SPELEOITHONIDAE, A NEW FAMILY OF COPEPODA (CYCLOPOIDA) FROM ANCHIALINE CAVES ON THE BAHAMA ISLANDS

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Two new species of minute troglobitic cyclopoid copepods belonging to *Speleoithona* gen. nov. and Speleoithonidae fam. nov. are described based on adult females and males caught from the plankton in anchialine caves on Eleuthera and San Salvador Islands, Bahamas.

Speleoithona is distinguished from other cyclopoids by the structure of the P5, rostrum and mandibular palp, number of segments and armature of the A1, presence of a row of pinnules on the caudal face of the Exp3 P2–P4, and absence of the inner apical seta on the caudal rami. Interspecific variation has been observed on the Enp P4, apical setae of the caudal rami, P5 of both sexes, and P6 of males.

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INTRODUCTION

During the study of cyclopoid copepods collected by one of us (T.M.I.) from anchialine caves on the Bahamas, two lots of minute diaphanous cyclopoids from Eleuthera and San Salvador Islands were found. Although quite similar to each other, several taxonomically significant differences were observed among specimens from the two islands justifying their separation into two new species. As they cannot properly be accommodated in any of the known cyclopoid families, a new family is erected to include them.

HABITAT

Eleuthera is a long, narrow island situated on the eastern margin of the Great Bahama Bank and composed of low hills of eolian limestone. Hatchet Bay Cave is located several km north of the settlement of Hatchet Bay and is about 1 km inland from the west coast of the island. The cave is developed on three levels. An entrance chamber, floored with blocks of collapse limestone, contains inactive stalactites and stalagmites and is inhabited by a colony of bats. An extensive middle level, reached by ladder, contains dry passages and larger chambers of phreatic origin. The lowest level, also accessible by ladder, consists of a chamber half-filled with water. Maximum depth in the central depression of this anchialine pool was about 3 m. Surface water on 15 June 1986 had a salinity of 32 ‰, a temperture of 21.7° C, and 6 ppm dissolved oxygen. Although no water currents were observed in the pool, levels clearly fluctuated with the tides. Also collected from this pool were two new troglobitic halocyprid ostracods *Danielopolina bahamensis* and *Deeveya jillae* (KORNICKER & ILIFFE 1989), a possible new genus of calanoid copepod (Audun Fosshagen, pers. commn), and a macellicephalan polynoid polychaete identified by Marian H. Pettibone (in litt., 1986) as perhaps a young *Pelagomacellicephala iliffei,* previously known only from anchialine Conch Bar Cave in the Turks and Caicos Islands (PETTIBONE 1985).

San Salvador Island occupies an isolated, steep-walled carbonate pedestal. It has never had a shallow water connection with any of the other Bahama Islands. Lighthouse Cave is situated in the northeast part of the island, about 1 km inland from the coast. The limestone in which the cave is formed is an emergent coral reef, about 125 000 years old, while the oldest stalagmites within the cave have been dated at 51 000 years B.P. (CAREW & al. 1984); therefore placing maximum and minimum ages on the cave itself. Lighthouse Cave consists of a series of rooms interconnected by tubular phreatic passageways (MYLROIE 1980). It was formed at an earlier, higher stand of sea level and has since drained. Anchialine pools to 2 m depths are present along the northern and western side of the cave. Surface water in these pools on 10 June 1986 had a salinity of 32.5 ‰, a temperature of 24.7° C and 4 ppm dissolved oxygen. At 0.7 m depth, salin-

ity, and temperature were nearly the same as in the surface waters but dissolved oxygen had decreased to 0.7 ppm. Other anchialine troglobitic species from the cave include *Enantiosis cavernicola,* a new calanoid copepod (BARR 1984); *Neostenetroides stocki,* a new asellote isopod (CARPENTER & MAGNIEZ 1982); *Bahalana geracei,* a new cirolanid isopod (CARPENTER 1981a); *Barbouria cubensis* (VON MARTENS), a hippolytid cave shrimp also known from Bermuda, Cuba and other locations in the Bahamas; and *Pellina penicilliformis, Prosuberites geracei,* and *Cinachyra subterranea,* three new species of sponges (VAN SOEST & SASS 1981). In addition, a diverse terrestrial fauna including bats, cockroaches, isopods, snails and pseudoscorpions inhabit the cave. The food webs in Lighthouse Cave have been discussed by CARPENTER (1981b).

