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NEW RECORDS AND NEW SPECIES OF THE  
GENUS *DIACYCLOPS* (CRUSTACEA; COPEPODA)  
FROM SUBTERRANEAN HABITATS  
IN SOUTHERN INDIANA, USA

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## New Records and New Species of the Genus *Diacyclops* (Crustacea; Copepoda) from Subterranean Habitats in Southern Indiana, USA

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### ABSTRACT

Ten species of the cyclopoid copepod crustacean genus *Diacyclops* were collected by Julian J. Lewis and his associates from caves, wells, and the hyporheic zone of streambeds in karst and non-karst terrain in southern Indiana, USA. These collections included six previously known species: *D. crassicaudis*, *D. brachycercus*, *D. jeanneli*, *D. navus*, *D. nearcticus*, *D. sororum*, and *D. yeatmani*. *Diacyclops jeanneli*, which was originally described from Marengo Cave in Crawford County, is redescribed herein. A population of *D. jeanneli* still exists in Marengo Cave, and other populations were discovered in caves in Floyd, Harrison, and Orange counties. All the sites where *D. jeanneli* was collected are located in the Blue River faunal basin, which was never covered by the Illinoian or Wisconsinian glaciers. A new species, *D. conversus*, is described from a gravel bar in the Blue River, also in the Blue River faunal basin. Three new species, *D. salisae*, *D. lewisi*, and *D. indianensis*, are described from wells and a cave in Big Oaks National Wildlife Refuge. The refuge lies within the

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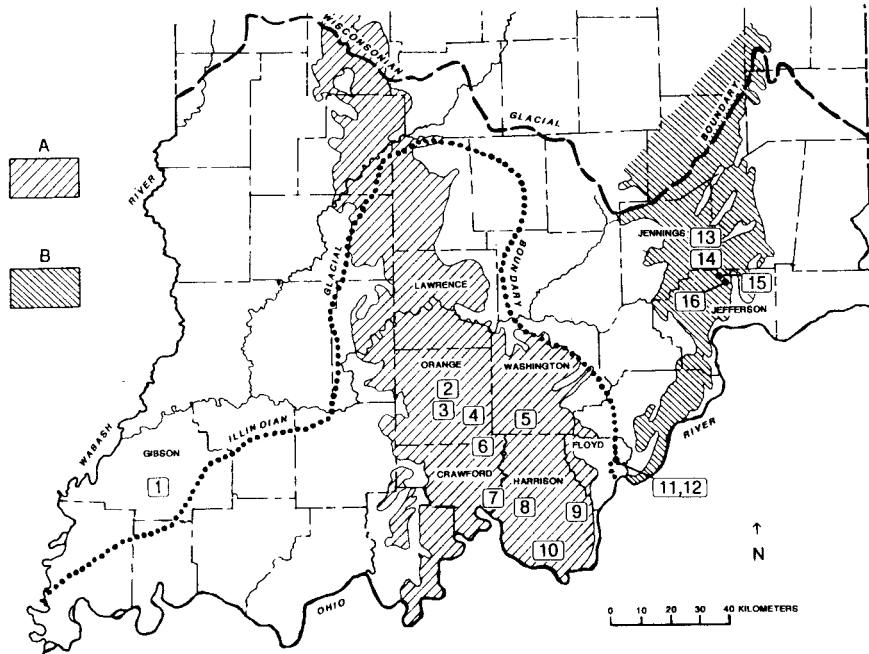
Muscatatuck faunal basin, which was covered by the Illinoian glacier. These three species show few or none of the morphological reductions that are normally associated with the subterranean habitat. They may have invaded subterranean habitats comparatively recently, i.e., after the Illinoian glacier began to retreat about 140,000 years ago. Female cyclopoids that are morphologically identical to *D. indianensis* were recently discovered in two caves in east-central Tennessee; therefore the primary habitat of *D. indianensis* may be groundwater rather than caves. Both *Diacyclops jeanneli* and *D. conversus* show several reductions that are typical of subterranean cyclopoids, and may be more ancient subterranean inhabitants than *D. salisae*, *D. lewisi*, and *D. indianensis*.

## INTRODUCTION

For several years, Julian J. Lewis and his associates have collected invertebrates from subterranean habitats in southern Indiana. In this area lie two main karst regions (Fig. 1). The south-central karst region was formed in rocks of Mississippian age. The southern part of this region, including Orange, Washington, Crawford, and Harrison counties where samples were taken for the present report, was not affected by the Illinoian or Wisconsinian glaciers. The southeastern karst region, including much of Jennings and Jefferson counties, was formed in rocks of Ordovician to Devonian age, and was covered by the Illinoian but not the later Wisconsinian glacier. Most of the collections were made in caves, wells, and

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Fig. 1. Map of the southern part of the state of Indiana, USA, showing the collection localities in relation to the karst areas and the southernmost boundaries of the Illinoian and Wisconsinian glaciers (base map redrawn from Powell, 1961). Legend: A, The south-central karst region; B, The southeastern karst region. Localities: 1, Sollman's Well, Gibson County; 2, Murray Spring Cave, Paoli, Orange County; 3, Apple Cave, Orange County; 4, Bond Cave, Orange



County; 5, Fredericksburg Cave, Washington County; 6, Marengo Cave, Crawford County; 7, Old Rothrock Mill site, Blue River, Wyandotte, Crawford County; 8, Devils Graveyard Cave, Harrison County; 9, Hiser Spring Cave, Harrison County; 10, Squire Boone Caverns, Harrison County; 11, old well across Grant Line Road from Indiana University Southeast, New Albany, Floyd County; 12, cistern near intersection of I-265 and Grant Line Road, New Albany, Floyd County (Localities 11 and 12 are across Grant Line Road from each other and about 1 km apart); 13, well in Otter Creek drainage, section 31 SW 1/4, Big Oaks National Wildlife Refuge, Jennings County; 14, well in Graham Creek drainage, section 18, NW 1/4, Big Oaks National Wildlife Refuge, Jennings County; 15, well in Big Creek drainage, section 7 NE 1/4, Big Oaks National Wildlife Refuge, Jefferson County; 16, Henry Dilk Falls cave, Big Creek no. 08, Big Oaks National Wildlife Refuge, Jefferson County.

streambeds within the south-central and southeastern karst regions, and a few were made outside these regions.

Although the south-central karst fauna has been the focus of numerous studies, the only previous reports of copepod crustaceans from there are by Chappuis (1929, 1931). In both these articles, which repeated essentially the same information, Chappuis described a new species of cyclopoid, *Diacyclops jeanneli*, from Marengo Cave in Crawford County. He also described four new species, the cyclopoid *Megacyclops donaldsoni* and the harpacticoids *Attheyella pilosa*, *Echinocamptus* (now *Bryocamptus*) *morrisoni*, and *Moraria cristata* from Donaldson Cave in Lawrence County. (Chappuis gave the name of this cave as "Donaldson" in the 1929 article and as "Donnelson's" in the 1931 article.) There are no published reports of copepods from the southeastern karst region [see Lewis (1983) for a review of records of obligate subterranean invertebrates from this region].

The recent collections have yielded, among other copepod taxa, ten species of the cyclopoid genus *Diacyclops*. *Diacyclops* is a large genus whose members inhabit a wide range of surface and subterranean aquatic habitats, from the plankton of large lakes to the interstitial spaces in sandy streambeds or cave pools. Most of the species are known from temperate Eurasia or North America, with a few tropical and austral representatives living in South America, Africa, and Australia. A total of 24 species and subspecies have been reported in North America, mostly from surface-water habitats. The North American species north of Mexico were listed by Williamson & Reid (2001).

