Diacyclops navus (Crustacea: Copepoda) Redescribed from Louisiana, U.S.A.

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Diacyclops navus (Crustacea: Copepoda) Redescribed from Louisiana, U.S.A.[1]

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Abstract. We redescribe the female and describe the male of *Diacyclops navus*, a cyclopoid copepod (Crustacea), from populations inhabiting discarded tires and woodland pools in Louisiana. These and other previously unpublished records greatly extend the known range of this species, heretofore known mainly from southern Canada and the northern United States. These also are the first records from artificial containers. In the laboratory, adults were observed to consume living first-instar larvae and the crushed bodies of fourth-instar larvae of the mosquito *Aedes aegypti*.

Collections from water-filled discarded tires and woodland pools in southwestern Louisiana yielded specimens of a cyclopoid copepod referable to *Diacyclops navus* (Herrick, 1882). These were identified only with some difficulty, since, due to incomplete knowledge of its morphology, the species is wrongly placed in the key of Pennak (1978). We redescribe the female, describe the male, summarize published and unpublished records, and furnish information on the habitats and feeding of this species in Louisiana.

Specimens were mounted temporarily in glycerine or permanently in glycerine jelly or in commercial polyvinyl lactophenol medium with chlorazol black E added, and drawn at 400× or 600× with the aid of a camera lucida mounted on a Wild M20 compound microscope. Details were confirmed using an Olympus BH-2 microscope adjusted for phase-contrast interference at 400×. Drawings are from several specimens.

TAXONOMIC ACCOUNT

Family Cyclopidae G. O. Sars, 1913
Genus *Diacyclops* Kiefer, 1927
Diacyclops navus (Herrick)
(Figs. 1–5)

Major synonyms: Cyclops navus Herrick, 1882; 229, pl. IV, figs. 6–13, 15–17. *Cyclops pulchellus* var. *navus*, Herrick, 1884; 151, 152–153. *Cyclops bicuspidatus* (part.), Schmeil, 1892; 75, 77. *Cyclops bicuspidatus* var. *navus*, Marsh, 1910; 1078, 1080, pl. LXXIX, fig. 11. *Cyclops bicuspidatus navus*,

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Yeatman, 1943; 27–30, 33–35, figs. 21–25. *Cyclops (Diacyclops) navus,* Yeatman, 1959; 806–807, fig. 29.125 a–c. *Cyclops (Acanthocyclops) navus,* Reed, 1963; 52, fig. 6, left side, E–H. *Diacyclops navus,* Watson & Smallman, 1971a; 855–861. *Thermocyclops dybowskii,* Nasci et al., 1987; 594–599.

Material examined. 8 females, undissected, and 2 females, each dissected on one slide, USNM (National Museum of Natural History) 235355; all from discarded tires near the town of Lacassine, Jeff Davis Parish, Louisiana, 30°14′N, 92°15′W, 1986. 10 females and 10 males, undissected, USNM 235356, from the same tires near Lacassine, Louisiana, 1987. Undissected specimens preserved in 70% ethanol.

Description

Female. Lengths, excluding caudal setae, of specimens collected in 1986, 1.18–1.35 mm; lengths of specimens collected in 1987, 0.76–0.90 mm. Prosomites (Fig. 1a) with rounded lateral margins and smooth hyaline fringes; last prosomite hairless, in some specimens with a small papilla on posterior margin (Fig. 1b). Posterior prosomites of some specimens with shallow circular tegumental pits (Fig. 5). Genital segment (Fig. 1b–d) longer than broad, broadened anteriorly, with faint lateral ridges or, in some specimens, tegumental pits at posterior two-thirds. Seminal receptacle of most specimens (Fig. 1b) with arched anterior margin, tapering, irregularly horizontal lateral arms, and rounded posterior expansion; pore-canal short and straight or slightly curved. Seminal receptacle of some, possibly immature specimens (Fig. 1c) with trapezoidal anterior margin and triangular posterior expansion. Hyaline fringes of urosomites crenulate. Anal operculum (Fig. 1e) weakly crescentic. Caudal ramus (Fig. 1a, e) four times longer than broad; inner surface hairless; in some specimens, outer surface with small dorsoventral ridge and one to several spinules at anterior ⅓–¼. Lateral seta inserted at posterior one-fourth of ramus. Caudal setae with fine homonomous plumage. Lengths of caudal setae of a single specimen in μm: lateral 44, dorsal 90, outer to inner terminal 82, 310, 430, 120.

