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NEW RECORDS OF COPEPODS FROM EVERGLADES NATIONAL PARK (FLORIDA): DESCRIPTION OF TWO NEW SPECIES OF *ELAPHOIDELLA* (HARPACTICOIDA, CANTHOCAMPTIDAE), AND SUPPLEMENTARY DESCRIPTION OF *DIACYCLOPS NEARCTICUS* KIEFER (CYCLOPOIDA, CYCLOPIDAE)

BY

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ABSTRACT

Two new species of harpacticoid copepods from Everglades National Park, Florida, *Elaphoidella marjoryae* sp. nov. and *Elaphoidella fluviusherbae* sp. nov., are described. Whereas *E. marjoryae* was collected from both surface waters and groundwater, *E. fluviusherbae* was found only in groundwater. The new species differ from congeners mainly in details of setation and spination of the swimming legs, and the shape and setation of the caudal rami. The ecology and geographical distribution of the genus *Elaphoidella* in North America are presented and discussed.

The find of the cyclopoid copepod *Diacyclops nearcticus* Kiefer in the Everglades extends the known distribution of this North American species considerably southward. We present supplementary observations on the morphology of the female, including some obtained by scanning electron microscopy, and we describe the male. Geographical distribution and known habitats of the species are also presented and discussed.

RIASSUNTO

Nel presente lavoro vengono descritte due nuove specie di copepodi arpacticoidi raccolti in Florida, Stati Uniti, Everglades National Park: *Elaphoidella marjoryae* sp. nov. e *Elaphoidella fluviusherbae* sp. nov. Mentre *E. marjoryae* é stata rinvenuta sia in acque superficiali che sotterranee, *E. fluviusherbae* é esclusiva di acque sotterranee. Le due nuove specie si differenziano dalle congeneri soprattutto per dettagli nell'ornamentazione dei pereiopodi, e per la forma e ornamentazione dei rami furcali. Nel presente lavoro, vengono presentate e discusse la distribuzione e l'ecologia del genere *Elaphoidella* in Nord America.

Il ritrovamento del copepode ciclopoide *Diacyclops nearcticus* Kiefer nelle Everglades, estende considerevolmente verso sud la distribuzione di questa specie nordamericana. Vengono fornite osservazioni supplementari sulla morfologia della femmina, e la descrizione del maschio; parte delle descrizioni sono state ottenute utilizzando la microscopia elettronica a scansione. Un aggiornamento sulla distribuzione ed ecologia della specie conclude il lavoro.

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INTRODUCTION

The Florida Everglades is an extensive subtropical wetland ecosystem formed during the past 5,000 years, when peat and marl formed within depressions in the limestone substratum, during seasonal inundations. The freshwater marshes in Everglades National Park (ENP) range from deeper sloughs and ponds flooded most of the year, to higher elevation marl prairies that now dry for eight to ten months each year, due to inadequate inflows and overdraining. The Rocky Glades are ephemeral wetlands in the eastern part of ENP that lie between Shark and Taylor Sloughs (fig. 1), at a slightly higher elevation than the sloughs, so that hydric soil types do not develop to the same extent as in the sloughs. The consequent extensive dissolution of the oolitic limestone bedrock produces a typical, karstic landscape with thousands of solution holes. Some holes are deep enough to connect with the groundwater, even during severe droughts (Loftus et al., 1992). During the wet season (May-October), rainfall and groundwater recharge fill the solution holes and reflood the wetland surface. In the dry season (November-April), surface water disappears because of evaporation, percolation, evapotranspiration, and very altered hydrology through overdrainage, leaving only the deepest holes with water.

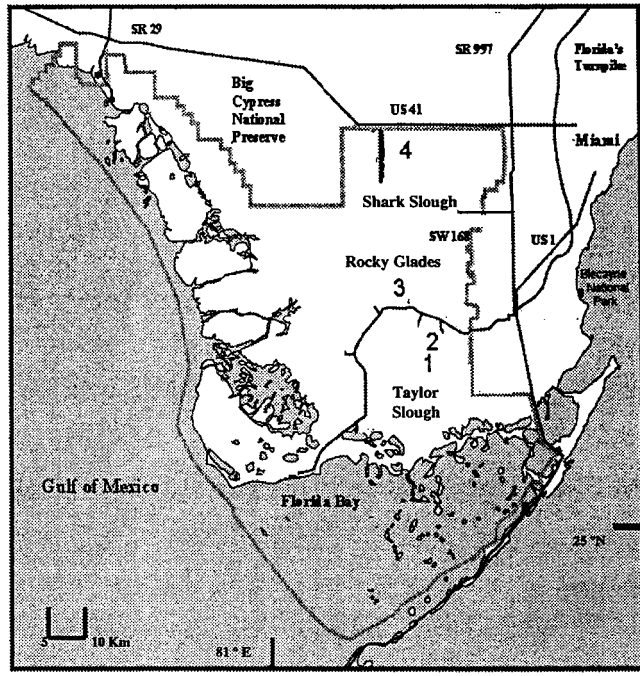


Fig. 1. Everglades National Park, Florida, U.S.A, collecting stations: 1, WIO2; 2, WIO3; 3, Long Pine Key; 4, G3302A.

Both new species of *Elaphoidella*, and all but one specimen of *D. nearcticus* were collected only in the Rocky Glades (fig. 1), even though extensive collections have been made in surface and ground waters inside ENP and outside the eastern and western boundaries of ENP (Reid, 1989, 1992b; Bruno et al., subm.; J. W. Reid and M. C. Bruno, unpubl. data).

The female of *Diacyclops nearcticus* Kiefer, 1934 was redescribed by Reid (1992a) from the type specimen, a female from the Kiefer Copepod Collection, collected in Massachusetts, U.S.A. in 1934. The male had not been described. In the same paper, four similar congeners, previously mistaken for *D. nearcticus*, were described from the U.S.A. and Canada. These species, forming the *D. nearcticus*-group, show a low degree of reduction in setation. Such reduction is common in other benthic and subterranean orders of Cyclopinae (Pesce & Galassi, 1985; Reid, 1991), and is considered typical of groundwater-related habitats (Reid, 1992a). According to Strayer & Reid (1999), who collected them in the hyporheos of streams in the eastern U.S.A., these species are interstitial specialists and are "probably among the most common and widespread stream-dwelling animals in eastern North America" (Strayer & Reid, 1999: 83). The authors reported *D. nearcticus* from Ohio, Virginia, Tennessee, and Alabama. This paper describes the male and provides further morphological details on the females, obtained by using both light and scanning electron microscopy, that might be useful to better distinguish this species from the others belonging to the *D. nearcticus*-group. *Diacyclops nearcticus* may live in the periodically dry solution holes, exhibiting diapause, as demonstrated by the emergence of one stage V copepodid specimen from rehydrated soil patches (Bruno et al., subm.); however, all the specimens were collected from wells, both in the Rocky Glades area and one specimen near the northern ENP boundary.

These three species, the two *Elaphoidella* and *Diacyclops nearcticus*, are the only stygobiotic or stygoxene copepod species recorded for southern Florida.

MATERIAL AND METHODS

Specimens were collected using a Par Jabasco® hand pump for the surface waters, or a Wayne® 1/2HP portable pump connected to a Coleman® 1750 portable generator for wells (Bou, 1974). Latitude and longitude were determined with a portable Garmin 48® GPS.

Samples were filtered using an 80 μm mesh plankton net, fixed in 5% buffered formalin, and mounted on permanent slides with Faure's medium. They were drawn at 400× and at 1,000× with an oil immersion lens, using a drawing tube mounted on a Leica DMLS® phase contrast microscope.

For scanning electron microscopy, some specimens fixed for 24 hours in 10% formalin were washed twice in cacodylate buffer at pH 7.2, post-fixed in 1% osmium tetraoxide in the same buffer, dehydrated in a graded ethanol series, critical-point-dried in a Balzers Union CPD 020® apparatus, and coated with gold in a Balzers Union MED 010® sputter coater. Observations were performed with a JEOL 1200 JEM EX II® scanning electron microscope.

The following abbreviations are used, when required, throughout the text and figures: A1, antennula; A2, antenna; Bsp, basipodite; enp, endopodite; exp, exopodite; Fu, furcal rami; Ga, genital field; Gsg, genital somite; Md, mandible; Mxl, maxillula; Mx, maxilla; Mxp, maxilliped; Op, anal operculum; P1-P5, thoracic appendages (legs) 1-5; R, rostrum.

The nomenclature and descriptive terminology follow Dussart & Defaye (1995) and Huys et al. (1996). Specimens have been deposited at the Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts (MCZ), and at the Everglades Original Collection Center (EVER), Everglades National Park, Homestead, Florida. Specimens prepared for SEM are deposited at the "Centro Interdipartimentale di Microscopia Elettronica", Tuscia University, Viterbo, Italy.

All scales in figures represent 0.025 mm.

The descriptions of the two new species are under the responsibility of M. C. Bruno and J. W. Reid only.