Five of the ten species were recorded from Indiana for the first time: *Diacyclops crassicaudis brachycercus* (Kiefer, 1929), *D. navus* (Herrick, 1882), *D. nearcticus* Kiefer, 1931, *D. sororum* Reid, 1992, and *D. yeatmani* Reid, 1988. A population of *D. jeanneli* is still living in Marengo Cave, and this species has also been found in caves in Washington, Harrison, and Orange counties and in a well in Floyd County. *Diacyclops jeanneli* is redescribed, and four new species are described herein. For each species,

detailed locality data for Indiana, and general information on the known habitats and geographical distribution are provided. The relative degrees of morphological adaptation to the subterranean habitat, and the geographical distributions of *D. jeanneli* and the four new species are discussed.

Recently, Julian Lewis sent to me for identification, copepods collected from caves in east-central Tennessee. Two of the samples contained a species of *Diacyclops*, of which the female is morphologically identical to the female of one of the new species from Indiana. These new records are listed herein as well.

#### MATERIAL AND METHODS

Copepods were collected with plankton nets or baited jars, and were fixed and preserved in 70% ethanol. For taxonomic examination, individual specimens were mounted temporarily in glycerin or lactic acid, or permanently in commercial CMC-10® (Masters Chemical Co., Wood Dale, Illinois) with a little chlorazol black E added to stain the integument. Measurements were made from specimens in glycerin. Total length was measured from the tip of the rostrum to the end of the caudal ramus, excluding the caudal setae. Drawings were made at magnifications of 400x, 600x, or 800x by the use of a Leica DMLB® microscope fitted with a drawing tube. Most of the specimens have been deposited in the National Museum of Natural History, Smithsonian Institution (USNM), Washington, D.C., or in the Virginia Museum of Natural History (VMNH Accession No. and Crustacea Catalog Database – CrustCatDB No.), Martinsville, Virginia. Specimens which were collected from federally managed lands and are therefore held as loans by the VMNH were not accessioned and received only CrustCatDB numbers. A few specimens are in the collection of Julian Lewis.

Detailed information on the cave localities in Tennessee may be obtained from The Nature Conservancy of Tennessee, 2021 21st Avenue South, Suite C-400, Nashville, Tennessee 37212 (contact Heather Garland, Cave and

Karst Program Manager: hgarland@tnc.org), or from the Tennessee Cave Survey, Inc. (contact Gerald Moni: moni7597@aol.com).

## RESULTS: LIST OF SPECIES AND TAXONOMIC DESCRIPTIONS

*Diacyclops crassicaudis brachycercus* (Kiefer, 1929)

### Material examined

One adult female, from Indiana, Harrison County, Hiser Spring Cave, ca. 2 miles (3.6 km) north of Elizabeth, 10 May 1997, collectors J. J. Lewis and A. Pursell. Specimen in collection of J. J. Lewis.

### Remarks

*Diacyclops crassicaudis brachycercus* is most often found in small ephemeral ponds and puddles, but occasionally occurs in groundwater-related habitats, especially in streambed sediments (the hyporheos). Most of the members of the circumboreal *Diacyclops crassicaudis*-complex have been recorded from Europe, but the ranges of two of its members, *D. c. brachycercus* and *D. crassicaudis* (G. O. Sars, 1863) s. str. extend to North America. Although several of the European subspecies are known only from caves, and *D. crassicaudis* s. str. is stygoxenic, *D. c. brachycercus* is seldom found in caves and is considered stygophilic (Pesce & Galassi, 1987). The North American range of *D. c. brachycercus*, as reviewed by Reid (1992), extends from Alaska as far south as Texas. Later records from southern Louisiana (Reid & Marten, 1995); southern Florida (Bruno et al., 2003), and Nova Scotia (Moseley, 1998) have somewhat amplified this distribution. The present record is the first from Indiana. As far as I am aware, this is only the third report of *D. c. brachycercus* from a cave in North America; the subspecies has also been found in caves in Texas (Reddell, 1965) and Nova Scotia (Moseley, 1998).

*Diacyclops jeanneli* Chappuis, 1929

Figs. 2-6

**Synonymy**

- Cyclops (Diacyclops) Jeanneli* Chappuis, 1929: 51-53, Figs. 1, 2.– Kiefer, 1929: 89, 95.– Chappuis, 1931: 348, Figs. 1, 2.– Chappuis, 1933: 11.
- Cyclops (Diacyclops) Jeanneli*.– Kiefer, 1931: 612.
- Cyclops (Diacyclops) jeanneli*.– Yeatman, 1944: 1, 5, 8, 58-60, Figs. 112, 113.– Wilson & Yeatman, 1959: 806, Fig. 29.124.
- Cyclops jeanneli*.– Yeatman, 1943: 29, 30, 32-33.– Pennak, 1953: 398.– Pennak, 1963: 359.– Yeatman, 1964: 98.– Bunting, 1973: 140.– Franke, 1989: 107.– Pennak, 1989: 427.
- Acanthocyclops jeanelli*.– Damian-Georgescu, 1963: 41.
- Diacyclops jeanneli*.– Monchenko, 1974: 273, 275.– Reid, 1988: 36.– Williamson, 1991: 810.– Reid & Strayer, 1994: 256, Table 2.– Lewis, 1995: 230, 231, 235.– Monchenko & Vaupel Klein, 1999: 256, Appendix.– Williamson & Reid, 2001: 953, Table III.
- Diacyclops jeanneli*.– Pesce, 1994: 14.
- Non *Diacyclops* nr. *jeanneli*.– Strayer & Reid, 1999: 82, 84, 86, Tables 1, 3.

**Material examined**

Four adult females (1 dissected on slide), 1 adult male, and 2 copepodid juveniles, from Indiana, Crawford County, Marengo Cave, rimstone pool and mud-bottomed drip pool next to trail in upper level passage, 15 November 1997, collector J. J. Lewis (USNM 243525). Ten adult females, 5 adult males, and 19 copepodid juveniles, from Indiana, Floyd County, New Albany, across Grant Line Road from Indiana University Southeast, old well (21 feet or 6.4 m deep), shrimp-baited jar on bottom of well, 26 April 1995, collector J. J. Lewis (USNM 264239). One adult male, from Indiana, Washington County, Fredericksburg Cave, 1.7 miles (3.06 km) north-



northeast of Fredericksburg, plankton tow of upper-level drip pool, 26 May 1997, collectors J. J. Lewis and T. Sollman (USNM 243548). Forty-one adult females, 9 adult males, and 4 copepodid juveniles, from Indiana, Harrison County, Devils Graveyard Cave, repeated dippings from isolated rimstone pools, 29 March 1998, collectors J. J. Lewis, V. Lewis, and R. Burns (USNM 243663). One adult female, from Indiana, Orange County, Paoli, Paoli Country Club, Murray Spring Cave, upper-level drip pool, 30 April 1998, collectors J. J. Lewis and S. T. Rafail (USNM 243677). Three adult females, 3 adult males, and 7 copepodid juveniles, from Indiana, Orange County, Apple Cave, ca. 2 miles (3.6 km) southwest of Paoli, rimstone pools, upper level, 20 July 2002, collectors J. J. Lewis, S. T. Rafail, and D. Rosenthal (VMNH Accession No. 2002-114, CrustCatDB No. 437).

The following redescription is based on the specimens from the type locality, Marengo Cave (USNM 243525), with a few references to the original description of Chappuis (1929).

### **Description of Adult Female**

Lengths of 4 specimens ranging from 782 to 968  $\mu\text{m}$  (length given by Chappuis, 1929 as 0.9 mm); additional measurements given in Table 1. Body (Fig. 2A) in dorsal view slender, pediger (pedigerous somite) 2 slightly expanded laterally, pedigers 3-5 little expanded and lateral margins rounded, without surface spines. Genital double-somite (Fig. 2A, B) slightly wider than long, tapering posteriorly. Seminal receptacle with wide anterior and posterior expansions and with short wide lateral arms; genital pore large and sclerotized; pore-canal short and sclerotized. Hyaline frills on posterior borders of prosomites and pediger 5 smooth, frills of abdominal somites crenate. Anal somite (Fig. 2C, D) with small spines along most of posterior margin, these spines increasing in size ventrally; anal operculum not sclerotized, only slightly crescentic, its free margin slightly irregular.