MATERIAL AND METHODS

Specimens of *Speleoithona* were collected by the junior author using a 92 μm mesh plankton net towed slowly through the water column while wading or swimming in the cave pools. Collections in Hatchet Bay Cave, Eleuthera were made in 0–3 m water depths, while those in Lighthouse Cave, San Salvador were from 0–1 m depths.

The preserved specimens were studied in glycerin. Complete dissections were made of several females and one male of each species. Dissected and whole specimens were examined for variation in characters described as well as for preparing and checking the drawings, all of which were made using an oil immersion lens.

The abbreviations used in the text are: A1= antennule; A2 = antenna; ae = aesthetasc; B1–2 = basal segments 1–2; Enp 1–3 = 1st to 3rd segments of endopodite; Exp 1–3 = 1st to 3rd segments of exopodite; Le = outer lobe; Li = inner lobe; Md = mandible; Mx1 = maxillule; Mx2 = maxillae; Mxp = maxilliped; P1–P6 = 1st to 6th legs; Pr = prosome; Ur = urosome; sp = spine; BM(NH) = British Museum (Natural History); MZUSP = Museu de Zoologia da Universidade de São Paulo.

TAXONOMY

Speleoithonidae fam. nov.

Diagnosis. As for the type genus.

Speleoithona gen. nov.

Diagnosis. Rostrum enlarged and notched medially. Gonopore on ventral surface of genital segment; after copulation, females bear pair of spermatophores attached side by side at a ventral position. Inner apical seta of caudal rami absent. A1 of 18 segments, with aesthetascs on segments 8, 17, and 18. A2 3-segmented; basal segment narrowed proximally and without outer seta. Md: B2 quadrangular and smooth; Enp 2-segmented with proximal segment unarmed and terminal segment with 3 setae; Exp 2-segmented with 4 setae. Mx1: Li1 with 5 setae; Li2 with 1 seta; Li3 with 3 setae distally; Exp 1-segmented and with 3 setae; Enp and setae of Le1 and B2 absent. Mx2 with only 2 setae on proximal endite of segment 2 and 1 seta on terminal segment. Fourth segment of Mxp with only 1 inner distal seta. P1–P4: only B1 P1 with inner seta; inner side of B2 P1–P4 protruded internally; Enp and Exp 3-segmented; Enp3 P1 with 5 setae; Enp3 P2–P4 with 4 setae and row of pinnules on caudal face of each; 4 different setae, but no more than 3 per species, may be modified on Enp P4. Pair of P5 joined by intercoxal plate, each leg 2-segmented and bearing very long seta in both sexes; P5 of male with 2 short setae on inner side of distal segment. P6 of female represented by spine curved forward and long seta. P6 of male with 2 setae.

Type species: *Speleoithona eleutherensis* sp. n.

Gender: feminine.

Etymology. From the Greek 'spelaion' meaning a cave; *Oithona,* a related cyclopoid genus.