Family CANTHOCAMPTIDAE G. O. Sars, 1906

Genus *Elaphoidella* Chappuis, 1929

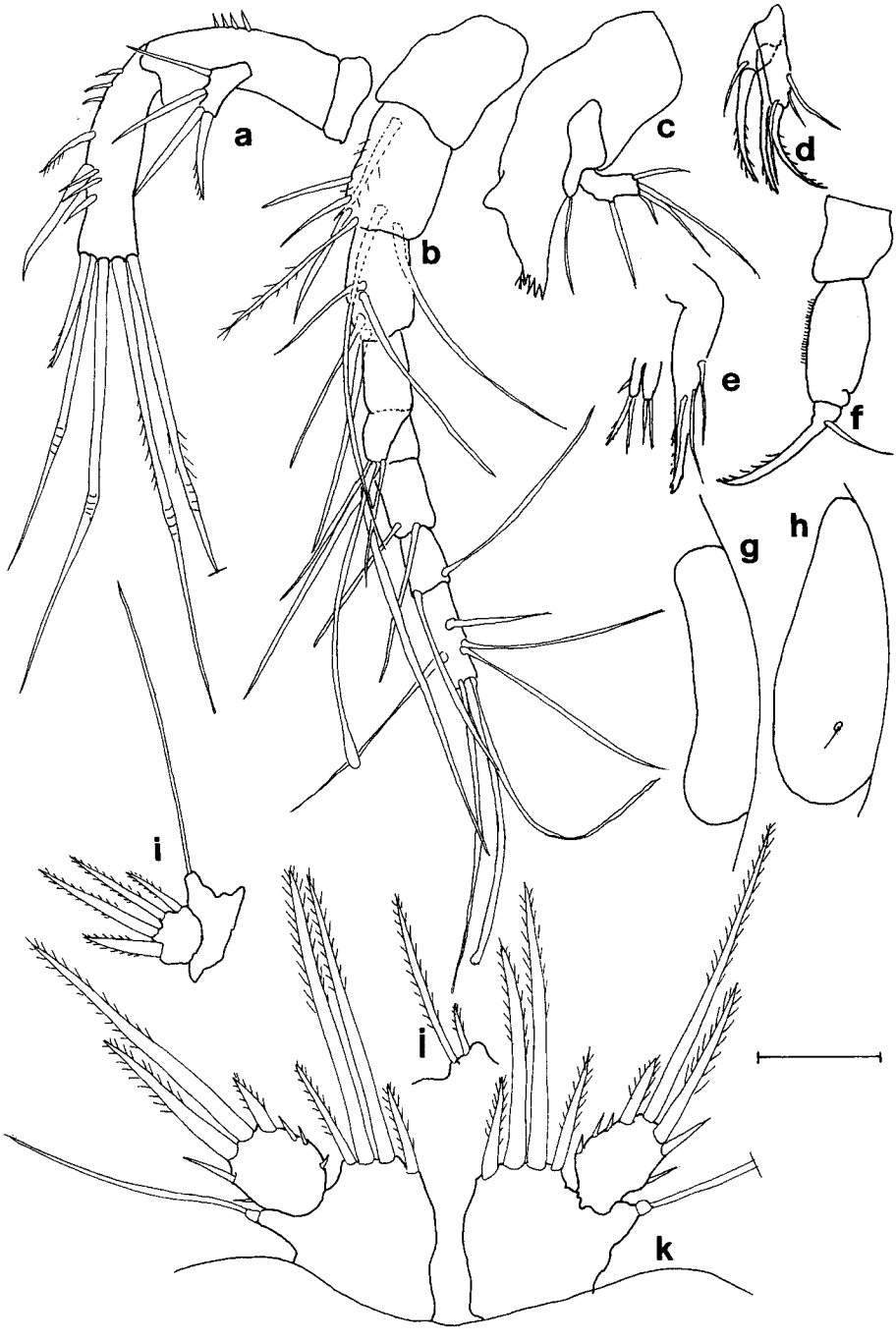
Elaphoidella marjoryae sp. nov. (figs. 2-4)

Material. — Holotype female dissected and mounted on slide (MCZ 25400), 26 January 1999, solution hole in Long Pine Key, 25°25′33.9″N 80°39′25.1″ W. Allotype male dissected and mounted on slide (MCZ 25401), 29 March 1999, emerging from a rehydrated soil patch, solution hole in Long Pine Key, 25°25′36.5″N 80°39′23.6″W. Paratypes: 3 females mounted on slides labeled "paratype female no. 1, 2, 3" (MCZ 25402, 25403, 25404), 7 January 1999, USGS well WIO2, 25°23′36.3″N 80°36′31.4″W. 1 female mounted on slide labeled "paratype female no. 4" (MCZ 25405), 10 January 1999, well WI02. 1 female mounted on slides labeled "paratype female no. 5" (EVER 308760), 21 October 1999, USGS well WIO3, 25°23′21.0″N 80°39′9.60″W.

All material collected from Everglades National Park, Florida, U.S.A., by M. C. Bruno.

Female. — Habitus (fig. 3h) cylindrical. Lengths of paratypes 1, 2, 3, 4, 5, measured from rostrum to distal apex of furcal rami: 520, 500, 512, 600, and

Fig. 2. *Elaphoidella marjoryae* sp. nov. a, b, h, j, k, holotype female; g, i, allotype male; c, d, f, paratype female no. 3; e, paratype female no. 2. a, antenna; b, antennule; c, mandible; d, maxillule; e, maxilla; f, maxilliped; g, cephalic integumental window; h, cephalic integumental window; i, P5; j, P6; k, P5. [For scale bars, see Material and Methods.]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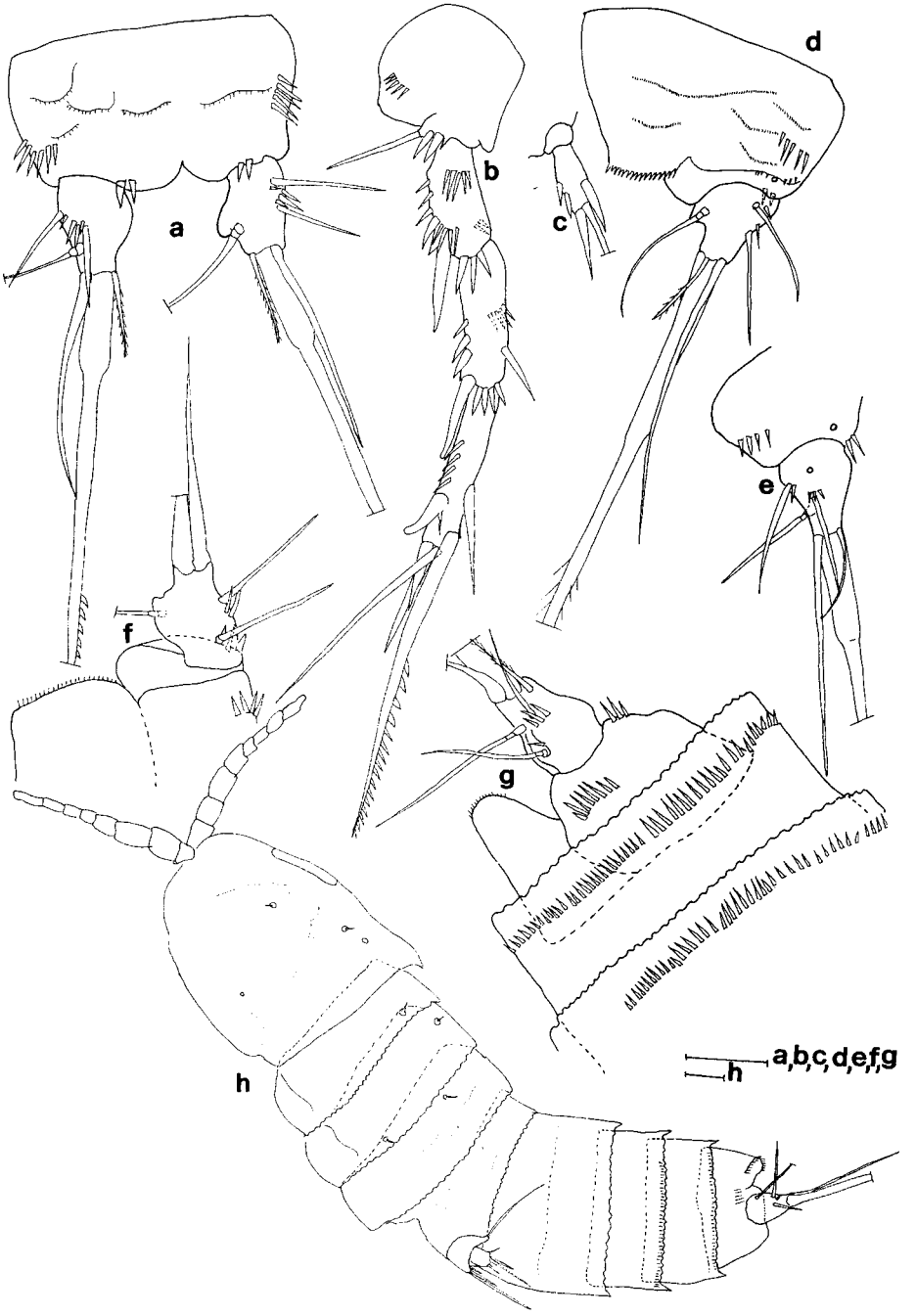
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600 μm, respectively. Cephalosome with dorsal subovoid integumental window (fig. 2h). Hyaline fringes of posterior margins of all somites except cephalosome slightly denticulate. All somites finely punctate, with scattered long hairs; all somites except cephalosome with transverse rows of tiny hairs. Genital somite with remnant of division visible beneath integument. Genital field passing midlength of segment. First and second urosomites posterior to genital somite each with one row of long ventral spines, extending laterally and dorsally along the distal margin. Anal somite with transverse row of long spines on each side, at about midlength of somite, and two ventral spines near inner side of each furcal ramus (fig. 3a, f). Anal operculum convex, with row of thin spinules along margin (fig. 3f).