Caudal ramus about 3.9 times longer than wide, its surface smooth, lacking spines at bases of lateral and lateralmost terminal setae. Lateral seta inserted at

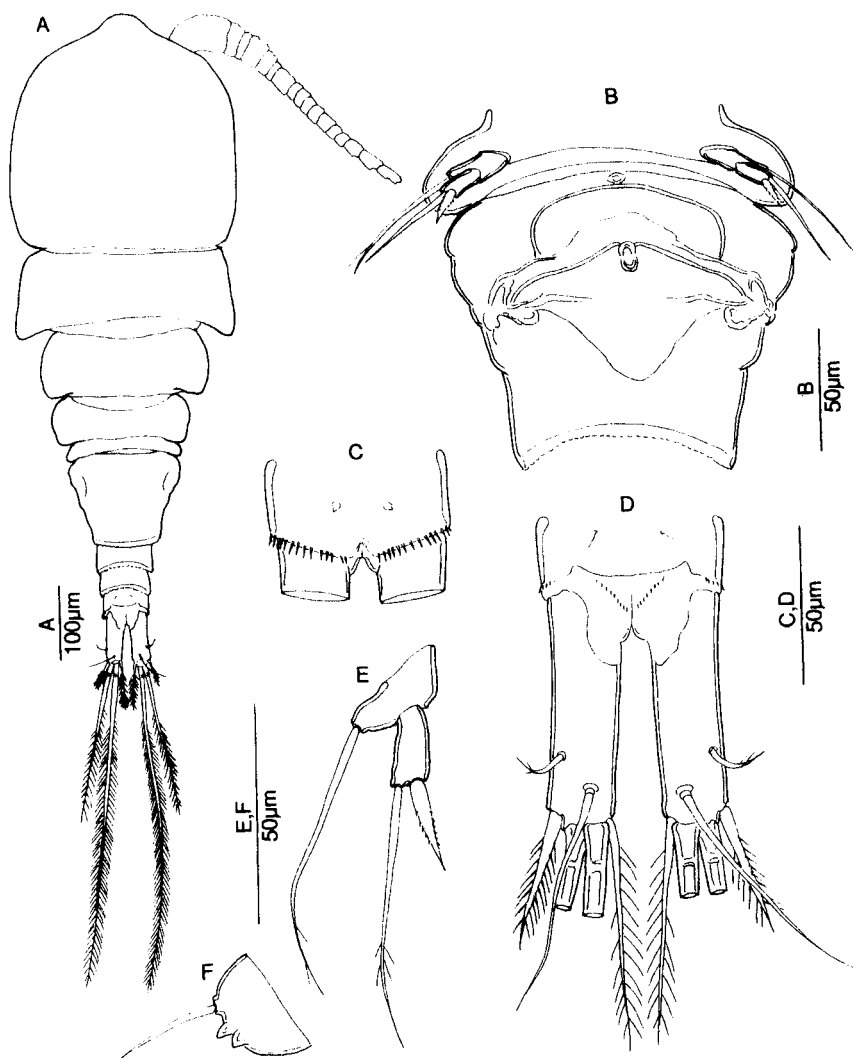


Fig. 2. *Diacyclops jeanneli* Chappuis, female: A, Habitus, dorsal; B, Pediger 5 and genital double-somite, ventral; C, Anal somite and part of caudal rami, ventral; D, Anal somite and caudal rami, dorsal; E, Leg 5; F, Leg 6.

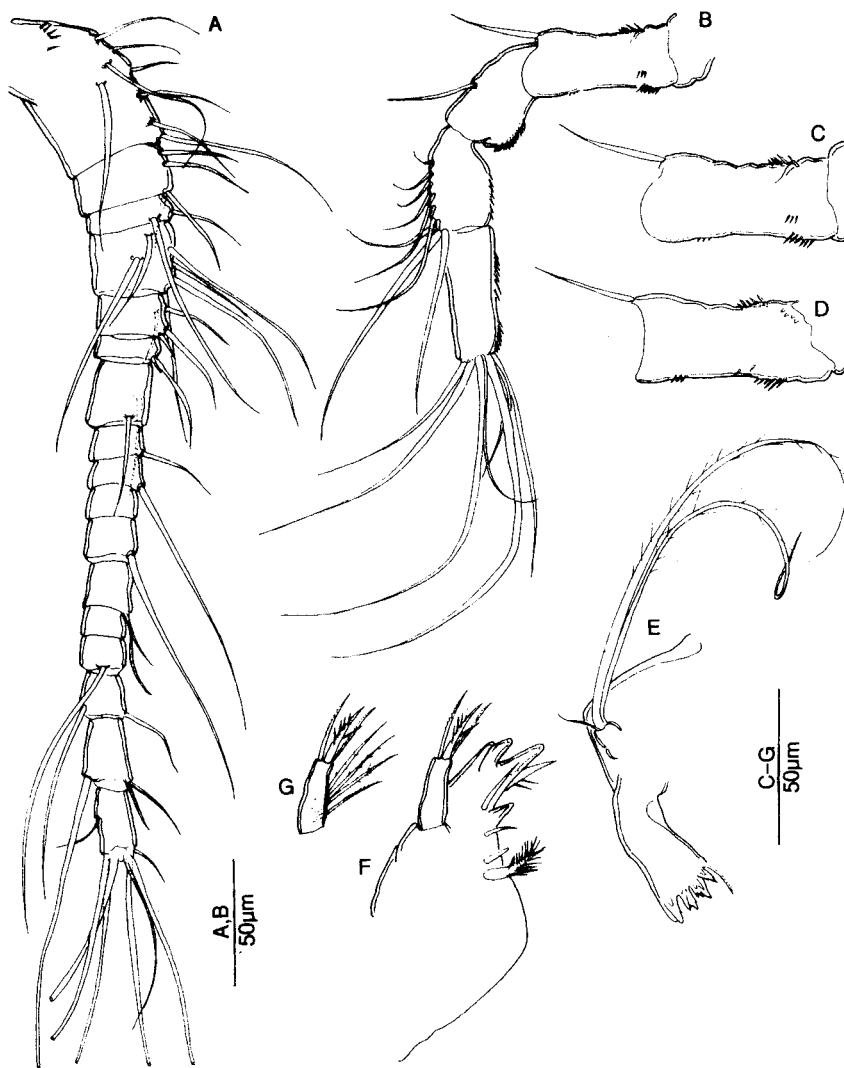


Fig. 3. *Diacyclops jeanneli* Chappuis, female: A, Antennule; B, Antenna, caudal; C, Antennal basipodite, caudal; D, Antennal basipodite, frontal; E, Mandible; F, Maxillule; G, Maxillular palp.

