JOURNAL OF CRUSTACEAN BIOLOGY, 18(2): 405–411, 1998

STOLONICYCLOPS HEGGIENSIS, NEW GENUS, NEW SPECIES, FROM GEORGIA, U.S.A. (COPEPODA: CYCLOPOIDA: CYCLOPIDAE)

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ABSTRACT

A previously unknown genus and species of cyclopoid copepod, *Stolonicyclops heggiensis*, was discovered in seepage areas on Heggie's Rock, a granite monadnock in Georgia, U.S.A. The genus is characterized by leg 5 fused to the somite, with 1 dorsal seta and 2 ventral setae on a small knob; the antennule of 11 segments in the female; the swimming legs with 2-segmented rami, except leg 4 endopodite segments partly fused in the female; the spine and seta formulae of swimming legs 2,3,3,3 and 5,4,4,4, respectively; the lack of a seta on the medial (inner) corner of the coxopodite of legs 2–4; leg 4 endopodite segment 2 with 5 appendages; and the lack of sexual dimorphism in the swimming legs, except for the difference in leg 4 endopodite fusion. In several respects, *S. heggiensis* resembles *Bryocyclops* (*Palaeocyclops*) *jankowskajae* Monchenko from Kazakhstan and Uzbekistan. However, the lack of modified appendages of leg 3 in the male of *S. heggiensis* precludes assigning it to the genus *Bryocyclops*. The nature of leg 3 of the male and other plesiomorphic characters of *S. heggiensis* may indicate that its ancestor diverged earlier than *Palaeocyclops* from the *Bryocyclops* ancestral line.

A population of a previously unknown genus and species of cyclopoid copepod inhabits ephemeral seepage areas between rock slopes on a granite monadnock in the state of Georgia, U.S.A. We describe the species and aspects of its habitat and biology.

For description, the specimens were transferred from 70% ethanol to glycerine and then to lactic acid. Drawings were made from specimens temporarily mounted in lactic acid, then permanently in CMC-10 with a little chlorazol black E added, using a Wild M30 microscope fitted with a drawing tube, at magnifications of 600× or 1,000× (with an oil immersion lens). Specimens were deposited at the National Museum of Natural History (USNM), Smithsonian Institution, the Invertebrate Collection of the Museum of Natural History, University of Georgia, Athens, Georgia (UGAMNH), and the Arthropod Collection of the Department of Entomology, Clemson University, Clemson, South Carolina (CUAC).

Cyclopoida G. O. Sars, 1886
Cyclopidae Burmeister, 1834
Cyclopinae Dana, 1853, char. emend.
Kiefer, 1927

Stolonicyclops, new genus

Diagnosis.—Cyclopidae, Cyclopinae. Until the discovery of additional species of this group, the diagnosis of the genus coincides with that of the species. Salient distinguishing characters: leg 5 fused to somite, with 1 dorsal seta and 2 ventral setae on small knob; antennule of 11 segments in female; swimming legs with 2-segmented rami, except leg 4 endopodite segments partly fused in female; spine and seta formulae of swimming legs 2,3,3,3 and 5,4,4,4, respectively; no seta on medial (inner) corner of coxopodites of legs 2–4; leg 4 endopodite segment 2 with 5 appendages; and lack of sexual dimorphism in swimming legs, except for partial fusion of leg 4 endopodite in female.

Type Species.—*Stolonicyclops heggiensis*, new species.

Gender—Masculine.

Etymology.—From the Latin *stolo*, meaning a branch or runner, in reference to the supposed early offshoot of this group from the *Bryocyclops* ancestor; prefixed to the genus name *Cyclops*.

Stolonicyclops heggiensis, new species
Figs. 1, 2

Material Examined.—Holotype: 1 ♀, dissected on slide (USNM 283160). Allotype: Adult ♂, dissected on slide (USNM 283159). Paratypes: 1 ♀, dissected on slide, and 4 ♀♀, 5 ♂♂, and 6 copepodids in 70% ethanol (USNM 283157). All from small pools in clear trickle streams from seepage areas on Heggie's Rock, Heggie's Rock Preserve, Columbia County, Georgia, U.S.A., 33°32′30″N, 82°16′00″W, 27 January 1997, coll. J. D. Spooner. Accompanying copepod species: *Attheyella* (*Mrazekiella*) *nordenskioldii* (Lilljeborg), 14 ♀♀, 16 ♂♂, and 14 copepodids (USNM 283158). Additional paratypes, all from Heggie's Rock, 25 April 1997, coll. J. D. Spooner: 1 ♂, from pool in right midrock seepage trickle (USNM 284165); accompanying copepods: *A.* (*M.*) *nordenskioldii*,

