also listed as having no second antenna and a three-segmented maxilliped. The last

two characters are shared with Nicothoidae sp. A, as well as species of many unrelated hosts.

Again we appeal to copepod specialists to pursue the systematics of these interesting parasites and compare their phylogeny to that of their hosts. A cladistic analysis of the host ostracode family Cypridinidae has been completed (Cohen and Morin, 2003).

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