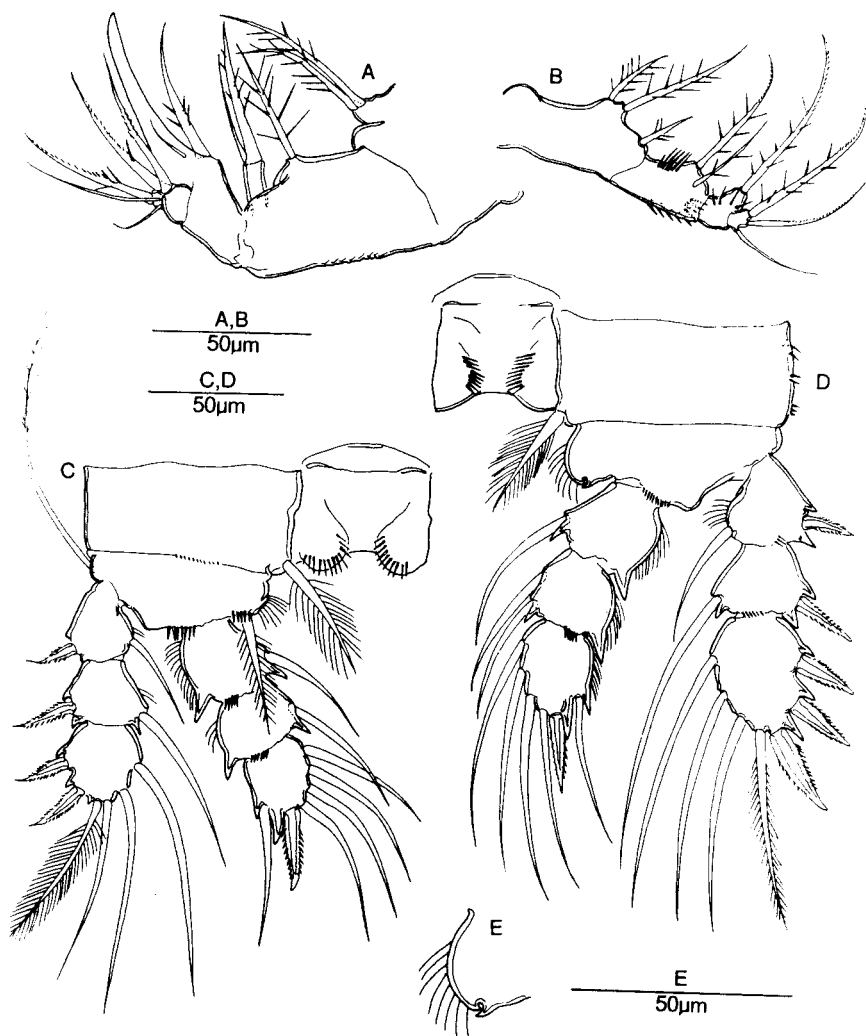


Fig. 4. *Diacyclops jeanneli* Chappuis, female: A, Maxilla; B, Maxilliped; C, Leg 1 and coupler (intercoxal sclerite), frontal; D, Leg 2 and coupler, frontal; E, Leg 2, medial expansion of basipodite (enlarged).

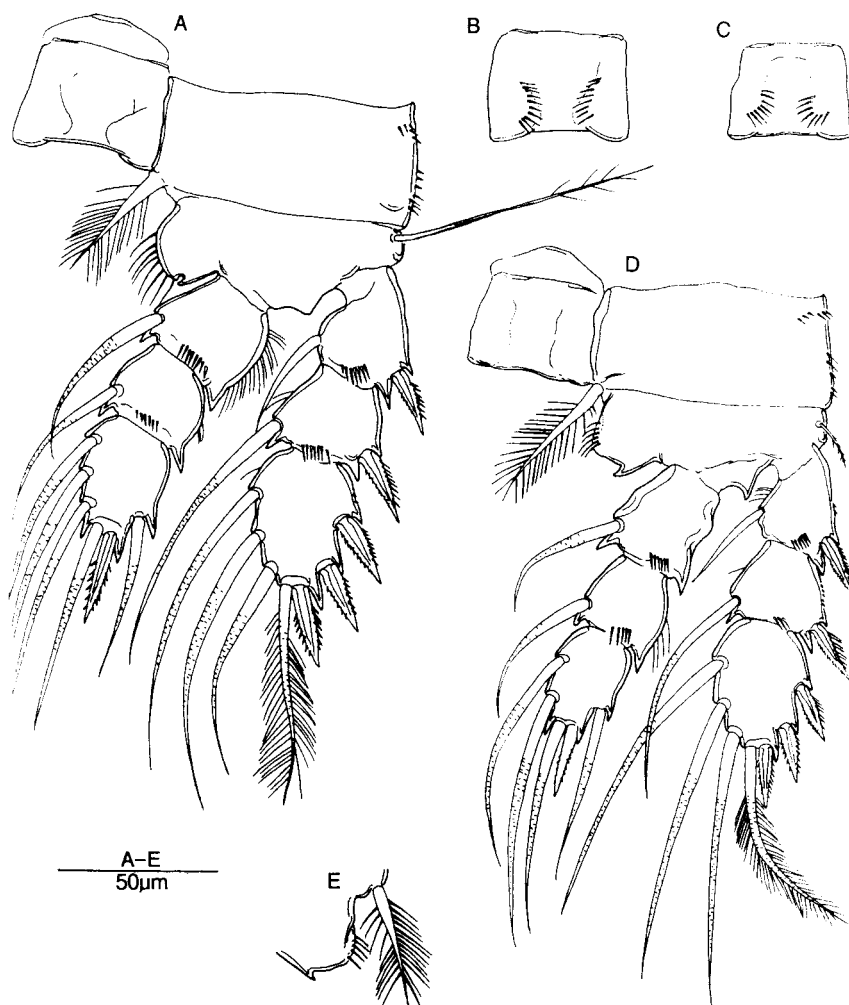


Fig. 5. *Diacyclops jeanneli* Chappuis, female: A, Lég 3 and coupler, caudal; B, Leg 3 coupler, frontal; C, Leg 4 coupler, frontal; D, Leg 4 and coupler, caudal; E, Leg 4, medial expansion of basipodite, frontal (enlarged).

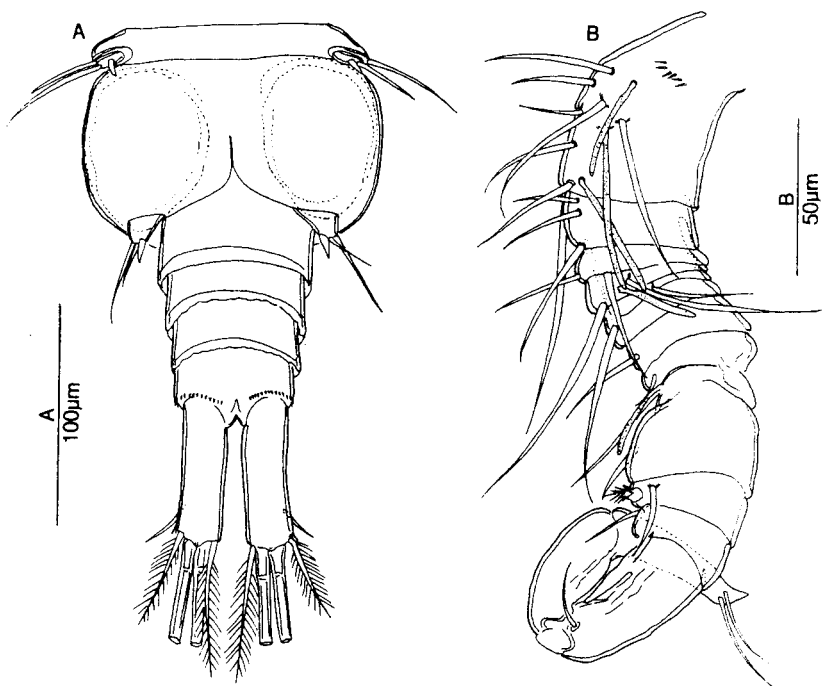


Fig. 6. *Diacyclops jeanneli* Chappuis, male: A, Urosome, ventral; B, Antennule.

Caudal ramus about 3.9 times longer than wide, its surface smooth, lacking spines at bases of lateral and lateralmost terminal setae. Lateral seta inserted at about posterior 3/4 of ramus. Dorsal seta smooth, lateral and terminal setae finely and homogeneously plumed. Lengths of caudal setae given in Table 1.

Antennule (Figs. 2A and 3A) when bent back reaching about middle of pediger 2; composed of 17 segments, bearing elements as follows (Roman numeral = segment, Arabic numeral = number of setae, sp = spine, ae = aesthetasc): I-8 + row of spines, II-4, III-2, IV-6, V-4, VI-1 + sp, VII-2, VIII-1, IX -1, X-0, XI-1, XII-1+ae, XIII-0, XIV-1, XV-2, XVI-2 +ae, XVII-7 + ae. Aesthetasc on segment XII reaching about midlength of segment XV. Segments XVI and XVII without visible hyaline membrane.