16 ♀♀, 5 ♂♂ (USNM 284164). 1 ♀, from pool in east seepage trickle (USNM 284167); accompanying copepods: *A.* (*M.*) *nordenskioldii*, 2 ♀♀, 5 ♂♂ (USNM 284166); *Megacyclops latipes* (Lowndes), 1 ♂, 2 copepodids (collection of J. D. Spooner); and *Microcyclops rubellus* (Lilljeborg), 19 ♀♀, 13 ♂♂ (collection of J. D. Spooner). 19 ♀♀ and copepodids, from left midrock seepage trickle pool (USNM 284168); 10 ♀♀, 10 ♂♂, from same sample (UGAMNH–IC181); and 10 ♀♀, 4 ♂♂, from same sample (CUAC).

Female.—Length of holotype 420 μm, of paratypes 412–552 μm. Body (Fig. 1A–C) slender in dorsal view, with few surface pits and paired hair-sensilla on some somites as illustrated, integument otherwise without special structures. Eye present. Posterolateral margins of pedigers 3–5 produced in dorsal view, smooth. Joint between pediger 5 and genital double-somite expanded and unusually flexible, more or less sclerotized (in different specimens) as pseudosomite. Genital double-somite expanded in anterior half, tapering posteriorly, greatest breadth about 1.2 times length. Seminal receptacle (Fig. 1C) with anterior part little produced and concave; posterior part little produced to broadly rounded in different specimens; lateral arms broad; pore canal long, gently curved. Urosomites lacking hyaline frills. Posterior margin of anal somite with slender spindles; anal operculum broad, quadrate, and little sclerotized; anal sinus smooth.

Caudal ramus (Fig. 1 A–D) about 2.0 times longer than broad, ornamented with tiny spinules at base of lateral seta and larger spinules at base of lateralmost terminal seta. Apical ventral tip produced, with pore (indicated by arrow in Fig. 1C). Lateral seta inserted just posterior to midlength of ramus. Lateral and middle terminal setae finely plumose; dorsal seta naked; lateralmost and medialmost terminal setae spiniform, finely serrate. Lengths of caudal setae of holotype in μm: lateral 20, dorsal 38, lateralmost to medialmost terminal 35, 145, 272, and 15.

Antennule (Fig. 1A, F) of 11 segments. Surface of segments smooth except for short comb of spinules on proximal part of segment 1. Segments (Roman numerals) with number of setae (Arabic numerals), spines, and aesthetascs in parentheses: I(8), II(4), III(5), IV(2), V(1 + spine), VI(2), VII(3), VIII(2 + aesth.), IX(2), X(2 + aesth.), XI(7 + aesth.). Spine on segment V stout. No hyaline membrane visible on terminal segments.

Antenna (Fig. 1G), basipodite with 1 short row of spinules on caudal surface; exopodite seta lacking; endopodite segments 1–3 with 1, 6, and 7 setae, respectively.

Labrum (Fig. 1H) with 10 marginal teeth between lateral corners; ventral side with 2 groups of long hairs and 1 transverse row of tiny denticles. Paragnaths (Fig. 1H) naked, shallowly bicuspidate. Mandible (Fig. 1I), palp with 2 short setae only. Maxillule (Fig. 1J), surface of palp smooth. Maxilla (Fig. 2A), claw with 3 small teeth proximal to midlength of inner margin. Maxilliped (Fig. 2B), segments 1 and 2 each with 1 transverse row of spinules.

Legs 1–4 (Fig. 2C–F) with 2-segmented rami, except leg 4 endopodite with only partial suture on frontal surface between original segments 1 and 2. Couplers of all legs without surface ornament, and with two rounded marginal protrusions, except margin of leg 4 coupler crenate. Medial (inner) corner of coxopodite of leg 1 with seta; corresponding corners of coxopodites of legs 2–4 lacking seta. Leg 1 with short slender spine on medial expansion of basipodite. Segment 1 of exopodites 1–4 without setae, segment 1 of endopodites each with 1 medial seta. Segment 2 of exopodites 1–4 with 2,3,3,3 spines and 5,4,4,4 setae, respectively. Legs 2 and 3 similar, except leg 3 slightly larger and lacking spinules near lateral seta of basipodite present on leg 2. Leg 4 endopodite segment 2 about 1.2 times longer than broad, with 4 setae and 1 terminal spine, length of spine about equal to length of segment 2.