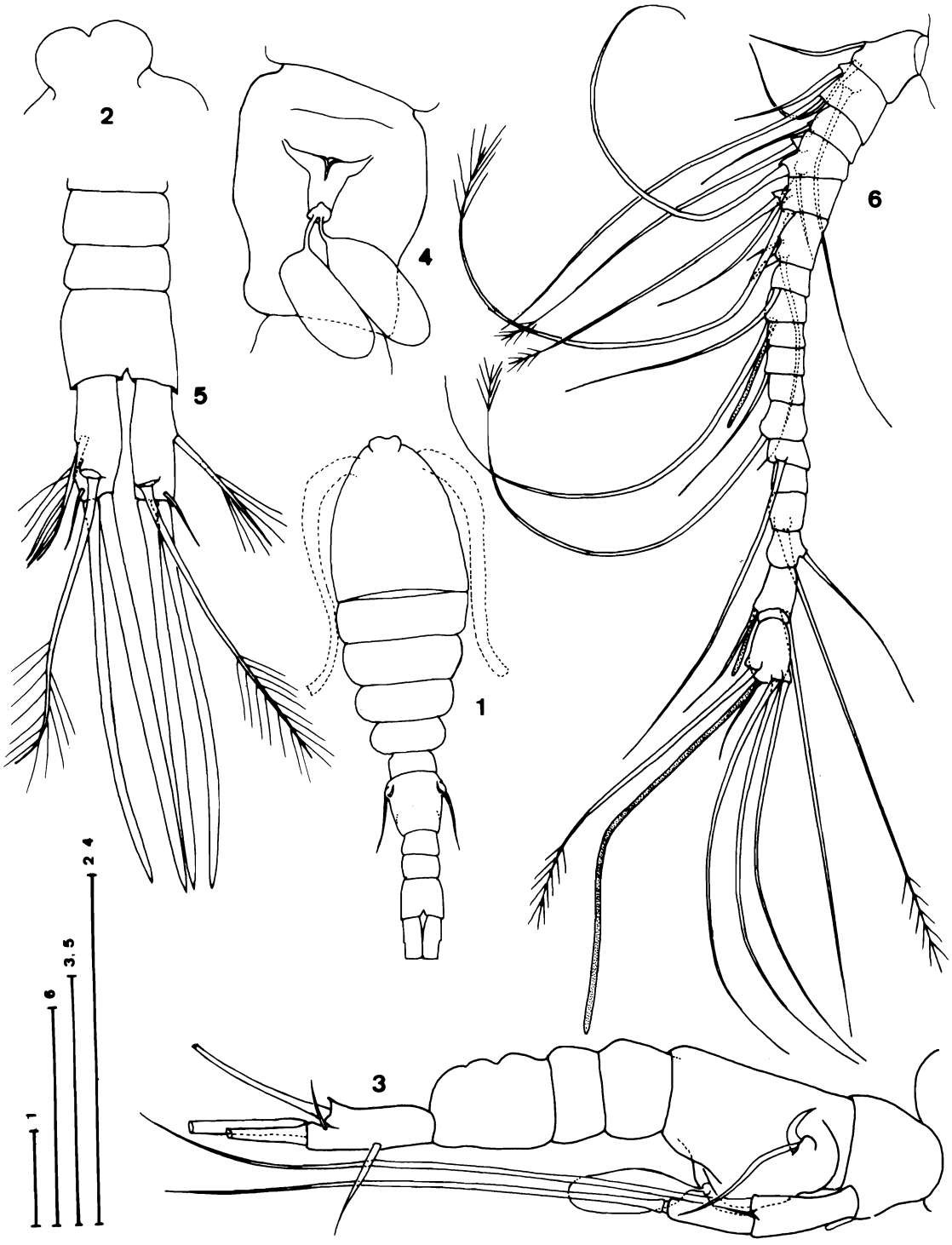
Speleoithona eleutherensis sp. n.
(Figs 1–22)

Material examined. 122 females and 4 males collected from Hatchet Bay Cave; Eleuthera Island, Bahamas on 15 June 1986. Female holotype (1989.547) and 50 paratypes (1989.548–588) in BM(NH); 30 paratypes (9710) in MZUSP.

Female. Body length 255–290 μm (n = 10). Pr : Ur ratio = 1.4–1.5 : 1. Body weak and diaphanous, making it difficult to distinguish clearly articulations of body somites or appendage segments. First metasomal somite free (Fig. 1). Rostrum (Fig. 2) enlarged and notched medially. Posterior margins of all body somites smooth. Genital segment (Figs 1, 3) swollen anteriorly and ventrally. Seminal receptacle as in Fig. 4. Several females bearing pair of oval spermatophores attached together with disc-like plug ventrally at distal part of receptacle (Fig. 4) by fertilization tubule. Anal somite (Fig. 5) as long as length of two preceding somites together and slightly notched medially.