Antenna (Fig. 3B-D), basipodite with 1 seta on anterior distal corner and no exopodite-seta on posterior distal corner; endopodite segments 1-3 with 1, 9, and 7 setae respectively. Ornamentation of basis consisting of 2 rows of spines along posterior margin, 1 short row of spines on caudal surface, few spines on frontal surface, 1 row along anterior margin, and 1 transverse row of tiny spines proximally on frontal surface.

Mandible (Fig. 3E) with no surface ornamentation, palp with 1 short and 2 long setae.

Maxillule (Fig. 3F, G) as in figure; palp with no spines on surface.

Maxilla (Fig. 4A), claw with no teeth along inner margin.

Maxilliped (Fig. 4B), segments 1-4 with 3, 2, 1, and 3 setae respectively; segments 2 and 3 also ornamented with surface spines.

Swimming legs 1-4 (Figs. 4C-E and 5) all with 3-segmented rami. Exopodite segments 1 and 2 and endopodite segment 1 each with 1 medial seta. Endopodite segment 2 of legs 1-4 with 1, 2, 1, 1 setae respectively. Exopodite terminal segments with 2, 3, 3, 3 spines and 4, 4, 4, 4 setae respectively. Couplers (intercoxal sclerites) of all legs with paired rounded protrusions on free margins, protrusions of legs 3 and 4 shallow. Each coupler ornamented with 2 rows of spines on frontal surface, its caudal surface bare. Seta present on distomedial corner of each coxopodite, plumage of seta of leg 4 slightly stouter than plumage of remaining setae. Leg 1 basipodite distomedial corner bearing long spiniform seta that reaches nearly to end of endopodite segment 2. Medial expansions of all basipodites with slender hairlike setules ("hairs"), hairs on basipodites of legs 3 and 4 thicker and stiffer than hairs of legs 1 and 2; medial expansions of legs 1 and 4 with shallow groove, medial expansions of legs 2 and 3 with small but deep round notch. Coxa of leg 4 ornamented with only few rows or groups of spines on caudal and lateral surfaces. Spines on exopodite of leg 1 with slender hairlike tips. Leg 4 endopodite segment 1 with medial and lateral margins sculptured. Leg 4 endopodite segment 3 about 1.4 times longer than wide, and bearing 2 medial, 1 terminal, and 1 lateral setae and 1 terminal spine; all setae extending far past end of terminal spine. Terminal spine short, about 0.7 times length of segment.

Leg 5 (Fig. 2E), segment 1 with long lateral expansion bearing seta; segment 2 about 2.2 times longer than wide, bearing long terminal seta and slender serrate subterminal spine, this spine slightly longer than segment.

Leg 6 (Fig. 2F) consisting of small plate located slightly dorsally on genital double-somite, without surface ornamentation and with 1 tiny seta and 2 short stout spines on its free margin.

### Description of Adult Male

Body length of single specimen from Marengo Cave, 600  $\mu\text{m}$ . Habitus similar to that of adult female except for usual sexual dimorphisms including the unfused genital somite and the geniculate antennules.

Genital somite (Fig. 6A) markedly swollen, as wide as pediger 5.

Caudal ramus (Fig. 6A) as in female except about 3.6 times longer than wide, and with tiny spines at base of lateralmost terminal seta. Lengths of caudal setae given in Table 1.

Antennule (Fig. 6B) geniculate, composed of 16 segments. Segment 1 with 3, and segments 4 and 9 each with 1 aesthetasc. Aesthetascs slender.

Leg 6 (Fig. 5A) consisting of small smooth plate bearing 1 medial spine and 2 setae on its margin, of which the spine is the shortest element.

Ethanol-preserved specimens colorless, transparent.

### Remarks

Chappuis (1929) described *Diacyclops jeanneli* from specimens collected in Marengo Cave by R. Jeannel. As was customary at that time, Chappuis provided a partial written description of the new species, and illustrated only the fifth leg and the terminal segment of the leg 4 endopodite of the female. In a later article, Chappuis (1931) repeated his earlier description and figures without changes. In the collections of the Emil Racovitza Speleological Institute in Cluj, Romania, where Chappuis was a member of the staff at the time of writing those articles, there are two slide preparations labelled "*Diacyclops jeanneli*, female, Marengo." Each contains an undissected specimen, which may have been mounted in glycerol; both are in very poor condition, dry and full of dust (S. Iepure, pers. comm., 2003). Two prepared slides of "*Cyclops jeanneli*" are listed in the catalog of the Kiefer Collection held at the Staatliches Museum für Naturkunde in



Karlsruhe, Germany (Franke, 1989); the locality is given as "Marengo-Höhle, USA", but the date and collector are not listed, and the slides are not labeled as types. Although it is possible that some or all of the older specimens were used by Chappuis to prepare his description, the poor condition of the specimens in Cluj and the incomplete label information makes it difficult to be certain. Therefore, the redescription presented here was done entirely from the recently collected material. No type material is designated at this time.

The rimstone pool and mud-bottomed drip pool where Julian Lewis made the recent collections are located in the upper-level passage, the same passage as the "Crystal Palace" where the original collection of *D. jeanneli* was made. In this section of the cave there is no stream, and water enters only through seepage and drip input (J. J. Lewis, pers. comm., 2002).

These specimens coincide closely with most of Chappuis' (1929) description. There are slight differences in the proportions of the caudal ramus, which Chappuis gave as 3.5 times longer than wide, and the leg 4 endopodite segment 3, which Chappuis gave as 1.5 times longer than wide.

*Diacyclops jeanneli* is easily distinguished from most of its North American congeners by having a terminal spine and seta rather than 2 terminal spines on leg 4 endopodite segment 3. *Diacyclops jeanneli putei* (Yeatman, 1943), known from a well in North Carolina, shares this character of terminal spine and seta on leg 4, but has the antennule composed of only 11 segments in the female. A morph from Alabama reported as "*Diacyclops* nr. *jeanneli*" by Strayer & Reid (1999) from Alabama also shares this character, but has the female antennule composed of 16 segments. All the Indiana populations of *D. jeanneli* have the female antennule of 17 segments, and therefore the Alabama population cannot be ascribed to this taxon.

*Diacyclops jeanneli* shows several of the most typical features of cyclopoids that live in subterranean habitats (see Reid & Strayer, 1994; Monchenko & Vaupel Klein, 1999). These features include the lack of the large antennal exopodite-seta, as well as the lack of one of the two setae that

are usually present on the anterodistal corner of the antennal basipodite. The genital double-somite of the female and the genital somite of the male are relatively large. Other unusual morphological features of this species, which may or may not be related to its subterranean existence, include the lack of teeth on the maxillar claw, the presence of ornamentation on the frontal rather than the caudal surfaces of all of the couplers of the swimming legs, the small but deep notches in the medial expansions of the basipodites of legs 2 and 3, and the modified stiff hairs on the basipodites of legs 3 and 4.

Following its description, *D. jeanneli* was included in various checklists and keys, but was not actually found again until these recent collections. A population is still present in the type locality, Marengo Cave in Crawford County. Other populations were discovered in several caves in Harrison, Orange, and Washington counties, and in an old well in Floyd County. The populations in all of the caves were found in rimstone pools and drip pools, isolated from streams. According to Chappuis (1929), Jeannel collected by sampling the "rassemblements" of water with a fine net; the term "rassemblements" may refer to these pools. As suggested by J. J. Lewis (pers. comm., 2003), its distribution within the caves suggests that its true habitat is within the epikarst, from which it enters caves through drip water. *Diacyclops jeanneli* has never been found in a cave stream.

*Diacyclops navus* (Herrick, 1882)

**Material examined**

One adult female and 1 copepodid juvenile, from Indiana, Floyd County, New Albany, cistern near intersection of highway I-265 and Grant Line Road, jar placed on bottom of cistern for 24 hours baited with fresh uncooked shrimp, 27 April 1996, collector J. J. Lewis (USNM 278140). One adult female and 1 copepodid juvenile, from Indiana, Gibson County, Sollman residence located 5.6 km east of Fort Branch, hand-dug brick-lined

well dug in 1929 into glacier lake bed sediment, with grayish sand at bottom, depth 6 m (no date), shrimp-baited jar, collector T. Sollman. Specimen in collection of J. J. Lewis.