Leg 5 (Fig. 1B, C, E) composed of dorsal seta implanted on somite, and 2 ventral setae on small protrusion, more ventral seta shorter. Leg 6 (Fig. 1B) composed of small plate bearing 2 dorsal setae and 1 ventral spine.

Paired egg sacs carried dorsolaterally. In females collected from Heggie's Rock in late April, each sac containing three large eggs, arranged in row (Fig. 1A). In females in culture, each sac with three to five eggs, in the latter case with middle eggs offset from each other (F. D. Ferrari, personal communication).

Male.—Length of allotype 350 μm, lengths of paratypes 344–364 μm. Habitus (Fig. 2G) and ornamentation of body much as in female except for usual sexual dimorphisms.

Antennule (Fig. 2H) geniculate, of 16 segments, segments I, IV, and IX with 4, 1, and 1 short aesthetascs, respectively.

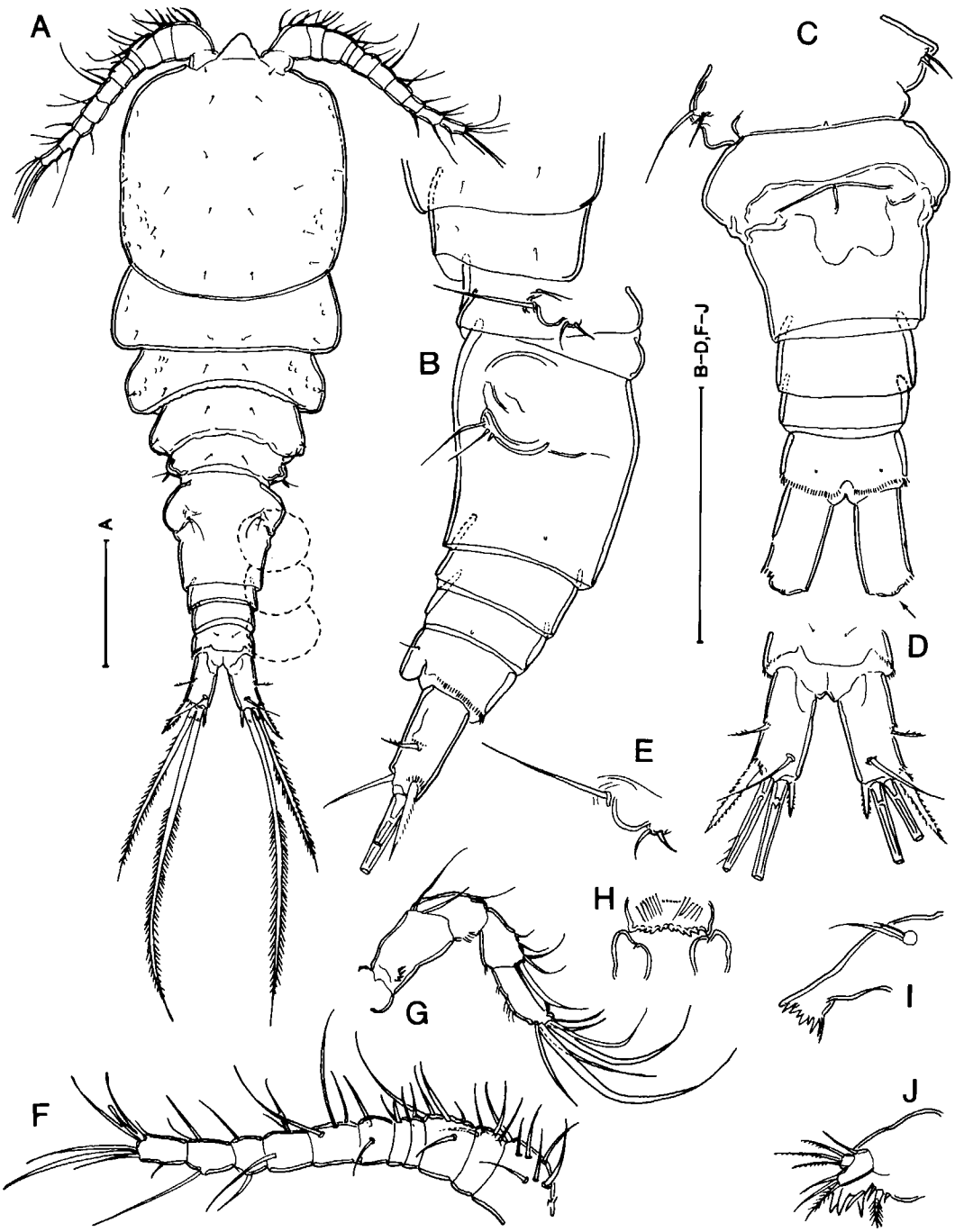

Fig. 1. *Stolonicyclops heggiensis*, new genus, new species. A–E, G–J, holotype female (USNM 283160); F, dissected paratype female (USNM 283157). A, habitus, dorsal; B, posterior prosomites and urosome, right lateral; C, pediger 5 and urosome, ventral; D, anal somite and caudal rami, dorsal; E, leg 5, enlarged; F, antennule; G, antenna, caudal; H, labrum and paragnaths, ventral; I, mandible; J, maxillule. Scales = 100 μm.