Furcal ramus (fig. 3a, f), length to width ratio 1.4, subovate, with dorsal keel. Biarticulate dorsal seta inserted at posterior end of keel. Two lateral setae, one spine near proximal seta, three spines near distal seta. Three terminal setae, the main middle seta lacking proximal fracture plane, basally expanded, and slightly pinnate in distal part. Outermost terminal seta with bulbous base, slender, 2.3 times as long as furcal ramus. Innermost terminal seta small, hairy, as long as furcal ramus.

Antennule (fig. 2b) 8-segmented, segment 4 with tubercle carrying two setae and long broad aesthetasc reaching past end of antennule. Last segment with one long aesthetasc and two long terminal setae of different lengths.

Antenna (fig. 2a) with allobasipodite, exopodite one-segmented with four setae, one seta pinnate.

Mandible (fig. 2c), exopodite two-segmented, first segment with one and second segment with five setae, respectively.

Maxillule (fig. 2d), basis with one endite, bearing one slender seta and one strong, pinnate seta. Exopodite with three apical setae, one of these setae strong and transformed, and two lateral setae.

Maxilla (fig. 2e), basis with three setae and a terminal pinnate claw, two endites, inner endite with two setae, outer endite with two setae and one spinule.

Maxilliped (fig. 2f) prehensile, basis bare.

P1-4 with three-segmented exopodites (fig. 4e, a, b, c); endopodite of P1 (fig. 4d) three-segmented, longer than exopodite; endopodites of P2-P4 two-segmented. Major setation/spination formula:

Fig. 3. *Elaphoidella marjoryae* sp. nov. a, holotype female; b, c, d, e, allotype male; f, h, paratype female no. 5; g, paratype female no. 2; h, paratype female no. 3. a, anal somite and furcal rami, ventral view; b, exopodite P4; c, endopodite P4; d, anal somite, anal operculum and furcal rami, lateral view; e, anal somite and furcal rami, dorsal view; f, anal somite, anal operculum and furcal rami, lateral view; g, last two abdominal somites, anal somite, anal operculum and furcal rami, lateral view; h, habitus, lateral.

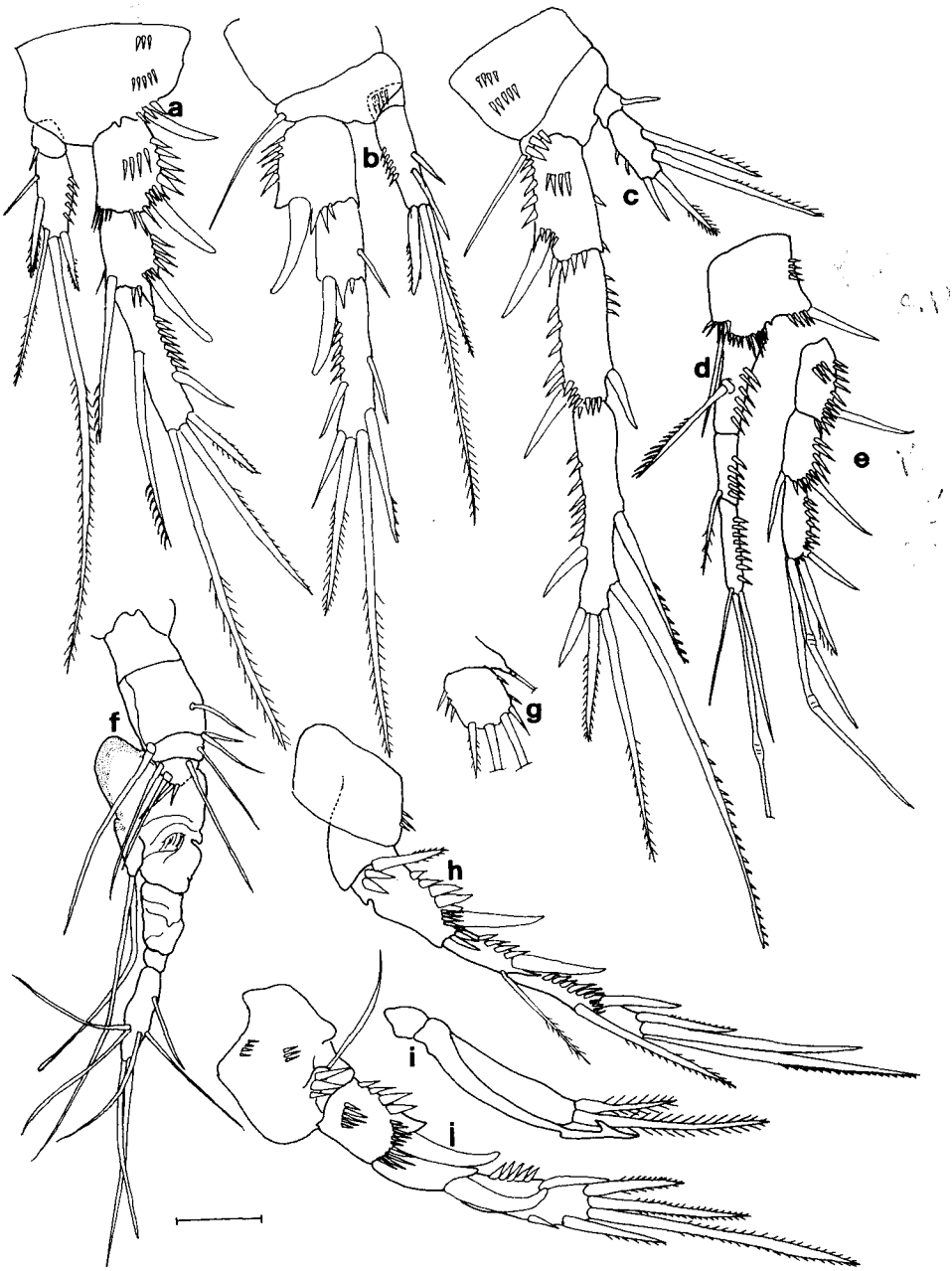


Fig. 4. *Elaphoidella marjoryae* sp. nov. a, b, c, d, e, holotype; f, h, i, j, allotype; g, paratype female no. 2. a, P2; b, P3; c, P4; d, endopodite P1; e, exopodite P1; f, antennule; g, P5; h, exopodite P2; i, endopodite P3; j, exopodite P3.

P1	basipodite 1-1	exp. 0-1;	1-1;	0,3,1
		enp. 1-0;	1-0;	1,3,0
P2	basipodite 0-1	exp. 0-1;	1-1;	1,3,1
		enp. 1-0;	3,2,0	
P3	basipodite 0-1	exp. 0-1;	1-1;	2,2,2
		enp. 0-0;	2,3,0	
P4	basipodite 0-1	exp. 0-1;	1-1;	2,2,2
		enp. 1-0;	2,1,1	

Distal spines on exp-1 and exp-2 of P3 large and curved posteriorly. Distal setae on each segment of exopodites of P2-P4 stout, almost spiniform. All couplers (intercoxal sclerites) bare.

P5 (fig. 2k), medial expansion of baseoendopodite not reaching midlength of exopodite, with four pinnate setae, inner and outer setae short and of equal lengths, two middle setae long, next outermost seta longest. Exopodite oval, with two long distal pinnate setae, next innermost seta longest, short pinnate seta on inner corner, and long spine on outer corner. Three spinules along inner margin, one spinule on outer margin.

P6, two pinnate setae, the inner one about 3.3 times as long as the outer one (fig. 2j).

Male. — Cephalosome with oval dorsal integumental window (fig. 2g). Integumental ornamentation as in female. First urosomite smooth. Urosomites 2-4 each with one ventral row of spines along distal margin, extending laterally, urosomite 2 with additional small row of spines on each side. Anal somite (fig. 3d, e) and anal operculum as in female (fig. 3d).

Furcal ramus (fig. 3d, e) as long as in female, similar in shape, length to width ratio 1.55. Outermost terminal seta without bulbous base, innermost terminal seta smooth.

Antennule (fig. 4f) subchirocer, seven-segmented, segment 4 with large expansion and distal tubercle carrying one aesthetasc and one seta, reaching beyond end of antennule.

Antenna, mandible, maxilliped, P1, P2 exopodite (fig. 4h): similar to those of female. Maxillulae and maxillae not visible.