### Remarks

*Diacyclops navus* occurs from southern Alaska to Louisiana (Reid, Hare, & Nasci, 1989). It is primarily an epigeic species, usually found in temporary ponds or pools which hold water for brief to extended periods, and in shallow wells; it may also occur in water-filled artificial containers, such as discarded tires (Reid, Hare, & Nasci, 1989; Reid & Marten, 1995). These are the first records from Indiana.

*Diacyclops nearcticus* Kiefer, 1931

### Material examined

Two adult females, 5 adult males, and 2 copepodid juveniles, from Indiana, Orange County, Bond Cave, 0.5 mile (0.9 km) south of Chambersburg, 30 March 2002, collectors J. J. Lewis and R. Burns (VMNH Accession No. 202-114, CrustCatDB No. 438). One adult female and 2 copepodid juveniles, from Indiana, Crawford County, Wyandotte, Blue River, gravel bar at old Rothrock Mill site, Bou-Rouch pump inserted into bar to a depth of about 1 m, 9 July 2000, collector J. J. Lewis (USNM 252724).

### Remarks

*Diacyclops nearcticus* was described by Kiefer (1931) from a pond in Massachusetts, and later redescribed by Reid (1992) from the single type specimen. Bruno, Reid, & Perry (2000) described the male, and reviewed confirmed records of *D. nearcticus* that were made after Reid's (1992) revision of the *nearcticus*-group. The known range of *D. nearcticus* includes

the eastern and central USA, from Massachusetts and the Laurentian Great Lakes to Florida and Alabama. The present records are the first from Indiana.

Members of the *nearcticus*-group appear to be common and widespread in the hyporheos of streams (Strayer & Reid, 1999). In the Everglades, *D. nearcticus* was found in driven wells in seasonally dry karstic terrain (Bruno, Reid, & Perry, 2000). The Blue River gravel bar is typical of the usual habitat of *D. nearcticus*. The record from Orange County is the first from a cave.

*Diacyclops sororum* Reid, 1992

**Material examined**

One adult female, 1 adult male, and 1 copepodid juvenile, from Indiana, Crawford County, Wyandotte, Blue River, gravel bar at old Rothrock Mill site, from shallow "well" consisting of a piece of perforated PVC pipe buried to a depth of about 35 cm in the bar, 24 August 1997, collectors J. J. Lewis and A. Pursell (USNM 260740). Three adult females and 2 adult males, from Indiana, Harrison County, Squire Boone Caverns, ca. 12 miles (21.5 km) south of Corydon, from shallow pools in upper level of cave, water dipped and strained through plankton net, 26 June 1999, collectors J. J. Lewis and S. T. Rafail (USNM 252813).

**Remarks**

*Diacyclops sororum* is a member of the *nearcticus*-group, which is distinguished by the possession of a stout spiniform seta, rather than the long slender setiform seta that is usual in cyclopoids, on the lateral margin of leg 4 endopodite segment 3. This species was described from the sandy sediments of the hyporheic zone of Goose Creek, in the Piedmont of northeastern Virginia (Reid, 1992). Strayer & Reid (1999) reported it from

streams in south-central Kentucky, western Virginia, and northern Florida. The present records are the first in Indiana and the first from a cave, and extend its distribution somewhat westward. Strayer & Reid (1999) included this among the so-called "southern" species, i.e., those which in their study had not been found north of the glacial border.

*Diacyclops yeatmani* Reid, 1988

### Synonymy

*Cyclops (Diacyclops) clandestinus* Yeatman, 1964: 95-98, Figs. 1-23.

*Diacyclops clandestinus* Yeatman.– Dussart & Defaye, 1985: 95.

*Cyclops clandestinus* Yeatman.– Pennak, 1989: 427.

*Diacyclops yeatmani*, nomen novum, Reid, 1988: 31, 36.– Reid & Strayer, 1994: 256, Table 2.– Monchenko & Vaupel Klein, 1999: 259, appendix table (I).– Williamson & Reid, 2001: 953, Table III.

*Diacyclops yetmani* Reid.– Pesce, 1994: 14 (lapsus).

Non *Cyclops* (now *Diacyclops*) *languidoides clandestinus* Kiefer, 1926: 276, Figs. 5-7.

Non *Diacyclops* nr. *yeatmani* Reid.– Strayer & Reid, 1999: 82, 84, 86, Tables 1, 3.

### Material examined

One adult female and 1 adult male, from Indiana, Crawford County, Wyandotte, Blue River, gravel bar at old Rothrock Mill site, Bou-Rouch pump at about 1 m depth in bar, 27 August 1998, collector J. J. Lewis (USNM 288049).

### Remarks

The name *Diacyclops yeatmani* was proposed by Reid (1988) as a nomen novum for *Diacyclops clandestinus* Yeatman, 1964, because Yeatman's name was preoccupied by *D. languidoides clandestinus* (Kiefer,

1926). Because of this change in name, the complete synonymy of *D. yeatmani* is provided.

The original description of Yeatman (1964) was based on several specimens from Bigmouth Cave in Grundy County, Tennessee, and other specimens collected from a drainage tile emptying into a creek near Fairmont, Vermillion County, Illinois. These two populations were so similar morphologically that Yeatman (1964) included them in the same taxon, although he considered the Illinois copepods as a "variant." The Indiana female specimen closely resembles Yeatman's description of the specimens from Illinois, in particular the proportions of the caudal ramus and leg 4.

Strayer & Reid (1999) reported "*Diacyclops* nr. *yeatmani*" from northern Alabama, but the material which they examined differed in several minor respects from both of the populations described by Yeatman. It is likely that there exists a complex of cryptic species with only minor morphological differences.

### *Diacyclops salisae*, new species

Figs. 7-10

#### **Material examined**

Holotype, adult female; allotype, adult male; paratypes, 1 adult male and 1 copepodid juvenile, all from Indiana, Jennings County, Big Oaks National Wildlife Refuge, well in Otter Creek drainage, section 31, southwest 1/4, shrimp-baited jars, 2-3 February 2001, collectors J. J. Lewis and S. T. Rafail (VMNH CrustCatDB No. 346).

#### **Description of Adult Female**

Body length of holotype 1410  $\mu\text{m}$ . Body (Fig. 7A) slender; in dorsal view pedigers 2 and 3 laterally expanded, pediger 4 rounded, pediger 5 laterally produced and ending in small papilla. Genital double-somite (Fig. 7A, B) slightly longer than wide, tapering posteriorly. Seminal receptacle indistinct, rounded

anteriorly and appearing little expanded posteriorly, with short wide lateral arms; genital pore small, sclerotized, pore-canal not visible in this specimen. Hyaline frills of all somites smooth. Anal somite (Fig. 7C, D) with small spines along most of posterior margin; anal operculum not sclerotized, little produced, with irregular free margin.

Caudal ramus 133  $\mu\text{m}$  long and 28  $\mu\text{m}$  wide, thus 4.75 times longer than wide; lateral surface without ornamentation except for several tiny spines at insertion of outermost terminal seta; medial surface with 3 small transverse rows or groups of tiny spines. Lateral seta inserted at about posterior 3/4 of ramus. Dorsal seta smooth, lateral and terminal setae finely and homogeneously plumed. Lengths of dorsal, lateral, and medialmost to lateralmost terminal setae 110, 47, 122, 610, 420, and 75  $\mu\text{m}$  respectively.

Antennule (Figs. 7A and 8A) when bent back reaching approximately to middle of pediger 2; composed of 17 segments, with following armature: I-8 + row of spines, II-4, III-2, IV-6, V-4, VI-1 + sp, VII-2, VIII-1, IX -1, X-0, XI-1, XII -1+ae, XIII-0, XIV-1, XV-2, XVI-2 +ae, XVII-7 + ae. Aesthetasc on segment XII reaching about midlength of segment XV. Segments XVI and XVII without visible hyaline membrane.