Antennule (Fig. 2a) of 17 articles, reaching posterior margin of prosomite 2; articles 12 and 17 each with esthetasc, article 6 with spine; two distalmost articles with finely serrate hyaline membrane (Figs. 2a, 5). Article 1 of antenna (Fig. 2b, c) with rows of spinules on frontal and caudal surfaces. Pars incisiva of mandible (Fig. 2d) multidentate, with three groups of long and short spinules on one side. Gnathobase of maxillule (Fig. 2e) with three terminal teeth. Article 2 of maxilla (Fig. 3a) rugose on proximal part of outer margin; beak-like extension of article 3 strongly curved, with fine teeth on inner margin. Article 2 of maxilliped (Fig. 3b) with three crescentic rows of setules.

Swimming legs 1–4 (Figs. 3c, d, 4a, b; leg 3 similar to leg 2) with rami each of three articles; spine formula 2,3,3,3. Medial expansion of basipod 2 of leg 1 with finely toothed spine. Basal connecting lamellae of all legs without ornament. Article 3 of endopod of leg 4 (Fig. 4a, b) about 2.4 times longer than broad; terminal spines subequal. Inner marginal setae of this article not reaching end of inner terminal spine.

Leg 5 (Fig. 1b, c), inner subterminal spine of article 2 about as long as outer terminal seta. Leg 6 (Fig. 1d) consisting of lateral expansion bearing one fine seta and two minute spinules.

Male. Lengths 0.64–0.71 mm. Habitus (Fig. 4c) and proportions and armament of caudal rami, mouthparts and swimming legs similar to those of female. Antennule (Fig. 4d, e) geniculate, of 17 articles; articles 1 and 15 with tegumental pits. Leg 6 (Fig. 4f, g) consisting of articulated flap with double row of minute spinules on surface and bearing one spine and two setae; spine shorter than succeeding somite.

Remarks. In the widely used keys of Pennak (1963, 1978), *D. navus* will be identified as *Thermocyclops dybowskii* (Landé, 1890). The point of error is couplet 18, which discriminates species possessing an antennular hyaline membrane from those that do not, *D. navus* being assigned to the latter category in the key. Unfortunately, no previous description of *D. navus* mentions the existence of such a membrane, although H. C. Yeatman (personal communication) confirmed its existence in populations of *D. navus* examined by himself and in another instance by D. Bunting. The only congener described as possessing an antennular membrane is *D. hispidus* Reid, 1988. Therefore, the genus diagnosis as recently given by Morton (1985) must be amended to embrace this feature. The error regarding the antennular membrane has been recently corrected by Pennak (1989) in his recast key to the Cyclopoida of the United States. However, Pennak's criterion of whether the hyaline membrane is "easily seen" or "very difficult to see" may still lead some users to *T. dybowskii*, which in the opinion of Reid (1989) is not present in the United States.

Discussion

Females of *Diacyclops navus* from Louisiana generally resemble extant descriptions, the most complete being those of Yeatman (1943, 1944). However, there is some evidence of morphological variation between populations. Ranges of body lengths of Louisiana specimens exceed the ranges given by Yeatman (1943, 1959) (0.90–1.16 mm) and the mean given by K. E. Smith & Fernando (1977) (1.20 mm). In the Louisiana specimens, there is not a single spinule, but a row of spinules at the base of the inner spine of leg 5. Yeatman (1943, 1944) did not mention the existence of tegumental pitting, although such pitting, particularly on the genital segment, caudal rami, and antennules is commonly found in members of *Diacyclops*, as well as of some other cyclopoid genera. Reed (1963) figured large circular pits on the caudal rami of specimens of *D. navus* from Canada. Specimens from a Connecticut salt marsh (see record, below) have similar large pits on posterior prosomites and all urosomites, as well as on the caudal rami and proximal articles of the antennules. Most Louisiana specimens have limited areas of pitting, as noted above. Although most authors (Herrick, 1882; Reed, 1963; T. G. Smith, 1968; Yeatman, 1944, 1959) figured the seta and spine of leg 5 of *D. navus* as of approximately equal lengths, Brewer (1898) and K. E. Smith & Fernando (1977) described the spine as being half as long as the seta. Some variation appears to exist in the relative lengths of the terminal spines of the endopod of the fourth swimming leg,

inasmuch as K. E. Smith & Fernando (1977) figured these spines curved outwards and the inner spine considerably (about two-thirds) shorter than the outer spine. Yeatman (1943) described slight variations between two North Carolina populations in the proportions of the lengths of these spines to the length of the distal article of the endopod, as well as of the length to breadth ratio of the article itself. Slightly longer (4–5 times longer than broad) caudal rami also were noted by Yeatman (1943) in one population.