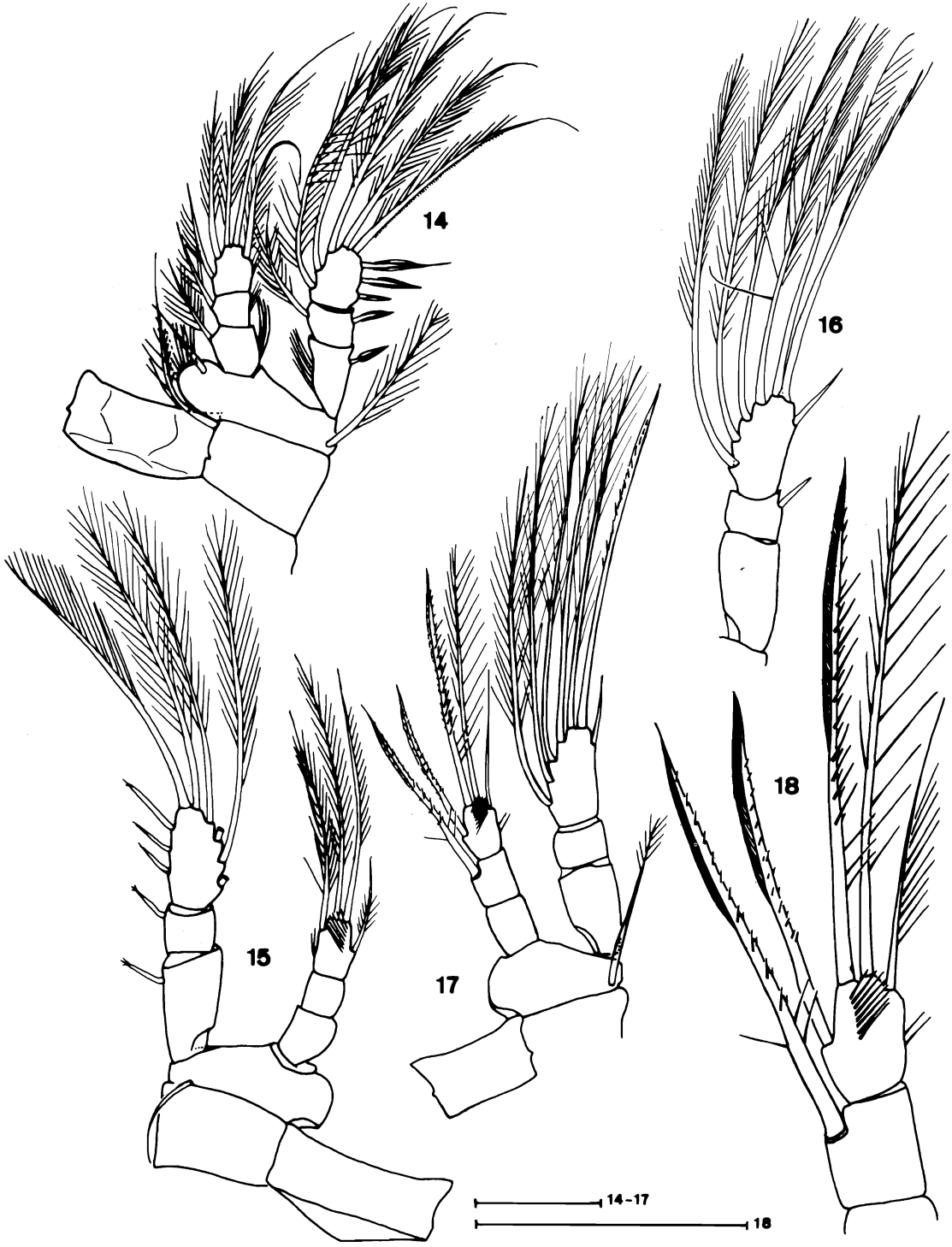
Caudal ramus (Fig. 5) as long as anal somite and about 2.5 times longer than wide. Lateral seta inserted about halfway along outer margin. Outer apical seta slender. Median apical setae similar in length, 3.2 times longer than ramus, thickened, smooth and bluntly pointed. Inner apical seta absent. Dorsal seta about 2.7 times as long as caudal ramus and shorter than median apical setae.