Antenna (Fig. 8B, C), basipodite with 2 setae on anterior distal corner and exopodite-seta on posterior distal corner; endopodite segments 1-3 with 1, 9, and 7 setae respectively. Ornamentation of basis consisting of 2 rows of spines along posterior margin, 2 short rows of 4 spines on caudal surface, and 1 row of 5 spines on frontal surface, in addition to 2 transverse rows of tiny spines proximally on frontal surface.

Mandible (Fig. 8D), without surface ornamentation, palp with 1 short and 2 long setae.

Maxillule (Fig. 8E) as in figure; palp with no spines on surface.

Maxilla (Fig. 8F), claw with numerous large teeth along its midlength.

Maxilliped (Fig. 8G), segments 1-4 with 3, 2, 1, and 3 setae respectively; segments 2 and 3 ornamented with surface spines.

Swimming legs 1-4 (Fig. 9) all with 3-segmented rami. (Leg 3 not illustrated; exactly like leg 2 except slightly larger.) Exopodite segments 1 and 2 and endopodite segment 1 each with 1 medial seta, endopodite segments 2 with 2 medial setae; exopodite terminal segments with 3,4,4,4 spines and 4,4,4,4 setae

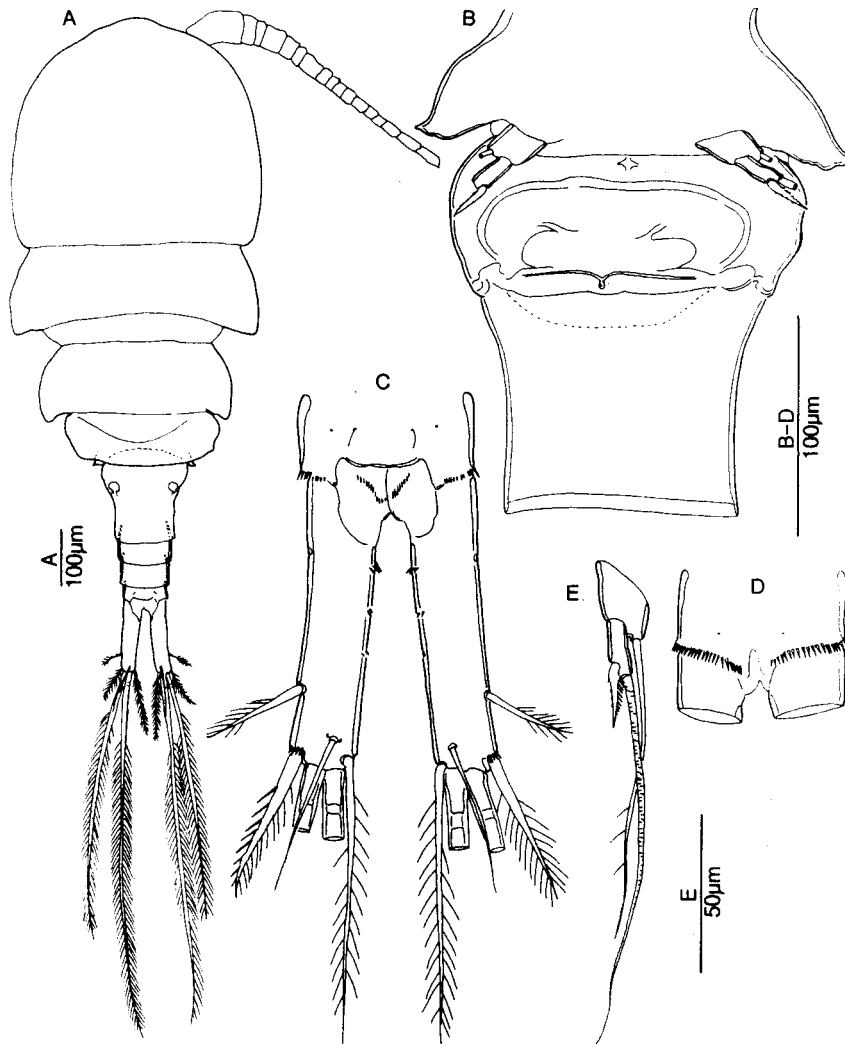


Fig. 7. *Diacyclops salisae*, new species, female: A, Habitus, dorsal; B, Pediger 5 and genital double-somite, ventral; C, Anal somite and caudal rami, dorsal; D, Anal somite and part of caudal rami, ventral; E, Leg 5.



respectively. Couplers of all legs with paired rounded protrusions on free margins, protrusions of leg 4 coupler shallower. Coupler of leg 1 bare, couplers of legs 2 and 3 each ornamented with 2 vertical rows of long spines on its frontal surface, and coupler of leg 4 with transverse row of tiny spines on its caudal surface. Leg 1 basipodite, distomedial corner with long spiniform seta that reaches past end of endopodite segment 2. Expanded medial margins of all basipodites ornamented with fine hairs, and margin of leg 4 basipodite with double spiniform tip. Coxa of leg 4 ornamented with several rows of spines on caudal and lateral surfaces. Spines on exopodite of leg 1 with slender hairlike tips. Leg 4 endopodite segment 1 with grooved lateral margin. Leg 4 endopodite segment 3, 85  $\mu\text{m}$  long and 30  $\mu\text{m}$  wide, thus about 2.8 times longer than wide, and bearing 2 medial setae, 2 terminal spines, and 1 lateral seta; setae extending slightly past ends of terminal spines. Medial terminal spine 55  $\mu\text{m}$  long, thus only about 1.1 times longer than lateral terminal spine (50  $\mu\text{m}$  long). Medial terminal spine directed medially at an angle from lateral terminal spine.

Leg 5 (Fig. 7B, E), segment 1 with short lateral expansion bearing relatively long seta; segment 2 about 2.6 times longer than wide, bearing long terminal seta and slender serrate subterminal spine, this spine slightly longer than segment.

Plate of leg 6 (not illustrated) located slightly dorsally on genital double-somite. Plate without surface ornament, and with 1 tiny seta and 2 short spines on its margin.

### Description of Adult Male

Body length of allotype specimen 1300  $\mu\text{m}$ , length of paratype specimen 1000  $\mu\text{m}$ . Habitus similar to that of female except for usual sexual dimorphisms. Both allotype and single male paratype overgrown with bacteria; as far as can be seen, general structure and fine details of appendages as in female, except in the following respects.

Genital somite (Fig. 10A) not markedly swollen, slightly narrower than pediger 5.

Caudal ramus (not illustrated) as in female except with tiny spine at base of lateral seta; medial surface overgrown, ornamentation, if present, not visible. Caudal ramus of allotype 103  $\mu\text{m}$  long and 21  $\mu\text{m}$  wide, thus 4.9 times longer than wide; ramus of paratype 90  $\mu\text{m}$  long and 22  $\mu\text{m}$  wide, thus 4.1 times longer