The seminal receptacles of *D. bicuspidatus* (Claus, 1857), *D. thomasi* (S. A. Forbes, 1882), and *D. navus* are similar, these species apparently being closely related. Marsh (1910) and Forbes (1897) both stated that they had found intermediate forms between *D. bicuspidatus* (=*thomasi*) and *D. navus*, and neither considered *navus* a distinct variety. Unfortunately, neither author specified the nature of the "intermediate" characters. Because recent workers who figured *D. navus* from various locales agreed as to the positioning of the lateral seta of the caudal ramus at the distal one-fourth, as well as to the general proportions of the caudal rami and the endopod of leg 4 (Reed, 1963; K. E. Smith & Fernando, 1977; Yeatman, 1943, 1944, 1959), and these characters differ from those of *D. thomasi* and *D. bicuspidatus*, continued treatment of *navus* as a distinct species seems valid in spite of the morphological variation discussed above. To allow for this variation, couplet 7 of Reid's (1988) key to North American species of *Diacyclops* should be recast as follows, to distinguish *D. navus* from *D. bicuspidatus* and *D. thomasi*:

7. Caudal ramus 5–6 times longer than broad; lateral seta of caudal ramus inserted at midlength, or at about two-thirds the distance from base to apex of ramus 8
– Caudal ramus 4–5 (usually 4) times longer than broad; lateral seta of caudal ramus inserted at about three-fourths the distance from base to apex of ramus ..... *D. navus*

Males from Louisiana are smaller than previously recorded lengths, Yeatman (1959) giving "about 0.86 mm" and K. E. Smith & Fernando (1977) 0.89 mm. Otherwise, males of this species never have been described. A distinctive feature of *D. navus* is the double row of spinules on the flap of leg 6; in congeners for which this structure has been described, the flap usually is smooth, with *D. cryonastes* Morton, 1985 possessing a single row of spinules at this location.

Published records of *D. navus* are predominantly from shallow, apparently freshwater, permanent or temporary pools and marshes; others include wells, lakes, and a river. Most localities are in the northern United States and southern Canada: Illinois, Minnesota, Nebraska, North Carolina, Wisconsin, British Columbia, Manitoba, Ontario, and Saskatchewan (Anderson, 1974; Brewer, 1898; Carl, 1940; Forbes, 1897; Herrick, 1882, 1884; Marsh, 1892, 1910; Reed, 1963; K. E. Smith & Fernando, 1977; T. G. Smith, 1968; Watson, 1986; Watson & Smallman, 1971 a,b; Yeatman, 1943, 1944). These, as well as the following previously unpublished records, were mapped (Fig. 6). R. E. Smith (1981) listed records from semipermanent and temporary ponds in marshes and woodlands of Dane, Iowa, Marquette, and Rusk Counties, Wisconsin. H. C. Yeatman

(personal communication) has records from: Hebgen Lake, Montana, 1965; pond, Beaufort, North Carolina, September 1975; temporary pond near Macomb, Illinois, April 1959; pond "E", Ann Arbor, Michigan, col. Roman Kenk, 19 June 1945; well near Moncure, Chatham Co., North Carolina, 25 November 1942; a pool near Florence, Alabama, 1970's. E. B. Reed (personal communication) has records from: a temporary pond in Prairie Divide, between Bull and Rabbit Creeks, affluents of the Cache la Poudre River, Larimer Co., Colorado, 20 August 1961; a small brown water pond at Fort Franklin, Northwest Territories, 31 August 1974; Grace Lake, a large (63 ha, 18 m maximum depth) lake near Yellowknife, 30 August 1974, and an unnamed small lake about 10 km west of Yellowknife, 4 September 1974, Northwest Territories; (from his dissertation, 1959) a temporary pond at Mile Post 787, Alaskan Highway 60°50'N, 136°50'W, British Columbia, col. W. Fuller. His record from Caribou Lake, Manitoba (Reed, 1959, 1963, personal communication) probably refers to a pond near the lake rather than to the lake itself. Records from specimens of *D. navus* deposited by H. C. Yeatman in the collections of the Division of Crustacea, NMNH are from: Henry's Lake, Fremont Co., Idaho, July 1956, col. R. B. Irving; roadside pool along Highway 54, approx. 4.7 mi S. Regina Beach, Saskatchewan,14 August 1957, col. R. W. Coleman; Madison, Wisconsin, 14 June 1963, col. P. H. Thompson. NMNH collections also include specimens collected by T. G. Andreadis from a salt marsh near Guilford, Connecticut, 25 March 1986 (det. J. Reid). Collections by G. G. Marten from temporary woodland ponds in New Orleans, Louisiana in 1988 and sent to J. Reid for determination included numerous specimens of this species.