A1 (Fig. 6) of 18 segments and ornamented as

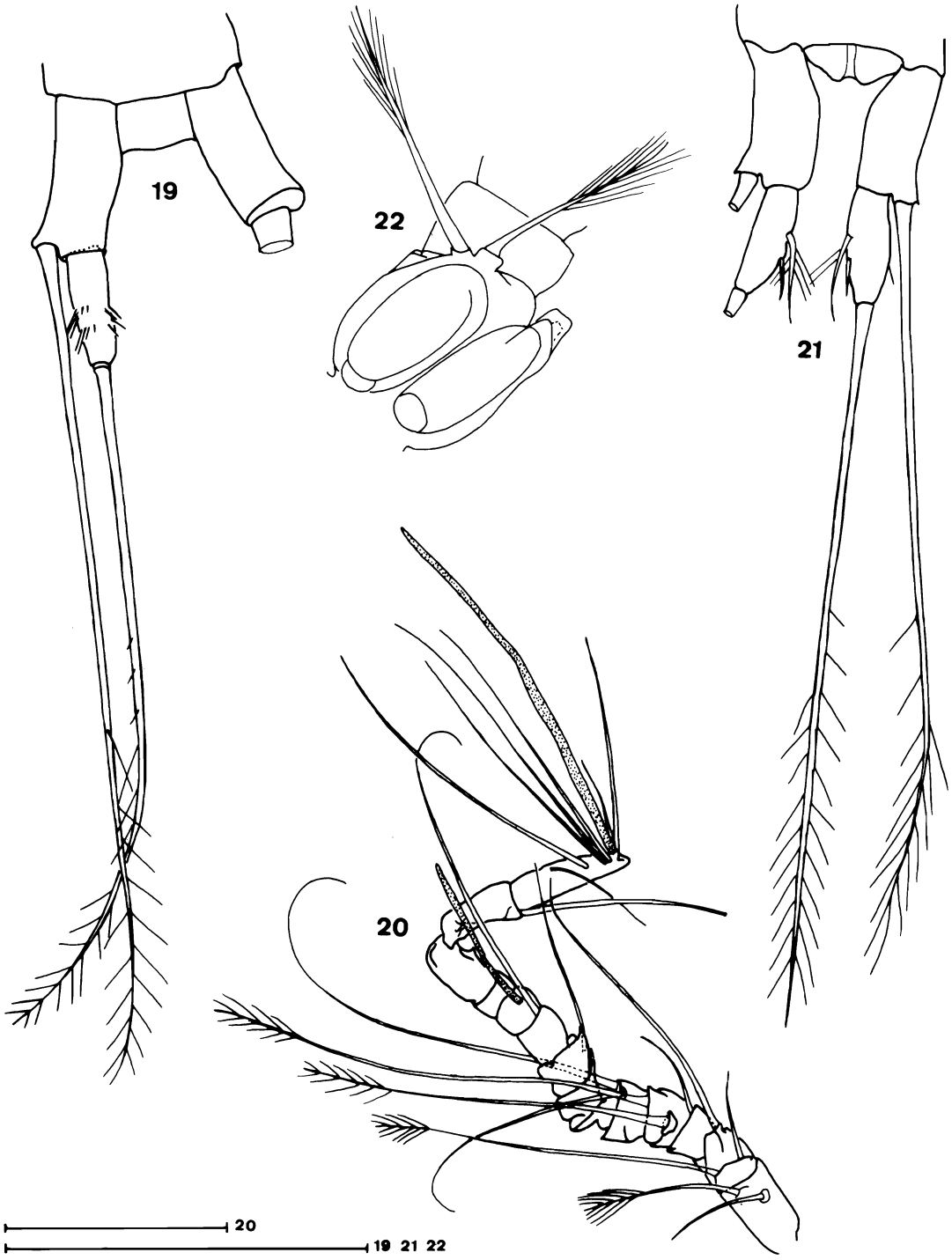


Figs 1–6. *Speleoithona eleutherensis* sp. n., female: 1. Habitus, dorsal. 2. Rostrum, dorsal. 3. Urosome, lateral. 4. Genital segment, ventral. 5. Abdominal somites and caudal rami, dorsal. 6. Antennule (space between last two segments represents the extended arthrodial membrane, not an additional segment). Scale bars = 50 μm.

Figs 7–13. *Speleoithona eleutherensis* sp. n., female: 7. Antenna. 8. Labrum, lateral. 9. Labrum, ventral. 10. Mandible. 11. Maxillule. 12. Maxilla. 13. Maxilliped. Scale bars = 50 μm.



Figs 14–18. *Speleoithona eleutherensis* sp. n., female: 14. First swimming leg. 15. Second swimming leg. 16. Exopod of third swimming leg. 17. Fourth swimming leg. 18. 2nd and 3rd endopodal segments of the fourth swimming leg. Scale bars = 50 μm.