P2 endopodite (not illustrated) obscured, segmentation and setation barely visible, but appearing to be 2-segmented, first segment with one seta, second segment with three setae in the arrangement similar to that of other species, such as *E. neotropica* Petkovski, 1973 and *E. synjakobii* Petkovski, 1980.

P3 exopodite (fig. 4j), major spines on first and second segment larger than in female, third segment shorter than in female, with outer lateral seta longer, and inner lateral seta shorter than in female. P3 endopodite (fig. 4i) three-segmented, modified; spiniform process on second segment reaching midlength of third

segment of corresponding exopodite. Third segment with two strong apical pinnate setae of different lengths.

P4, last segment of exopodite (fig. 3b) with very strong outer spine with rounded tip and acute basal expansion. Three strong, smooth apical setae of different lengths, and one long strong subapical seta, crenate in proximal half and pinnate near apex. P4 endopodite (fig. 3c), second segment with one short inner subapical seta and two strong apical setae of different lengths. Accessory ornamentation consisting of two spines on outer margin.

P5 (fig. 2i), baseoendopodite reduced, lacking armament; exopodite broader than long, with four stout apical spiniform setae, next innermost seta longest.

Variability. — Female paratype 2 has three spines near the caudal ramus; the row of spines on the last two urosomites extends all around the distal margin (fig. 3g); and the P5 exopodite has two spinules on the outer margin (fig. 4g). In female paratype 3, the row of spines on the distal margin of the last urosomite extends all around the somite, and there is a short row of spinules on the lateral distal margin of the genital somite. In female paratype 5, the row of spines on the distal margin of last urosomite extends all around the somite.

Etymology. — The species is named after Marjory Stoneman Douglas, who devoted her life to the protection and preservation of the Everglades. The epitheton is to be treated as a noun in the genitive singular.

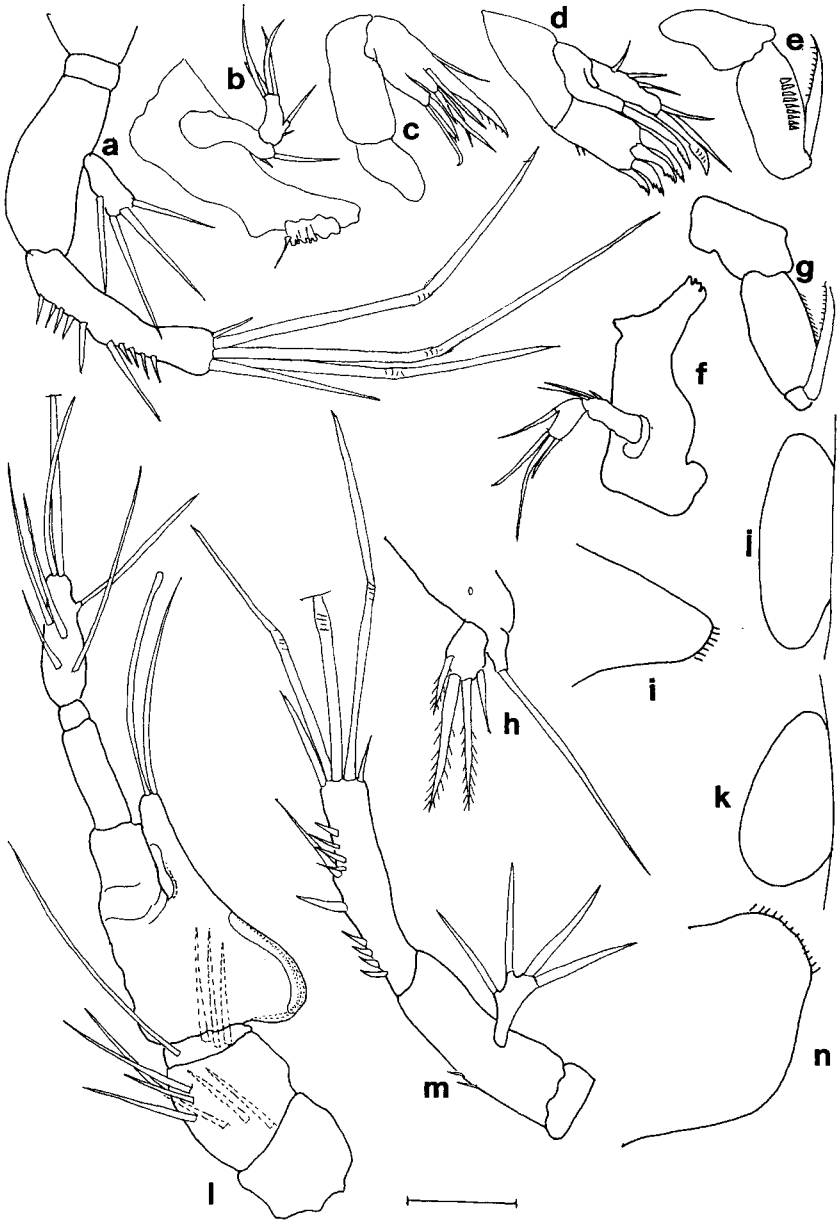
Elaphoidella fluviusherbae sp. nov. (figs. 5-8)

Material. — Holotype female, dissected and mounted on slide (MCZ 25406), 2 April 1999. Allotype male, dissected and mounted on slide (MCZ 25407), 1 October 1998. Paratypes: 1 female, mounted on slide labeled "paratype female no. 1" (MCZ 25408), 7 January 1999; 1 male, mounted on slide, labeled "paratype male no. 1" (MCZ 25409), 7 January 1999; 1 male, dissected and mounted on slide, labeled "paratype male no. 2" (EVER 308761), 2 April 1999.

All material collected from USGS well WIO2, 25°23′36.3″N 80°36′31.4″W, Everglades National Park, Florida, U.S.A., by M. C. Bruno.

Female. — Habitus (fig. 6a) cylindrical. Length of paratype 1, measured from rostrum to distal apex of furcal rami, 680 μm. Cephalosome with elongate ovoid integumental window (fig. 5j). Hyaline fringes of posterior margins of all somites and of cephalosome denticulate; all somites finely punctate, with scattered long hairs, and all somites except cephalosome with transverse rows of tiny hairs.

Fig. 5. *Elaphoidella fluviusherbae* sp. nov. a, b, c, d, e, j, n, holotype female; f, g, h, k, allotype male; i, l, m, paratype male no. 1. a, antenna; b, mandible; c, maxilla; d, maxillule; e, maxilliped; f, mandible; g, maxilliped; h, P5; i, rostrum; j, cephalic integumental window; k, cephalic integumental window; l, antennule; m, antenna; n, rostrum.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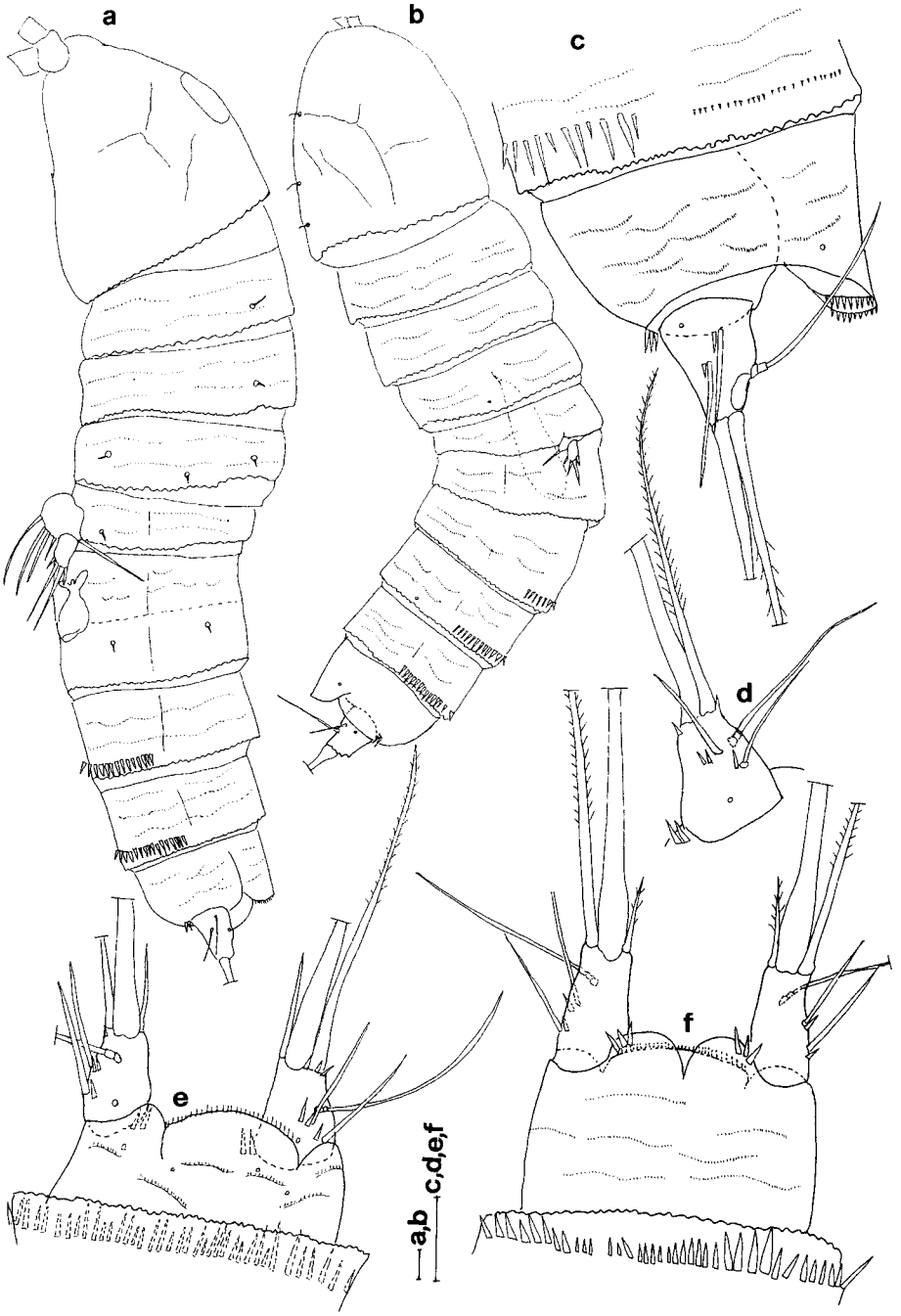
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Genital somite with remnant of division visible beneath integument (fig. 6a). Genital field reaching past midlength of somite. First and second urosomites posterior to genital somite each with one row of long ventral spines, extending laterally along posterior margins. Anal somite with three ventral spines near inner side of each caudal ramus (fig. 6c, f). Anal operculum convex, with row of thin spinules along margin (fig. 6c, f).