Diacyclops navus was collected from a variety of habitats in southwestern Louisiana (reported as *Thermocyclops dybowskii* by Nasci et al. 1987). Populations occurred throughout the year in water-filled, discarded tires near Lacassine (Jeff Davis Parish; see above). The tires, which contained water all year, were located in a partially shaded area on the edge of a woodlot. Specimens also were collected from three woodland pools in Moss Bluff (30°19'N, 93°19'W), Lake Charles (30°7'N, 93°19'W), and Chloe (30°17'N, 93°06'W) (Calcasieu Parish), Louisiana. The woodland ponds varied from a deep (ca. 75 cm maximum), almost permanent pond with a bottom of dead leaves and pine needles (Moss Bluff) to a very shallow (ca. 10 cm maximum) soil-bottom tire rut that dried quickly after flooding with rain water. *D. navus* was present throughout the year in the more permanent woodland ponds, but was infrequently collected from the shallow, rapidly drying site.

In spite of its year-round persistence in tires and some woodland ponds in Louisiana, *D. navus* is not always collected frequently, even from apparently suitable habitats. E. B. Reed (personal communication) described extensive collections from small, as well as large, lakes in Colorado in which this species did not appear, and noted that it seems to be absent from the open waters of the big lakes on the barren grounds between Hudson Bay and Great Bear Lake. Anderson (1974) collected *D. navus* in only seven of 340 lakes and ponds in the Canadian Rocky Mountains. Intensive collecting in North Carolina resulted in only a few records, mostly from wells (Yeatman, 1943, 1944). However, K.

E. Smith & Fernando (1977) mentioned many records of *D. navus* from marshes and temporary ponds in southern Ontario. The record from a Connecticut salt marsh is the first from an apparently brackish-water habitat. The Louisiana tire dump yielded the first records from artificial containers.

Several generations of *D. navus* were produced and maintained in the laboratory by S. Hare and R. Nasci. They were grown at 27°C in 80-liter glass aquaria containing filtered rainwater from an outdoor cistern. Air was bubbled through the water. In the laboratory, adults fed on newly hatched, first-instar larvae and freshly ground bodies of fourth-instar larvae of the mosquito *Aedes aegypti* (L., 1762). Although there were nauplii and copepodites in the same aquaria, only adults were observed to attack and feed on live mosquito larvae. Densities of copepods in the laboratory colony fluctuated, possibly owing to predation on immature stages by adults.