Figs 19–22. *Speleoithona eleutherensis* sp. n., female: 19. Pair of fifth legs. Male: 20. Antennule. 21. Pair of fifth legs. 22. Genital segment and sixth leg. Scale bars = 50 μm.

follows (Roman numerals = segments; Arabic numerals = number of setae): I = 2, II = 3, III = 1, IV = 3, V = 3, VI = 2 + 1 sp, VII = 1, VIII = 1 + 1 ae, IX = 0, X = 1, XI = 0, XII = 1, XIII = 1, XIV = 0, XV = 1, XVI = 1, XVII = 2 + 1 ae, XVIII = 5 + 1 ae.

A2 (Fig. 7) 3-segmented. Basal segment narrowed proximally and with 2 inner setae; outer seta absent. Second segment bearing 2 marginal and 2 distal inner setae. Terminal segment with 7 apical setae, the 3 innermost flexed inward.

Labrum (Figs 8, 9) well-developed, swollen and with long setules curved backward.

Md (Fig. 10) bearing biramous palp. Blade not seen clearly, but ending in long slender teeth. B2 longer than wide, slightly notched distally and smooth. Enp 2-segmented; proximal segment smooth; terminal segment with 3 setae. Exp 2-segmented; basal segment with 1 seta; distal part inconspicuously divided and bearing 3 setae.

Mx Li1 (Fig. 11) with a proximal spiniform seta armed with spiral row of setules, fine smooth seta and 3 distal spiniform setae. Li2 with 1 seta present. Li3 with 2 spiniform setae ornamented with setules and fine, short and smooth seta. Exp 1-segmented, with 3 setae. Enp and setae of Le1 and B2 absent.

Mx2 (Fig. 12) 6-segmented; B1 subdivided into 2 parts; proximal one bearing 3 setae on proximal endite and 1 on distal endite, and distal part with 2 and 3 setae on proximal and distal endites, respectively; segment 3 (B2) produced medially into bifide lacinia having distal part extended as short claw and proximal part supporting long seta; segment 4 (Enp1) with 2 external and 2 internal setae, each on protuberance; segment 5 and 6 with 2 and 1 setae, respectively.

Mxp (Fig. 13) 5-segmented (as B1 subdivided into 2 parts) and with setal formula 3.2.2.1.3.

P1–P4 (Figs 14–17) with rami 3-segmented; armature formula as follows:

	coxa	basis	endopod	exopod
P1	0–1	1–1	0–1;0–1;1,2,2	I–0;I–1;III,2,3
P2	0–0	1–0	0–0;0–0;1,2,1	I–0;I–0;III,2,4
P3	0–0	1–0	0–0;0–0;1,2,1	0–0;I–0;I,2,4
P4	0–0	1–0	0–0;0–1;1,2,1	0–0;0–0;I,2,4

Pinnule rows present on inner corner of B2 P1, inner margin of Exp1 P1 and on outer margin of Enp1–3 P1 and Enp3 P2–P4. Vertical pinnule rows also present on caudal face of Enp3 P2–P4. Outer margin spines of Exp P1–P4 diaphanous; only those of Exp P1 with lateral membrane. Outer apical seta of Exp3 with row of minute spines externally and plumose internally on P1 and smooth externally and plumose internally on the other legs. Enp3 P4 about 1.5 times longer than wide. Inner setae of Enp2–3 P4 and inner apical seta of Enp3 P4 (Fig. 18) thick, barbed and with fringe of hairs on inner side of distal half. Intercoxal plates wider than long, mainly those of P2 and P3, and completely smooth on both sides.

Pair of P5 (Fig. 19) joined by intercoxal plate. Each leg uniramous, with basal segment about twice longer than wide, 1.4 times length of terminal segment and bearing long plumose seta on outer distal corner; terminal segment 2.5 times as long as broad and with 2 transverse pinnule rows and long plumose apical seta. Both setae reaching beyond end of caudal rami (Fig. 3).

P6 (Fig. 3) a curved, strong spine and a long, smooth seta surpassing posterior margin of genital segment.

Male. Body length 240–260 μm (n = 4). Pr : Ur ratio = 1.35–1.4 : 1. Cephalosome without lateral flap and accompanying integumental organs. Both A1 bigeniculate and ornamented as in Fig. 20. P5 (Fig. 21) bisegmented; terminal segment with long apical seta and 2 inner setae, proximal-most twice length of distal-most. P6 (Fig. 22) represented by 2 long slender plumose setae. A2, mouthparts, swimming legs and caudal rami are identical to those of female.