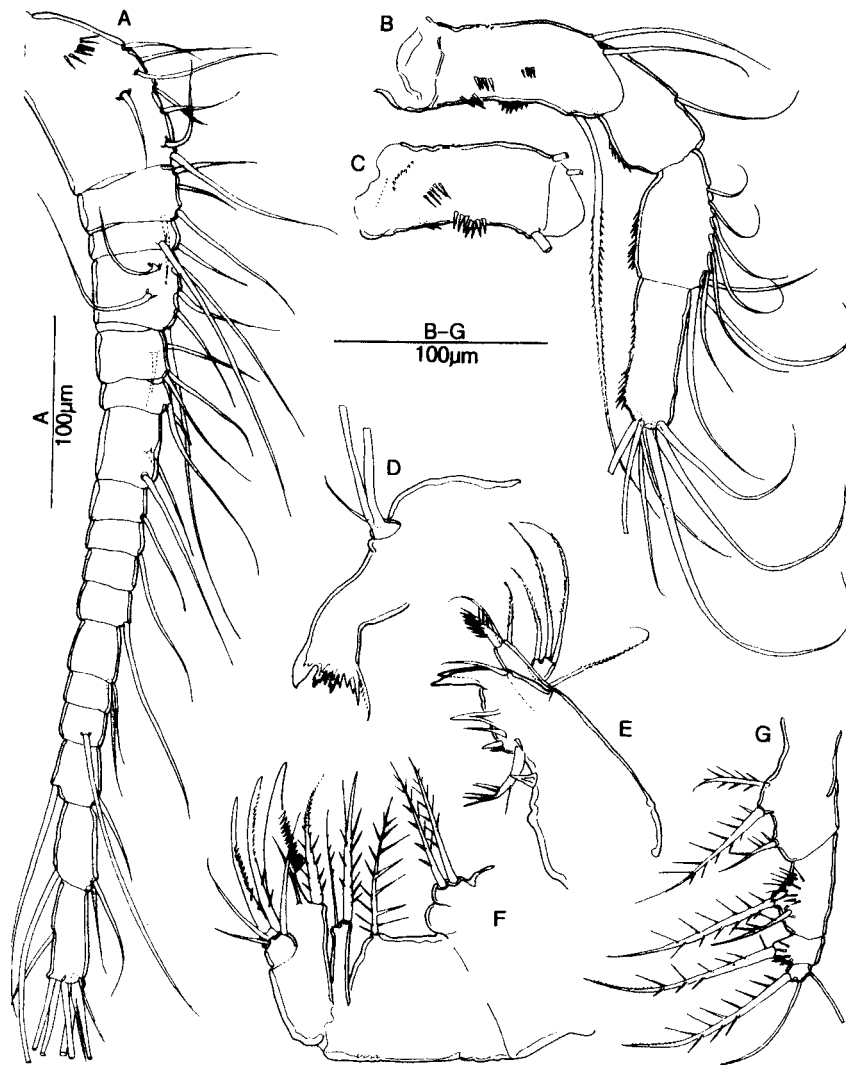


Fig. 8. *Diacyclops salisae*, new species, female: A, Antennule; B, Antenna, caudal; C, Antennal basipodite, frontal; D, Mandible; E, Maxillule; F, Maxilla; G, Maxilliped.

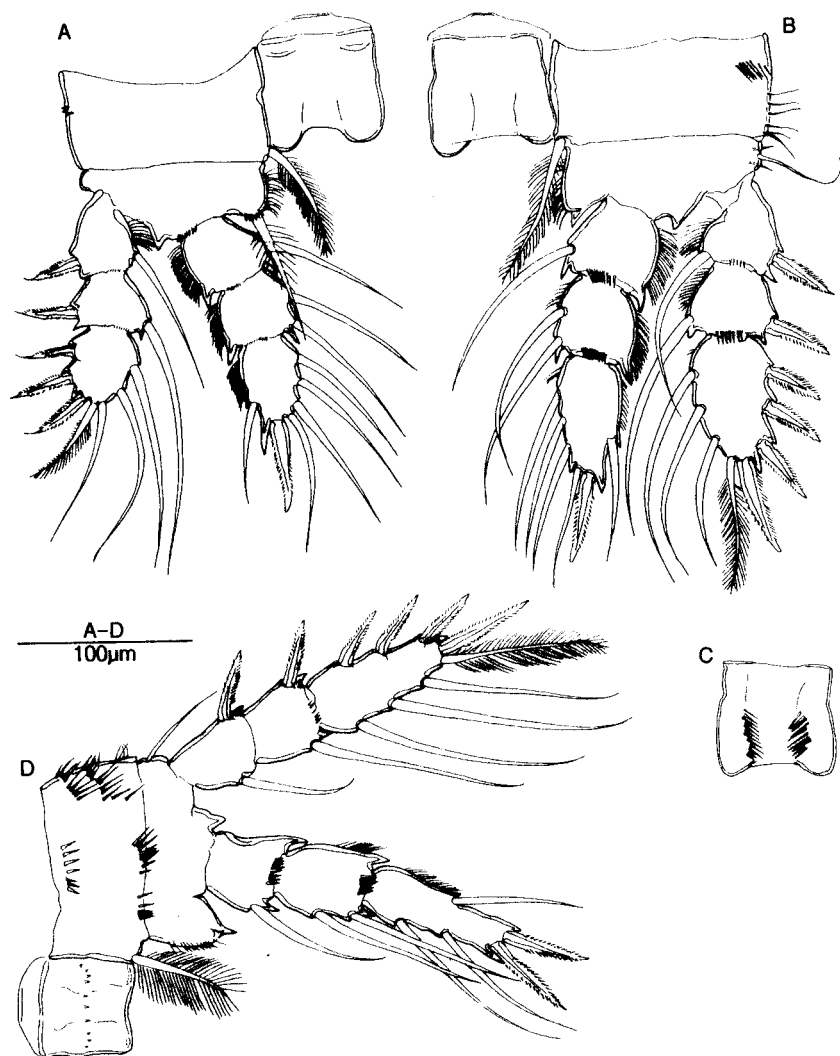


Fig. 9. *Diacyclops salisae*, new species, female: A, Leg 1 and coupler, frontal; B, Leg 2 and coupler, caudal; C, Leg 2 coupler, frontal; D, Leg 4 and coupler, caudal.

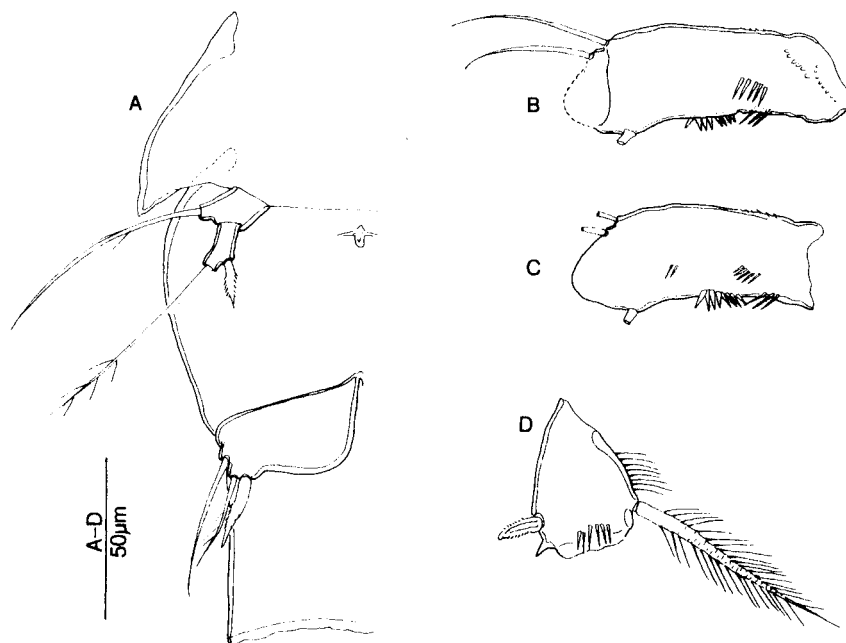


Fig. 10. *Diacyclops salisae*, new species, male: A, Pediger 5 and genital and succeeding somites, ventral; B, Antennal basipodite, frontal; C, Antennal basipodite, caudal; D, Leg 2 exopodite segment 1.

than wide. Lengths of dorsal, lateral, and medialmost to lateralmost terminal setae, respectively, of allotype 80, 33, 117, 520, 330, and 62  $\mu\text{m}$ ; of paratype 90, 38, 113, 662, 315, and 61  $\mu\text{m}$ .

Antennule (not illustrated) geniculate, composed of 16 segments. Segment 1 with 3 aesthetascs and segments 4, 9, and 12 each with 1 aesthetasc. All aesthetascs short and slender.