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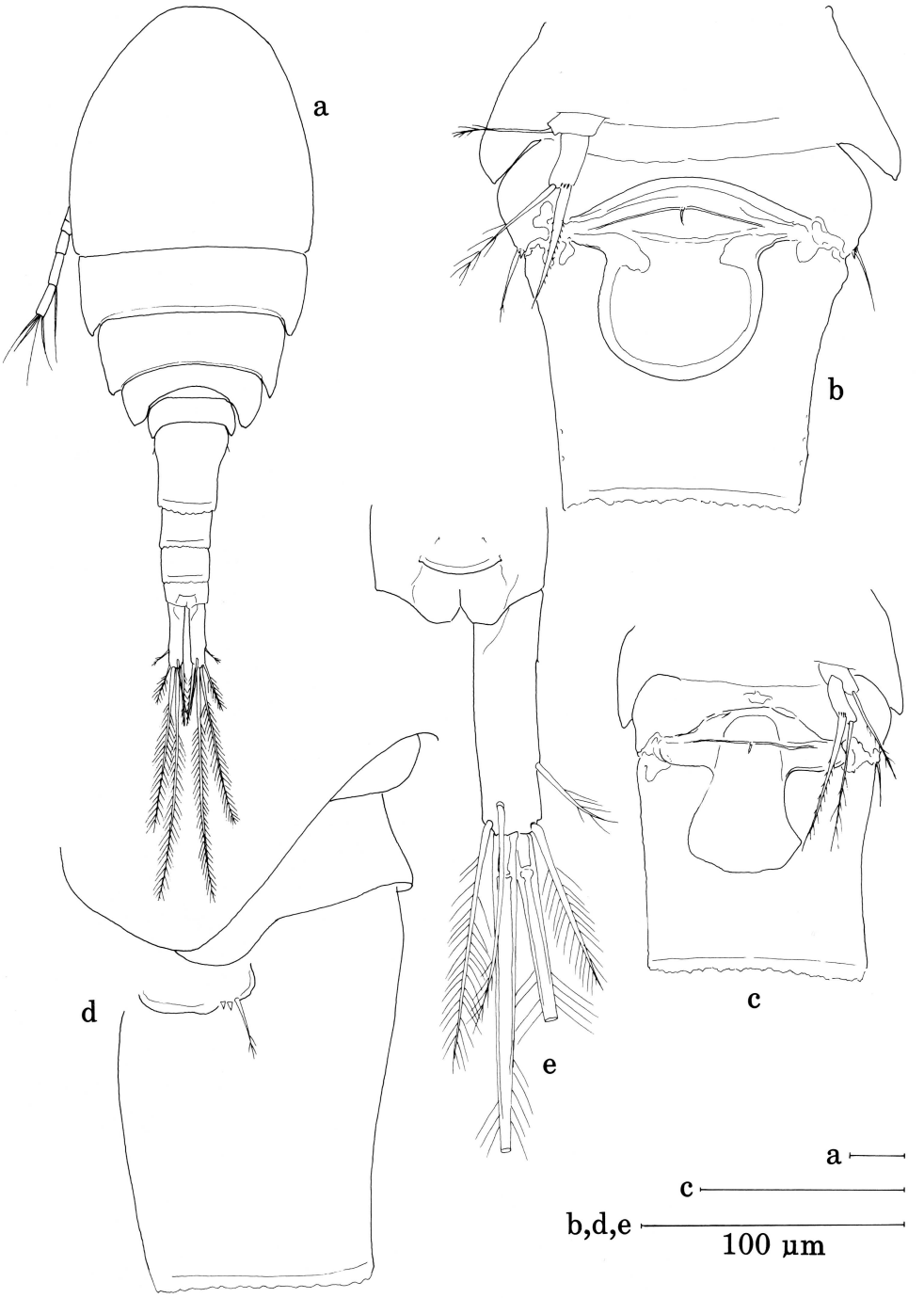
FIG. 1. *Diacyclops navus* (Herrick), female: a, habitus; b, genital segment and leg 5, ventral; c, genital segment and leg 5 of another specimen, ventral; d, genital segment, lateral; e, anal somite and caudal ramus, dorsal.

FIG. 2. *Diacyclops navus* (Herrick), female: a, antennule; b, antenna, caudal side; c, article 1 of antenna, frontal side; d, mandible with details of spinules on reverse of pars incisiva; e, maxillule.