Etymology. The specific name refers to the island where the species was found.

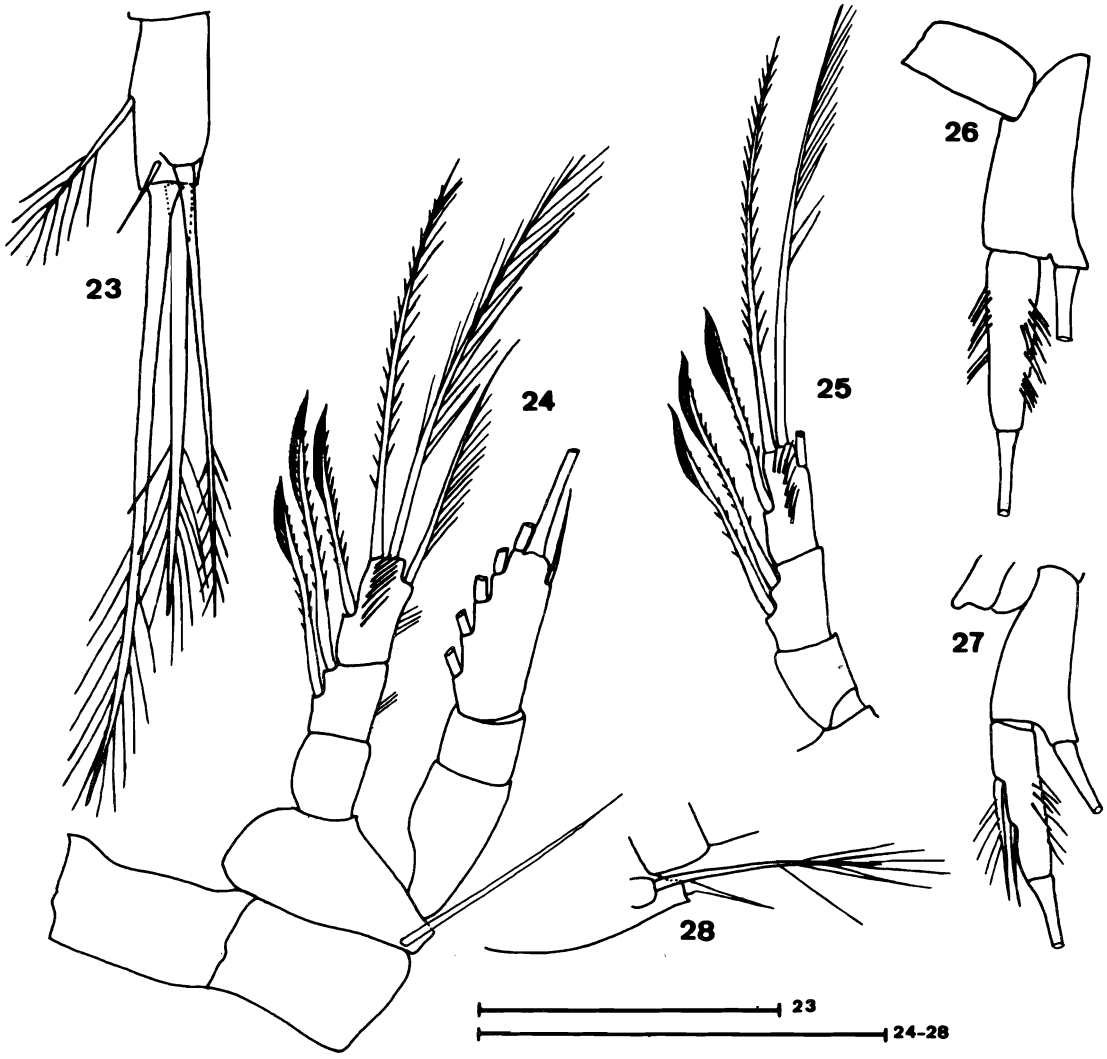
Type locality. Hatchet Bay Cave, Eleuthera, Bahama Islands.

Speleoithona salvadorensis sp. n.
(Figs 23–28)

Material examined. 24 females, 6 males and 2 copepodites collected from Lighthouse Cave, San Salvador Island, Bahamas on 10 June 1986. Female holotype (1989.589) and 10 paratypes (1989.590–599) in BM(NH); 10 paratypes (9711) in MZUSP.