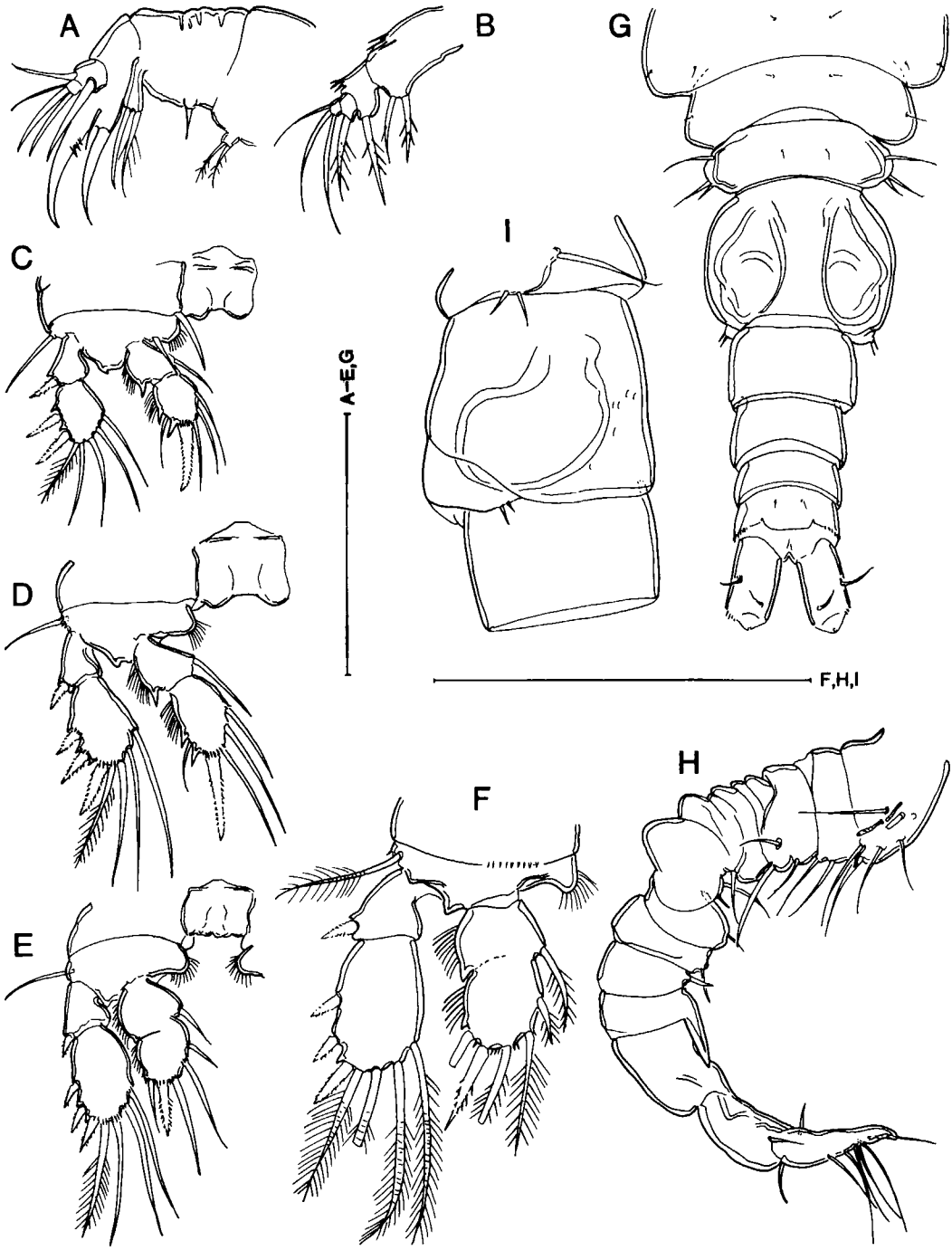

Fig. 2. *Stolonicyclops heggiensis*, new genus, new species. A, B, F, holotype female (USNM 283160); C–E, dissected paratype female (USNM 283157); G–I, allotype male (USNM 283159). A, maxilla; B, maxilliped; C, leg 1 and coupler, frontal; D, leg 2, frontal; E, leg 4, frontal; F, leg 4, caudal; G, posterior prosomites and urosome, dorsal; H, antennule; I, legs 5 and 6. Scales = 100 μm.

Antenna, mouthparts, and legs 1–5 as in female, except leg 4 endopodite segments distinct.

Leg 6 (Fig. 2I) consisting of broadly trapezoidal plate bearing only 2 short marginal setae, dorsal seta about one-half length of ventral seta.

Color.—Living animals are clear to white, some individuals with tinges of gray or yellowish tan. Fat bodies are orange, the eye red.

Distribution and Etymology.—Known only from the type locality, Heggie's Rock, for which the species is named. Heggie's Rock is the easternmost granite monadnock outcrop in Georgia in the lower Piedmont physiographic province. The Heggie's Rock Preserve lies in the drainage basin of Little Kiokee Creek, an affluent of the Savannah River.

Discussion.—Several genera of cyclopine copepods include small species, mostly of interstitial or semiterrestrial habitat, with antennules of 10 or 11 segments, oligomerization of the swimming legs, and a reduced leg 5 with the