Furcal ramus (fig. 6c, f), length to width ratio 2.1, cylindrical, slightly keeled dorsally. Biarticulate dorsal seta inserted at end of keel, plus two lateral setae, each with one spine near its insertion. Three distal setae, the strong middle seta lacking proximal breaking plane, with bulbous basal expansion, slightly pinnate distally. Outermost terminal seta with bulbous base, slender, three times as long as furcal ramus. Innermost terminal seta small, plumose, shorter than furcal ramus.

Rostrum as in fig. 5n.

Antennule (fig. 7g) 9-segmented (usually single terminal segment clearly divided); segment 4 with tubercle carrying one seta and long broad aesthetasc reaching past end of antennule. Last segment with two long apical setae and one long aesthetasc.

Antenna (fig. 5a) with allobasipodite, exopodite one-segmented with four setae.

Mandible (fig. 5b), exopodite two-segmented, first segment with one seta and one small spinule, second segment with four apical setae and one lateral seta with one small spinule near its insertion.

Maxillule (fig. 5d), arthrite of praecoxa with four dentate claws, basis with one endite bearing one pinnate terminal claw; exopodite with three apical setae, one transformed, and three lateral setae.

Maxilla (fig. 5c), basis with two setae and one terminal pinnate claw, two endites: inner endite with three setae, outer endite with two pinnate claws and one seta.

Maxilliped (fig. 5e) prehensile, basis bare.

P1-4 (fig. 7a, c, d, e, f) with three-segmented exopodite, endopodite of P1 (fig. 7b) three-segmented, longer than exopodite; endopodites of P2-P4 two-segmented. Major setation and spination formula:

Fig. 6. *Elaphoidella fluviusherbae* sp. nov. f, holotype female; e, allotype male; a, c, paratype female no. 1; b, d, paratype male no. 1. a, habitus, lateral; b, habitus, lateral; c, last abdominal somite, anal somite, anal operculum and furcal rami, lateral view; d, furcal ramus, lateral view; e, last abdominal somite, anal somite, anal operculum and furcal rami, dorsal view; f, last abdominal somite, anal somite, anal operculum and furcal rami, ventral view.

Fig. 7. *Elaphoidella fluviusherbae* sp. nov. a, b, c, d, e, f, g, i, holotype female; h, paratype male no. 1. a, exopodite P1; b, endopodite P1; c, endopodite P2; d, exopodite P2; e, P4; f, P3; g, antennule; h, P1; i, P5.

P1	basipodite 1-1	exp. 0-1;	1-1;	0,3,1
		enp. 1-0;	1-0;	1,2,0
P2	basipodite 0-1	exp. 0-1;	1-1;	1,3,1
		enp. 1-0;	2,2,0	
P3	basipodite 0-1	exp. 0-1;	1-1;	2,3,1
		enp. 1-0;	2,2,1	
P4	basipodite 0-1	exp. 0-1;	1-1;	2,2,2
		enp. 1-0;	2,2,0	

Outer distal setae on each segment of exopodites of P2-P4 stout, spiniform. All couplers (intercoxal sclerites) bare.

P5 (fig. 7i), baseoendopodite slightly expanded medially, with four pinnate setae, outer seta very short and innermost seta longest; one large pore near insertion of exopodite. Exopodite oval, with two distal pinnate setae of unequal lengths and one short pinnate seta on each inner and outer corner, and four long spinules along each margin.

Male. — Length of paratype 1, measured from rostrum to distal apex of furcal ramus, 700 μm. Habitus in fig. 6b. Cephalosome with dorsal integumental window (fig. 5k) larger than in female. Somites and cephalosome ornamented as in female; second, third and fourth urosomite each with one ventral row of long spines along posterior margin, extending laterally. Anal somite (fig. 6d, e) with two spines near caudal rami; anal operculum as in female.

Spermatophore as in fig. 8d.

Furcal ramus (fig. 6d, e) shorter than in female, similar in shape, length to width ratio 1.61. Two spines near insertion of proximal lateral seta. Outermost terminal seta without bulbous base, with few spinules at its base; innermost terminal seta smooth.

Rostrum as in figure 5i.

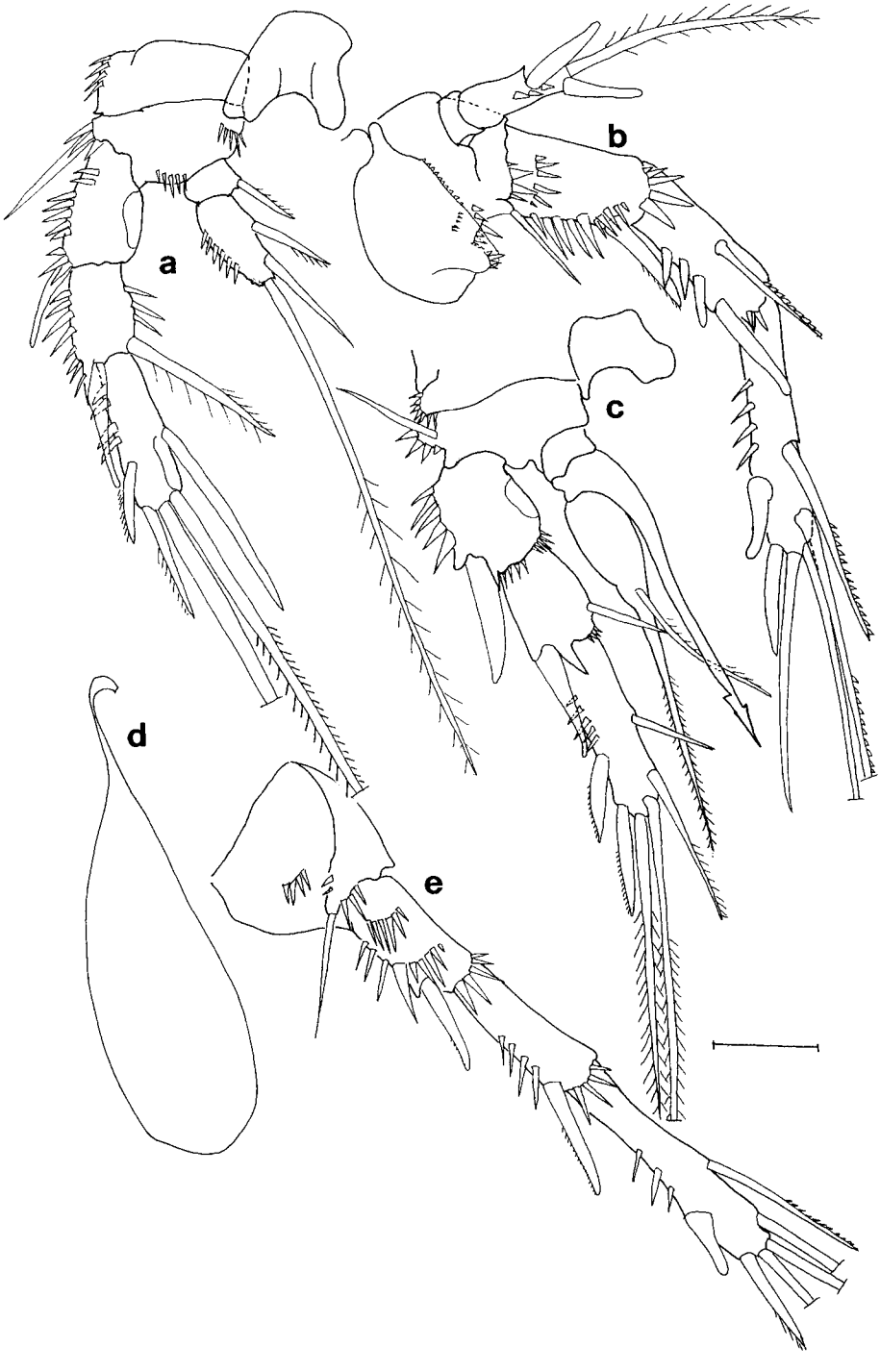
Antennule (fig. 5l) subchirocer, seven-segmented. Fourth segment with large expansion with distal tubercle carrying one aesthetasc and one seta, of similar lengths, reaching end of last segment.