FIG. 3. *Diacyclops navus* (Herrick), female: a, maxilla; b, maxilliped; c, leg 1, anterior; d, leg 2, posterior. Fine plumage of most setae of swimming legs omitted for clarity.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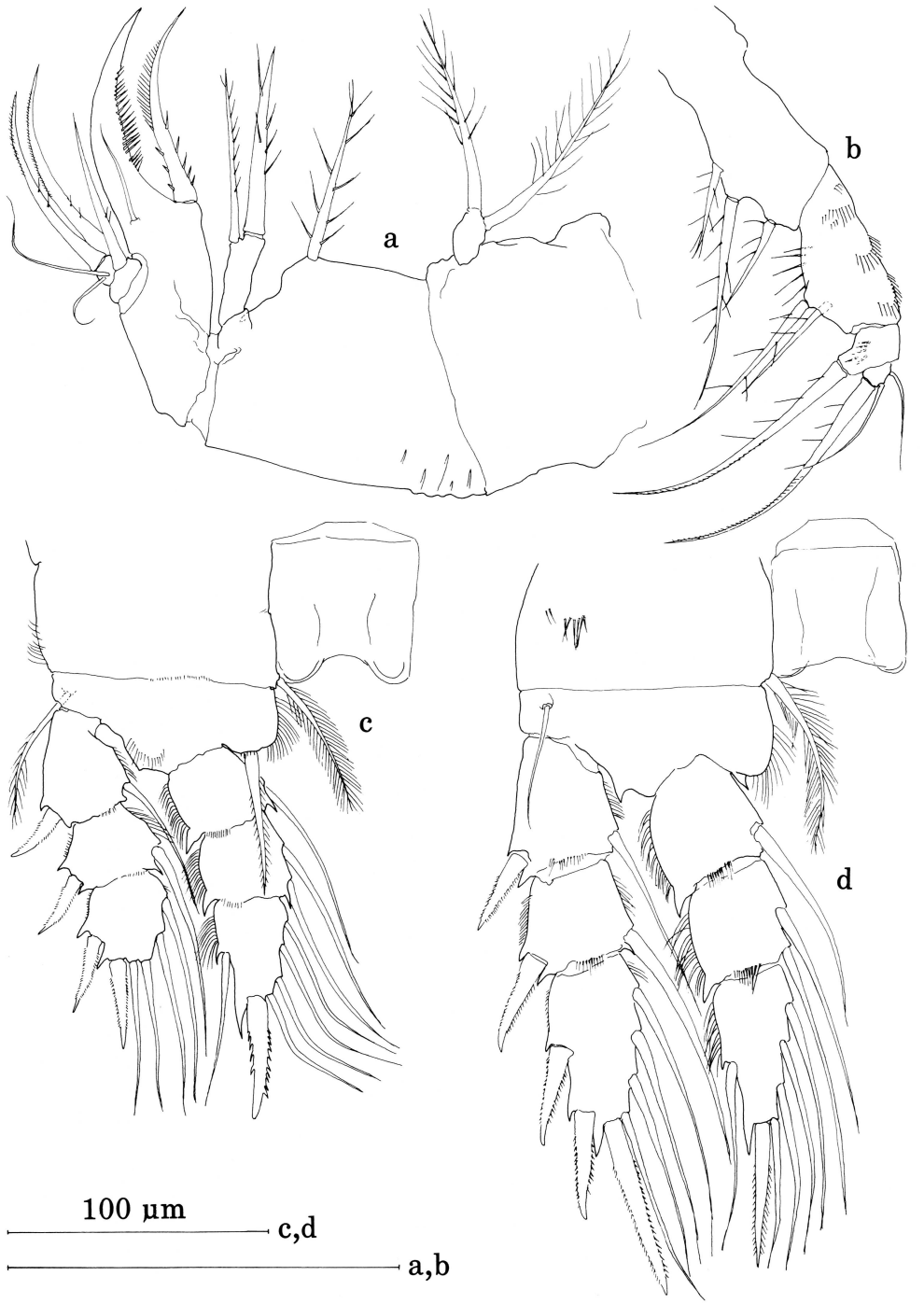
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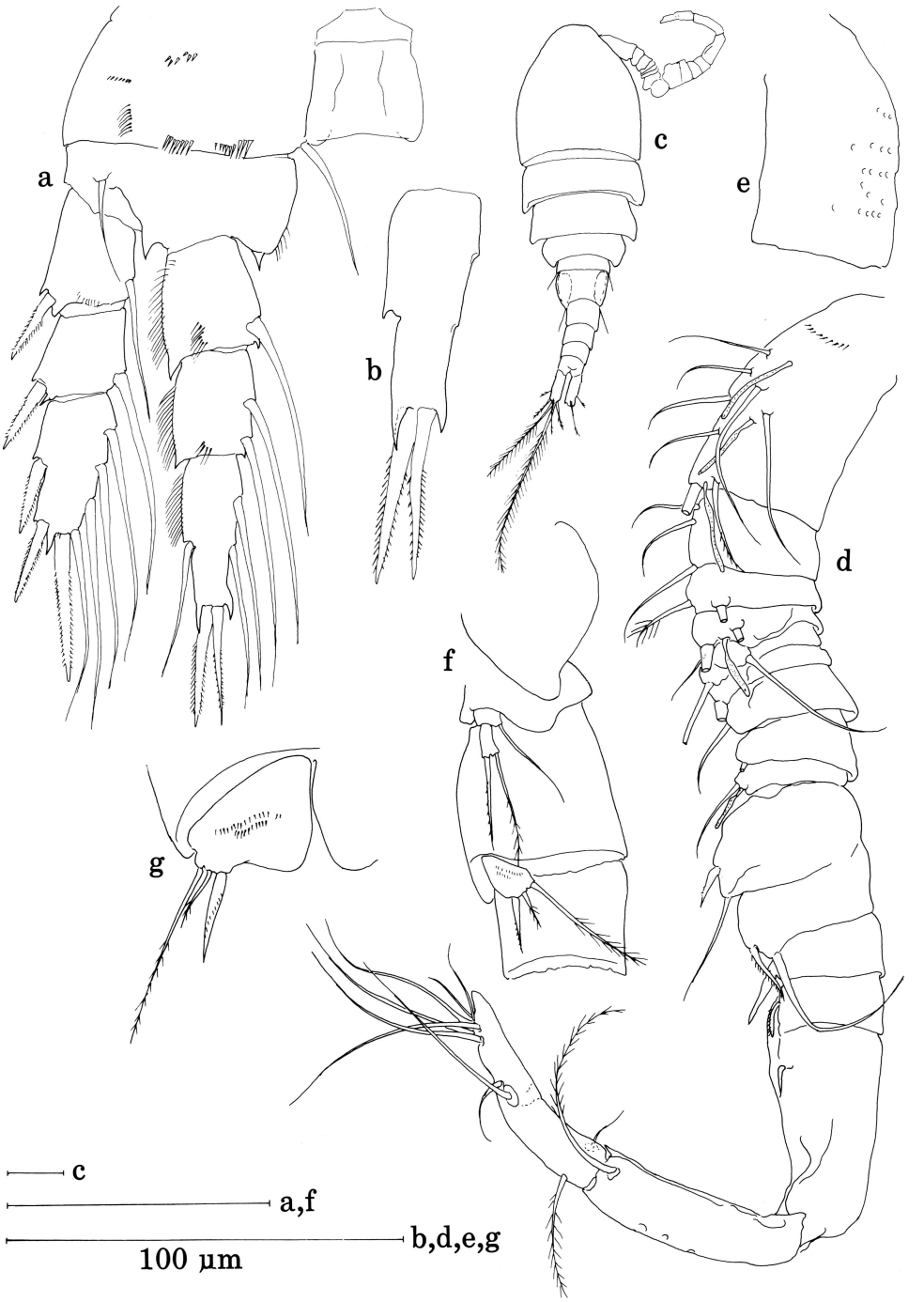
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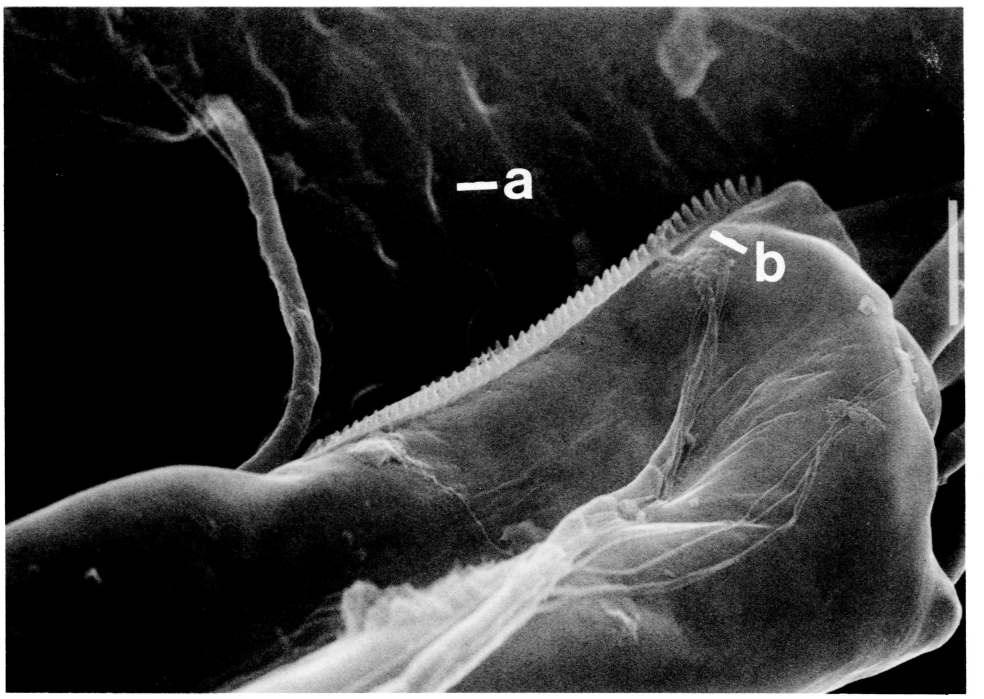