proximal segment partly or completely absent (usually represented by a seta implanted directly on the somite) and the distal segment distinct or fused to the somite. Most of these genera differ from *Stolonicyclops heggiensis* in having all swimming legs of two distinct segments in both sexes, and possessing a seta at least (as far as has been described) on the medial corner of the coxopodite of leg 4. This group includes *Graeteriella* Brehm, 1926, sensu lato, emend. Lindberg, 1954; *Metacyclops* Kiefer, 1927, sensu Lindberg, 1961; *Allocyclops* Kiefer, 1932; *Muscocyclops* Kiefer, 1932; *Speocyclops* Kiefer, 1932, emend. Lindberg, 1954; *Apocyclops* Lindberg, 1942; *Goniocyclops* Kiefer, 1955; *Psammocyclops* Kiefer, 1955; *Cochlacocyclops* Kiefer, 1955; *Psammophilocyclops* Fryer, 1956, emend. Shen and Tai, 1964; *Teratocyclops* Plesa, 1981; *Yansacyclops* Reid, 1988; and *Fimbricyclops* Reid, 1993a. In *Menzeliella* Lindberg, 1954, the setation of the coxopodites of legs 1–4 is not known, but legs 1–4 have 2-segmented rami and the distal segment of leg 5 is fused but protrudes from the somite. *Diacyclops virginianus* Reid, 1993b, the generic status of which is under reconsideration (Reid, unpublished data), has, among other differences, the coxopodites of legs 1–4 all with inner setae and the distal segment of leg 5 distinct from the somite.