Antenna (fig. 5m), maxilliped (fig. 5g), and P1 (fig. 7h) as in female; maxillulae and maxillae not visible.

Mandibular palp (fig. 5f), first segment with two setae, no lateral spinule on second segment.

P2 (fig. 8a), endopodite with one long apical seta, first segment of exopodite lacking inner seta.

P3 (fig. 8c) exopodite, similar to that of female. P3 endopodite three-segmented, modified; spiniform process on second segment reaching almost to end of third segment of corresponding exopodite. Third segment with two strong pinnate apical setae, of unequal lengths.


a
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d
e

P4 (fig. 8b), exopodite similar to that of female; first segment of P4 endopodite bare, second segment with one long pinnate seta and one short strong seta on apex, and one strong subapical seta accompanied by three spines.

P5 (fig. 5h), baseoendopodite reduced, lacking armament, with pore near exopodite insertion. Exopodite longer than broad, with four stout apical spiniform setae, all pinnate except outer seta, next innermost seta longest.

Variability. — No variation was detected among the female specimens. The males differ in the number of spinules on the second and third segments of the P4 exopodite: paratype 1 has, respectively, 4 and 3 spinules (fig. 8e), paratype 2 has, respectively, 4 and 4 spinules.

Etymology. — The species name, from the Latin "fluvius" (= river) and "herba" (= grass), refers to "river of grass", the appellative M. Stoneman Douglas used for the Everglades. The epitheton is a noun in the genitive singular.

REMARKS

Morphological comparisons

The two new species are morphologically quite similar, but are distinguishable by the body shape of both sexes, *E. marjoryae* sp. nov. being shorter and stouter than *E. fluviusherbae* sp. nov.; the row of lateral spines on the anal somite of *E. marjoryae* and the number of spines near the caudal rami insertions for both sexes; the shape of the furcal rami, which are shorter and with a more pronounced keel in *E. marjoryae*; the number of spines near the lateral caudal setae and the bulbous expansion on the terminal caudal setae, in both sexes; and the shape and ornamentation of enp-P3 in males. Other minor differences can be detected in the secondary body ornamentation, as follows:

– Body ornamentation: all somites are denticled in *E. marjoryae* and only slightly denticled in *E. fluviusherbae*. In the former species, the rows of spines on the first and second urosomites extend dorsally, in some specimens completely around the somites.

– Antennule of female: 8-segmented in *E. marjoryae*, 9-segmented in *E. fluviusherbae*. The latter species has a larger aesthetasc on segment 4. The 9-segmented antennule is unusual for the genus, specimens with the more common 8-segmented A1 may be collected.

Fig. 8. *Elaphoidella fluviusherbae* sp. nov. a, b, c, d, allotype male; e, paratype male no. 1. a, P2; b, P4; c, P3; d, spermatophore; e, exopodite P4.

– Antennule of male: the tubercle on segment 4 is long in *E. fluviusherbae*, while the corresponding seta and aesthetasc are much shorter in *E. marjoryae*.

– Antenna: the lengths of the apical setae on the last segment differ: the inner and outer setae are shorter in *E. fluviusherbae*.

– Mandibular palp: segment 1 with one seta and one spine in *E. fluviusherbae*, but only one seta in *E. marjoryae*; segment 2 with one lateral seta and one spine in *E. fluviusherbae*, only one seta in *E. marjoryae*.

– P1 and P2 exopodites of female: the two spiniform setae on the outer corner of last segment are stronger in *E. fluviusherbae*.

– P3 of female: endopodite, first segment bare in *E. marjoryae*; exopodite, two spiniform setae on outer corner of last segment stronger in *E. fluviusherbae*.

– P3 of male: exopodite, apical setae on last segment are stronger in *E. fluviusherbae*.

– P4 of female: endopodite, all spiniform setae are longer in *E. fluviusherbae*; exopodite, the two spiniform setae on outer corner of last segment are longer in *E. fluviusherbae*.

– P4 of male: exopodite, all setae and spiniform setae are stronger in *E. fluviusherbae*; the outer tip of the last segment has a peculiar shape in *E. marjoryae*. Endopodite: setae are stronger and with a rounded tip in *E. fluviusherbae*.

– P5 of female: baseoendopodite broader in *E. marjoryae*, setae with different lengths in the two species. The exopodite is squat in *E. marjoryae*, elongate in *E. fluviusherbae*; and the medial setae differ in length in the two species; the outer seta is bare in *E. marjoryae*, but pinnate in *E. fluviusherbae*.

– P5 of male: exopodite more elongate in *E. fluviusherbae*, setae with different lengths in the two species.

Following the taxonomic key proposed by Reid & Ishida (1993), females of both new species most resemble *E. subgracilis* (Willey, 1934). In regard to the major setation/spination patterns of the swimming legs of all North American species, including the five described by Reid (2001), the setation of the female of *E. marjoryae* is closest to that of *E. cadesi* Reid, 2001, except for lacking a seta on P3 enp1, present in *E. cadesi*. *Elaphoidella marjoryae* differs from *E. cadesi* in several features of the caudal ramus, e.g., in the more pronounced "bottle-shape" with the distal third slender (in *E. cadesi*, the caudal ramus is broadly convex); in the much less pronounced, subtly sculptured medial surface (in *E. cadesi*, the inner surface is strongly sculptured and dentate in dorsal view); and in the simple inner and outer terminal caudal setae (in *E. cadesi*, the bases of these setae are strongly broadened, and the base of the inner seta has a distinctive longitudinal row of strong stiff spines). The male of *E. cadesi* is unknown.

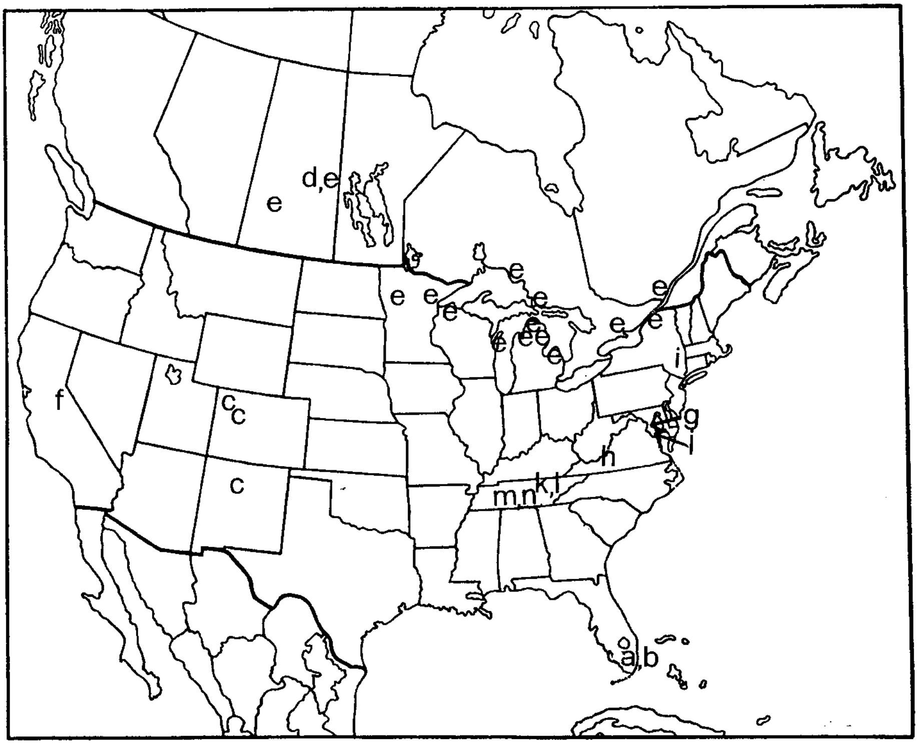
Elaphoidella marjoryae and *E. fluviusherbae* resemble *E. subgracilis*, *E. californica* Wilson, 1975, *E. reedi* Wilson, 1975, and *E. campestris* Reid, 2001 in the general form of the caudal ramus, which is a simple bottle-shape with no surface sculpturing or protrusions except for the dorsal keel. The species in this group are best distinguished by different setation of the appendages. In *E. reedi* and *E. californica* the leg 5 exopodite has 5 setae. *Elaphoidella marjoryae* and *E. fluviusherbae* share with *E. subgracilis* and *E. campestris* the leg 5 exopodite with only 4 setae; however, in *E. campestris* the P3 enp2 has only 3 setae, as opposed to 4 setae on the corresponding endopodite in *E. subgracilis* and *E. fluviusherbae*, and 5 setae in *E. marjoryae*.