FIG. 5. *Diacyclops navus* (Herrick), female, distal portion of antennule article 17, lying over prosomite 3; SEM. a, shallow tegumental pit on prosomite; b, serrate hyaline membrane of antennule. Scale bar represents 4 μm.

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FIG. 4. *Diacyclops navus* (Herrick), a, b, female; c–g, male: a, leg 4, posterior; b, leg 4 endopod article 3; c, habitus; d, antennule, ventral; e, antennule article 1, dorsal; f, legs 5 and 6, lateral; g, leg 6, ventral.

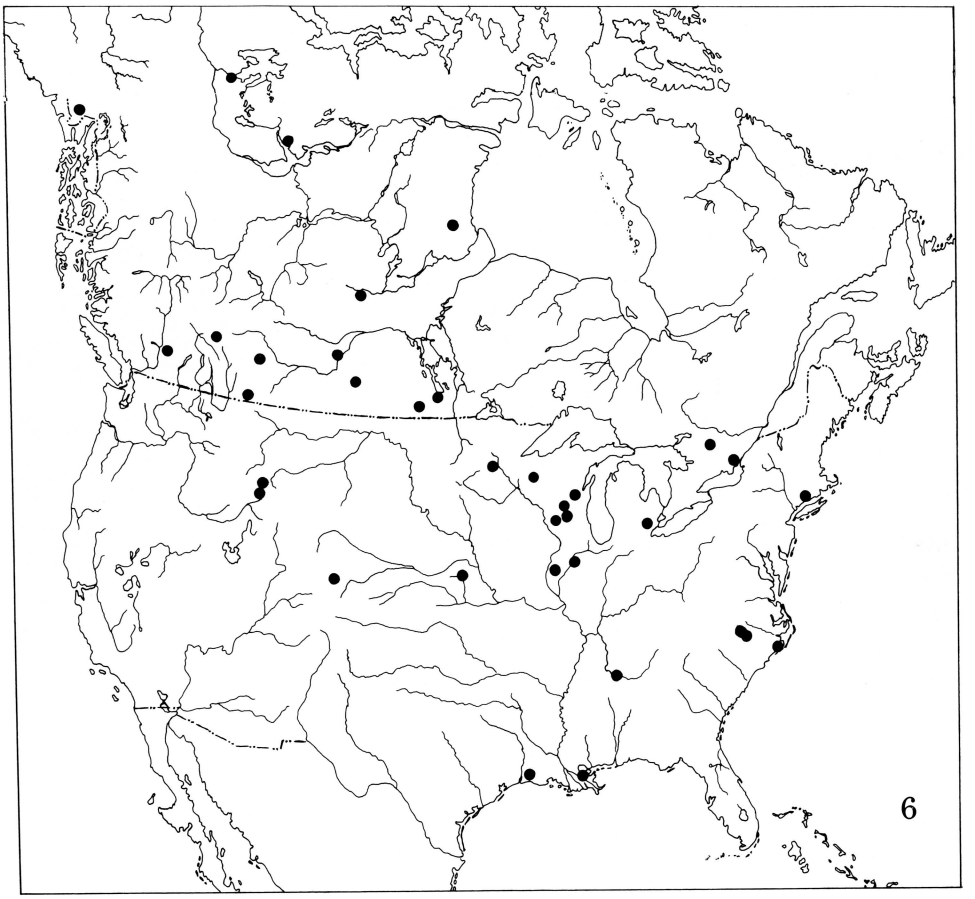

FIG. 6. Geographic records of *Diacyclops navus* (Herrick). Localities cited by Carl (1940), Forbes (1897), Herrick (1882, 1884), Marsh (1892), and K. E. Smith & Fernando (1977) are approximate; Smith & Fernando (op. cit.) note many records of this species from all of southern Ontario.