In the lack of a medial seta on the coxopodites of legs 2–4 and the partial fusion of leg 4 endopodite in the female, *Stolonicyclops heggiensis* resembles the genus *Bryocyclops* Kiefer, 1927, sensu lato. The confused systematics of *Bryocyclops* have been discussed by Lindberg (1956), Monchenko (1972), Dussart (1982), and Rocha and Bjornberg (1987). The species of *Bryocyclops* are unified by the absence of a seta on the medial corner of the coxopodite of leg 4, and, as far as known, by modifications of the terminal spine and one or more setae of the endopodite segment 2 of leg 3 in males. Some species, e.g., *B. campaneri* Rocha and Bjornberg, 1987, and *B.* (*Palaeocyclops*) *jankowskajae* Monchenko, 1972, also lack a medial seta on legs 2 and 3, in common with *S. heggiensis*. *Stolonicyclops heggiensis* resembles *B.* (*P.*) *jankowskajae*, known from the Kisilkum Desert in Kazakhstan and Uzbekistan, and both differ from other known species of *Bryocyclops* in several additional characters, most notably the spine formula, the presence of five appendages on the endopodite segment 2 of leg 4, and the relatively long caudal ramus. The latter two characters are probably plesiomorphic in *Bryocyclops*. However, in *B.* (*P.*) *jankowskajae*, the setal formula is 5,5,5,4, the anal operculum is produced well past the posterior margin of the anal somite, the endopodite segments of leg 4 are distinct in the female, and the terminal spine and two setae of the endopodite of leg 3 are modified in the male, as in other species of *Bryocyclops*. The lack of modified appendages in the endopodite of leg 3 of the male of *S. heggiensis* make it necessary to propose a new genus to accommodate this species. The suite of plesiomorphic characters present in *Stolonicyclops*, particularly the lack of sexual dimorphism in the swimming legs, but also the low degree of reduction in leg 4 in the female (more reduced in most species of *Bryocyclops*), the five appendages on the endopodite 2 of leg 4, and the relatively undeveloped anal operculum support an argument that the ancestor of *S. heggiensis* diverged early from the *Bryocyclops* ancestor. Evolution of the former probably then followed an independent line, since the lack of setae on the basipodite of legs 3 and 4 and the setal formula show relative oligomerization and can therefore be considered apomorphic features compared to *Palaeocyclops*.

Most species of *Bryocyclops* are found in tropical Africa, Madagascar, tropical Asia, Pacific islands (Fiji, Hawaii, Indonesia), and Brazil, with one each from Iran, Israel, Kisilkum, and Mongolia. No native *Bryocyclops* is known from North America, although a population of the Indonesian species *Bryocyclops* (*Bryocyclops*) *muscicola* (Menzel, 1926) was recently found in a plant nursery in Florida (Reid, in preparation). Did the more advanced species outcompete their more primitive congeners in the tropics, leaving a few older remnants in the temperate zones of the Old and New Worlds?

Stolonicyclops heggiensis shows aspects of the typical facies of a benthic/interstitial cyclopoid (Reid and Strayer, 1994): small size, flexible postpediger 5 pseudosomite, relatively broad genital double-somite, short antennule with few segments, loss of the antenna exopodite-seta and of some setae on endopodite segment 2, and oligomerization of the swimming legs. Although it is usual for reductions in the mouthparts to occur in benthic and interstitial cyclopoids, the only such feature in *S. heggiensis* is the two short mandibular setae (a reduction from the plesiomorphic two long and one short setae). The lack of elaborate accessory ornamentation of the body or swimming legs may be related to its habitat.

The habitat of the new species is similar to those of species of *Bryocyclops*, which occur mainly in epigean and hypogean semiterrestrial habitats such as moist moss and leaf litter, ephemeral seeps, phytotelmata, the psammon, and caves. On the granite face of Heggie's Rock there are over 100 solution depressions ("solution pits" of Baker, 1945, 1956), a few of which hold water for five to seven months in the rainy season (late fall until spring). No crustaceans have been found in the solution depression pools. The copepods were collected from small pools in rainy season trickle streams from seepage areas located between rock slopes. Quarterman *et al.* (1993) stated that seepage areas on granite outcrops did not appear to have a unique flora, but contained many species characteristic of wet areas in the general region. While that description fits certain seepages on Heggie's Rock, other large seepage areas are dominated by extensive mats of *Selaginella* or *Selaginella* and *Polytrichum* invaded by patches of *Andropogon* and/or *Senecio tomentosa* Michx. The trickle streams run more or less continuously during the rainy season, then dry in summer. Quarterman *et al.* (1993), in summarizing the available literature on biodiversity of fauna and flora on granite outcrops of the southeastern U.S.A., made no mention of copepods.

Females of *S. heggiensis* kept in culture and fed on algae produced no eggs until a mixed soil culture including nematodes was fed to them. Individual copepods were observed to ingest small nematodes (F. D. Ferrari, personal communication).

Acknowledgements

We are grateful to Drs. F. D. Ferrari, V. I. Monchenko, J. C. Morse, and C. E. F. Rocha for their thoughtful comments on an earlier draft, and to F. D. Ferrari for observations on specimens in culture. This research was supported in part by The Nature Conservancy of Georgia, manager of the Heggie's Rock Preserve. The Department of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution, afforded research facilities to J. W. Reid.

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RECEIVED: 23 May 1997.
ACCEPTED: 2 September 1997.

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