The major setation of the female of *E. fluviusherbae* is identical to that of *E. subgracilis*. This pair of species is also most easily distinguished by characters of the caudal rami. Following the redescription of the female of *E. subgracilis* by Wilson (1975), in *E. fluviusherbae*, the caudal ramus is shorter and lacks the pronounced dorsal keel and proximal expansion of the inner surface of the ramus of *E. subgracilis*. *Elaphoidella subgracilis* has a short row of spines on each side of the anal somite, while *E. fluviusherbae* lacks such spines. The last antennular segment is undivided in *E. subgracilis*. The male of *E. subgracilis* is undescribed.

Biogeographical and ecological considerations

The two new species of *Elaphoidella* in ENP bring to 16 the number of described species of the genus present in North America, excluding Mexico. Of these, only 7 may be considered strictly subterranean: *E. shawangunkensis* Strayer, 1989 from the hyporheos of a stream in the state of New York, U.S.A.; *E. amabilis* Ishida, 1993 from groundwater (a spring) in the state of Maryland (Reid & Ishida, 1993); *E. musaica* Reid, 2001, *E. stupkai* Reid, 2001, and *E. cadesi* from groundwater-related habitats in the Great Smoky Mountains, state of Tennessee (Reid, 2001), and *E. marjoryae* and *E. fluviusherbae* in Florida. This number is very low compared to the total of about 127 subterranean species of *Elaphoidella* known worldwide (Dussart & Defaye, 1990; Rouch, 1986; G. L. Pesce, pers. comm.).

In North America north of Mexico, most species of *Elaphoidella* have been found only in the cool-temperate regions (figs. 9, 10). No species except *E. bidens* Schmeil, 1893 (of which the North American form is *E. bidens coronata* (G. O. Sars, 1904)) has been previously collected south of North Carolina and Tennessee in the eastern U.S.A., and central New Mexico in the west (figs. 9, 10). The genus *Elaphoidella* is widespread in temperate and tropical regions worldwide, and is especially speciose in the tropics (Dussart & Defaye, 1990; Reid, 1994). Therefore, the North American pattern may reflect more the lack of investigation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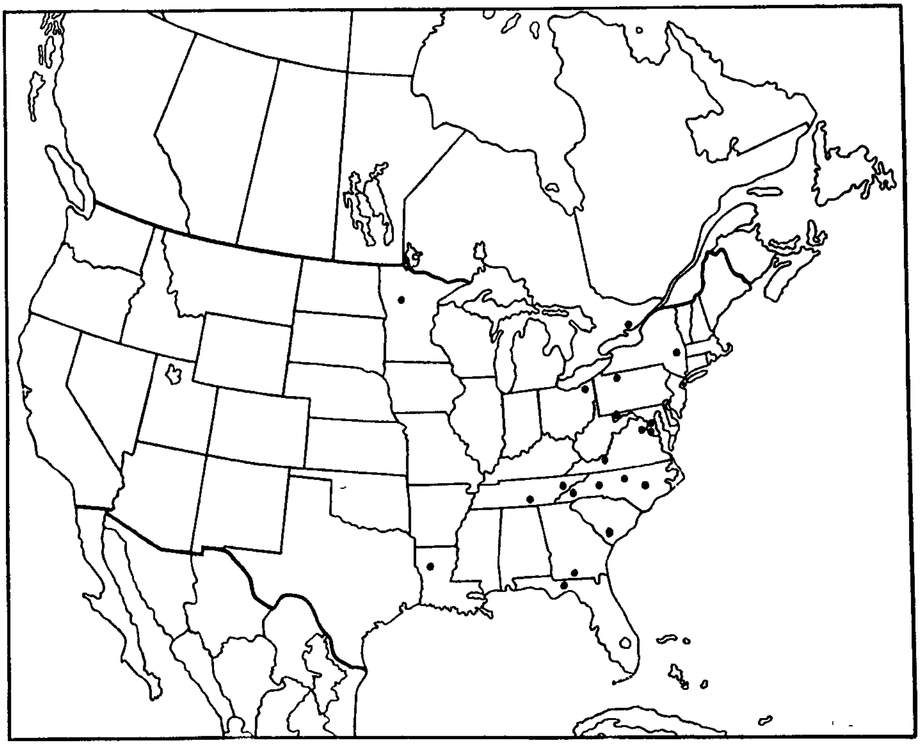

of appropriate habitats in most of the continent, than any biogeographical reality (Reid, 1986).

The four species found farthest north, and limited to the part of the continent covered by the last episode of glaciation, are *E. subgracilis*, *E. kodiakensis* Wilson, 1975, *E. reedi*, and *E. shawangunkensis*. *Elaphoidella subgracilis* is distributed from southern Quebec westward through the Laurentian Great Lakes region to central Saskatchewan (Willey, 1934; Wilson, 1975; Shiozawa, 1991; Hudson et al., 1998; detailed records from the Great Lakes, mentioned but not listed in extenso by Hudson et al., 1998, are indicated in fig. 9). *Elaphoidella kodiakensis* is known only from Kodiak Island, Alaska (Wilson, 1975), *E. reedi* from central Saskatchewan (Wilson, 1975), and *E. shawangunkensis* from the lower Hudson River Valley, New York (Strayer, 1989).

Several other species are known from mountainous regions. *Elaphoidella californica* was collected in Yosemite National Park, California (Wilson, 1975). *Elaphoidella wilsonae* Hunt, 1979 has been found in the Rocky Mountains of Colorado (Hunt, 1979) and New Mexico (Reid & Ishida, 1993). *Elaphoidella carterae* Reid, 1993 was found in Mountain Lake, in the Appalachian Mountains of Virginia (Reid & Ishida, 1993). Four species were collected on the Tennessee side of the Great Smoky Mountains National Park: *E. musaica*, *E. stupkai*, *E. campestris*, and *E. cadesi*.

Two species have been described from low-altitude piedmont localities: *E. amabilis* in Maryland (Reid & Ishida, 1993), and *E. douglasi* Reid, 2001 in the nearby District of Columbia.

The known distribution of *E. bidens* in North America is peculiar. North of Mexico, *E. bidens* has been collected in Ontario, Canada and in the U.S.A. in the District of Columbia, in the states of Maryland, New Mexico, New York, Pennsylvania, Virginia, South Carolina, North Carolina, Minnesota, Ohio, Tennessee, Louisiana, Georgia, and northern Florida (fig. 10). Distributional records were reviewed by Wilson (1975) and Reid & Ishida (1993). More recent records were given by Palmer et al. (1995), from Virginia, Hudson et al. (1998), from Ontario, and Reeves (2000) for South Carolina. The collections by Reid

Fig. 9. Records of *Elaphoidella* in North America. a, *E. marjoryae* sp. nov.; b, *E. fluviusherbae* sp. nov.; c, *E. wilsonae* Hunt, 1979; d, *E. reedi* Wilson, 1975; e, *E. subgracilis* (Willey, 1934); f, *E. californica* (Wilson, 1975); g, *E. amabilis* Ishida, 1993; h, *E. carterae* Reid, 1993; i, *E. shawangunkensis* Strayer, 1989; j, *E. douglasi* Reid, 2001; k, *E. musaica* Reid, 2001; l, *E. stupkai* Reid, 2001; m, *E. cadesi* Reid, 2001; n, *E. campestris* Reid, 2001: o, *E. kodiakensis* Wilson, 1975 (not on map).

Fig. 10. Records of *Elaphoidella bidens coronata* (G. O. Sars, 1904) in North America (some dots represent more than one record).

(1996) from the District of Columbia refer to: (1) Rock Creek in the northern end of Rock Creek National Park, 5 October 1990, coll. J. W. Reid & T. Ishida (USNM 251796); (2) natural pond by Visitor Center in Kenilworth National Park and Aquatic Gardens, 1 June 1996, coll. J. W. Reid and W. A. Reid; and (3) natural pond by Visitor Center in Kenilworth National Park and Aquatic Gardens, 4 October 1996, coll. S. W. Syphax & J. W. Reid (USNM 278180). The records of *E. bidens* from Great Smoky Mountains National Park, reported by Reid (1999) refer to two locations: (1) Sample GS-98-25, 5 females from cultures of damp mud taken from a slough, west end of Cades Cove, Tennessee, 35°35′36″N 83°50′24″W, 16-21 October 1998; (2) Sample GS-99-28, 1 female from inlet of Chilhowee/Calderwood Lake by US Highway 129, North Carolina, 35°32′34″N 83°59′37″W, 27 May 1999; both collected by J. W. Reid & W. A. Reid. From inspection of the distributional map (fig. 10), *E. bidens* appears to be limited to the eastern half of the continent. However, this species has been reported from the states of Coahuila, Nuevo León, and San Luis Potosí in central and northern Mexico (Suárez-Morales & Reid, 1998). Therefore, the gap in the western U.S.A. may result from less intensive collecting there (cf. Reid, 1986).