Female. Body length 250–285 μm (n = 10). Pr : Ur ratio = 1.47–1.56 : 1. Caudal ramus (Fig. 23) 2.13–2.25 times as long as wide. Median apical setae tapering gradually toward tip and plumose terminally; outer seta 3.8 times length of ramus and 1.4 times longer than inner one. Dorsal seta reaching tip of inner median apical seta.

Enp P4 (Figs 24–25) armature as follows: 0–0; 0–2; 1–2–1. Enp3 twice as long as wide. Inner marginal setae of Enp2–3 thick, curved, barbed and bearing fringe of juxtaposed hairs on inner border distally, median seta being somewhat longer than



Figs 23–28. *Speleoithona salvadorensis* sp. n., female: 23. Caudal ramus, dorsal. 24. Fourth swimming leg. 25. Endopod of the fourth leg of the same pair as that represented by Fig. 24. 26. Fifth leg. Male: 27. Fifth leg. 28. Sixth leg. Scale bars = 50 μm.

other two. One specimen with these setae varying in length in each member of pair of P4 (compare Figs 24 and 25). Inner apical seta of Enp3 thicker than other one, barbed and slightly curved. Outer marginal seta of Enp3 reaching beyond tips of all inner marginal setae of Enp.

Terminal segment of P5 (Fig. 26) as long as basal segment, about 3.7 times longer than broad and with hairs on inner and outer sides.

Male. Body length 230–250 μm (n = 3). Enp3 P4 similar to that of female illustrated by Fig. 25. P5 (Fig. 27) differing from that of female by having 2 setae on inner margin, the proximal-most about 1.5 times length of distal-most. P6 (Fig. 27) represented by 2 unequal setae.

In all other respects, this species is similar in those characters discribed for *Speleoithona eleutherensis*.

Etymology. The specific name refers to the island where the species was found.

Type locality. Lighthouse Cave, San Salvador Island, Bahama Islands.

DISCUSSION

Within the Cyclopoida, *Speleoithona* is most closely related to the Oithonidae SARS in sharing a slender and very delicately structured body, thin integument, slender A1 armed with long setae in females, and the general structure of the A2, Mx1, Mxp, and swimming legs. Unlike the Oithonidae, *Speleoithona* has a claw on the basis of the Mx2. Since the lack of the character is a synapomorphy for Oithonidae (Ho & THATCHER 1989), the new taxon is placed in the new family Speleoithonidae defined by the following apomorphies: (1) rostrum bilobed, (2) presence of a vertical row of pinnules on the caudal face of the Enp3 P2–P4, (3) absence of the inner apical seta of the caudal ramus, (4) presence of four inner setae on Enp2 A2, and (5) five setae on the Li1 Mx1.

Ho & THATCHER (1989) proposed a phylogenetic hypothesis for the eight cyclopoid families. HUYS (1990) tentatively regarded the Mantridae, a family of copepods living in the mantle-cavity of bivalved molluscs and previously assigned to the Siphonostomatoida, as the sister group of Notodelphyidae/Ascidicolidae-clade. Speleoithonidae is considered the sister group of Oithonidae which diverged from the cyclopoid lineage before the reduction in the number of segments of the A1 to 15–17 segments, the synapomorphy of the Oithonidae/parasitic cyclopoids-clade (Ho & THATCHER 1989). A synapomorphy shared by these copepods and Speleoithonidae might be the P5 which is bisegmented by fusion of the coxa and basis of this leg.

It is here proposed that *Speleoithona* evolved in its restricted habitat, developing very charactistic features (the five apomorphies aforementioned), while retaining some primitive traits that are also diagnostic, such as sexual dimorphism in the P5, paired spermatophores attached side by side at the ventral pore of the seminal receptacle, P5 ventrally placed and joined by an intercoxal plate, A1 of 18 segments bearing aesthetascs on segments 8, 17 and 18, and structure of the mandibular palp, which is more reminiscent of the primitive misophrioids than the cyclopinids.

The two isolated populations sampled represent new species differing only in P4, caudal rami, P5 of both sexes and P6 of males. Nevertheless, more intensive collections from anchialine caves are required to determine what other populations of these cyclopoids occur in the Caribbean region or elsewhere, thus providing data on their distribution and ecology as well as details for clarifying their evolutionary history.

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