What is clear, is that the great majority of records of *E. bidens* in North America come from disturbed locations, in some cases associated with the presence of organic (agricultural) enrichment. Typical examples include an artificial pond and a stream within the city of Valdosta, Georgia (Carter & Bradford, 1972); Rock Creek, District of Columbia (where much of the drainage basin contains high-density urban and suburban communities and farms); and a pond surrounded by fertilized lawn in Kenilworth Aquatic Gardens, District of Columbia. Both records from the Great Smoky Mountains National Park come from valleys which are either still in cattle pasture (Cades Cove), or a managed reservoir, at a formerly farmed site (Chilhowee/Calderwood Lake). *Elaphoidella bidens* is one of the more common copepod species in Goose Creek, which drains suburbs and farmlands in northern Virginia (Palmer et al., 1995). *Elaphoidella bidens* appears to have a strong predilection for human habitation (past or present). Since this famously parthenogenetic species is not closely related to its other North American congeners, all of which belong to the *gracilis*-group, we speculate whether it might have been introduced in this continent.

The two new Everglades species, very similar morphologically, appear to differ in habitat. *Elaphoidella marjoryae* was collected both in ground and surface waters, although in the latter during the dry season, when the deep solution holes which do not dry are connected and recharged by groundwaters. The species seems to be able to enter diapause in order to survive the drought, as indicated by the collection of the male allotype from a rehydrated soil patch (Bruno et al., subm.). *Elaphoidella fluviusherbae* was collected exclusively from groundwaters, in one single location.

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Family CYCLOPIDAE Rafinesque, 1815

Diacyclops nearcticus Kiefer, 1934 (figs. 11-17)

Material. — 1 female mounted on slide labeled "female no. 1" (MCZ 25410), 10 July 1998, USGS well WIO2, 25°23′36.3″N 80°36′31.4″W. 1 female dissected, mounted on slide labeled "female no. 2" (MCZ 25411), same date and location. 1 female mounted on slide labeled "female no. 3" (EVER 308762), 2 September 1998, same location. 1 female mounted on slide labeled "female no. 4" (EVER 308763), 1 October 1998, USGS well WIO3, 25°23′21.0″N 80°39′9.6″W. 1 female mounted on slide labeled "female no. 5" (EVER 308764), 8 October 1998, USGS well G3302A, 25°45′42″N 80°42′17″W. 6 females mounted on slides labeled "female no. 6, 7, 8, 9, 10, 11" (EVER 308765, 308766, 308767, 308768, 308769, 308770), 7 January 1999, USGS well WIO2. 2 females mounted on slides labeled "female no. 12, 13" (EVER 308771, 3078772), 2 April 1999, USGS well WIO2. 1 male mounted on slide labeled "male no. 1" (MCZ 25412), 7 February 1999, USGS well WIO2. 2 males mounted on slides labeled "male no. 2, 3" (MCZ 25413, EVER 308773), 4 February 1999, USGS well WI02. 2 females and 1 male, prepared for scanning electron microscopy, on a stub labeled: "female no. 14, 15, male no. 4", 22 October 1998, USGS well WIO2.

All material collected from Everglades National Park, Florida, U.S.A., by M. C. Bruno.

Supplementary description of female. — Lengths of paratypes 1 and 3-13, measured from rostrum to distal apex of furcal rami: 640, 580, 768, 960, 620, 672, 480, 580, 620, 632, 520, 600 μm, respectively.

Habitus in fig. 11k. Genital operculum as in figs. 15b, 12i. Anal somite (figs. 13c, 17a) with transverse row of scattered thin hairs, some denticles, and two ventral pores about 2/3 of length.

Furcal ramus (figs. 13c, 17a), length/width 3.2-4.4, cylindrical, bare, with a pore on the lateral outer margin.

Antennule (fig. 12a), four setae on segment 2 (fig. 16e), six setae on segment 4, and seven setae on the segment 17.

Antenna (fig. 12b), first article with two groups of spines, and some scattered short hairs on caudal side (fig. 16e, g). Second segment with lateral row of spines and one subapical seta. Third article with row of lateral spines and seven setae, two of these transformed. Last article with lateral row of spines and three normal and three transformed apical setae.

Mandible, palp with two long setae, similar in length (fig. 11a).

Maxillule as in fig. 11b, palp (fig. 15c) with long seta.

Maxilla as in figs. 11g, 17d, endopodite also in fig. 15a.

Maxilliped (fig. 11e), last segment with three setae.

P1 (fig. 14b): basipodite, inner spine pinnate, almost reaching end of 2-enp; one row of spinules along anterior margin, near insertion of endopodite. Exopodite with all outer spines pinnate, with one row of spinules near each segment, and with one transverse row of spinules along distal margins of first and second segments. Spiniform process on each inner corner of first and second segment. Third segment

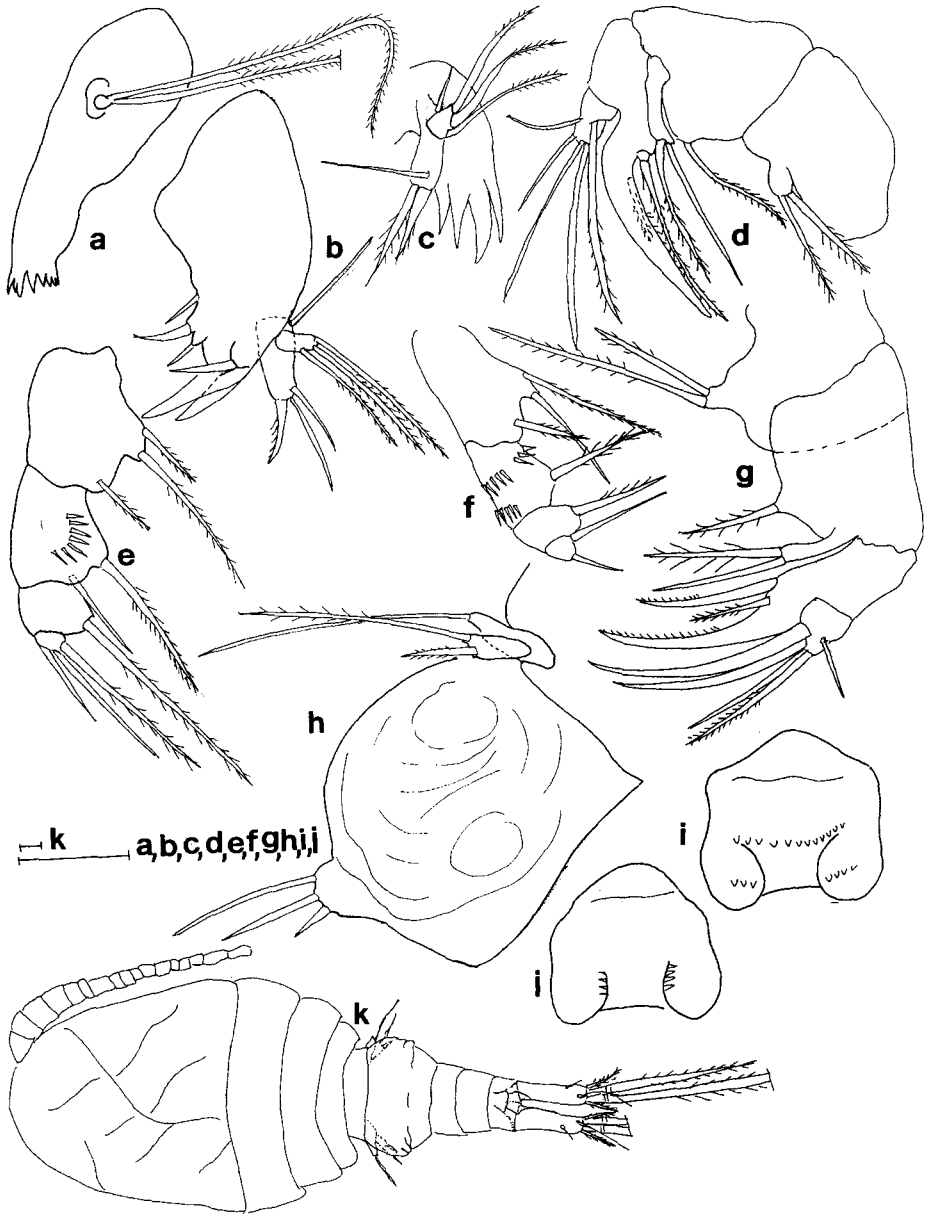

Fig. 11. *Diacyclops nearcticus* Kiefer, 1934. a, b, g, i, j, k, female no. 1; e, i, female no. 5; c, d, f, male no. 1; h, male no. 2. a, mandible; b, maxillule; c, maxillule (part); d, maxilla; e, maxilliped; f, maxilliped; g, maxilla; h, P5 and P6; i, coupler P4; j, coupler P4; k, habitus, dorsal.

Fig. 12. *Diacyclops nearcticus* Kiefer, 1934. a, c, female no. 1; b, female no. 3; d, e, f, g, h, i, male no.1. a, antennule; b, antenna; c, P5; d, antenna; e, antennule; f, antennule, protrusion on 10th segment; g, exopodite P4; h, endopodite P4; i, genital operculum.

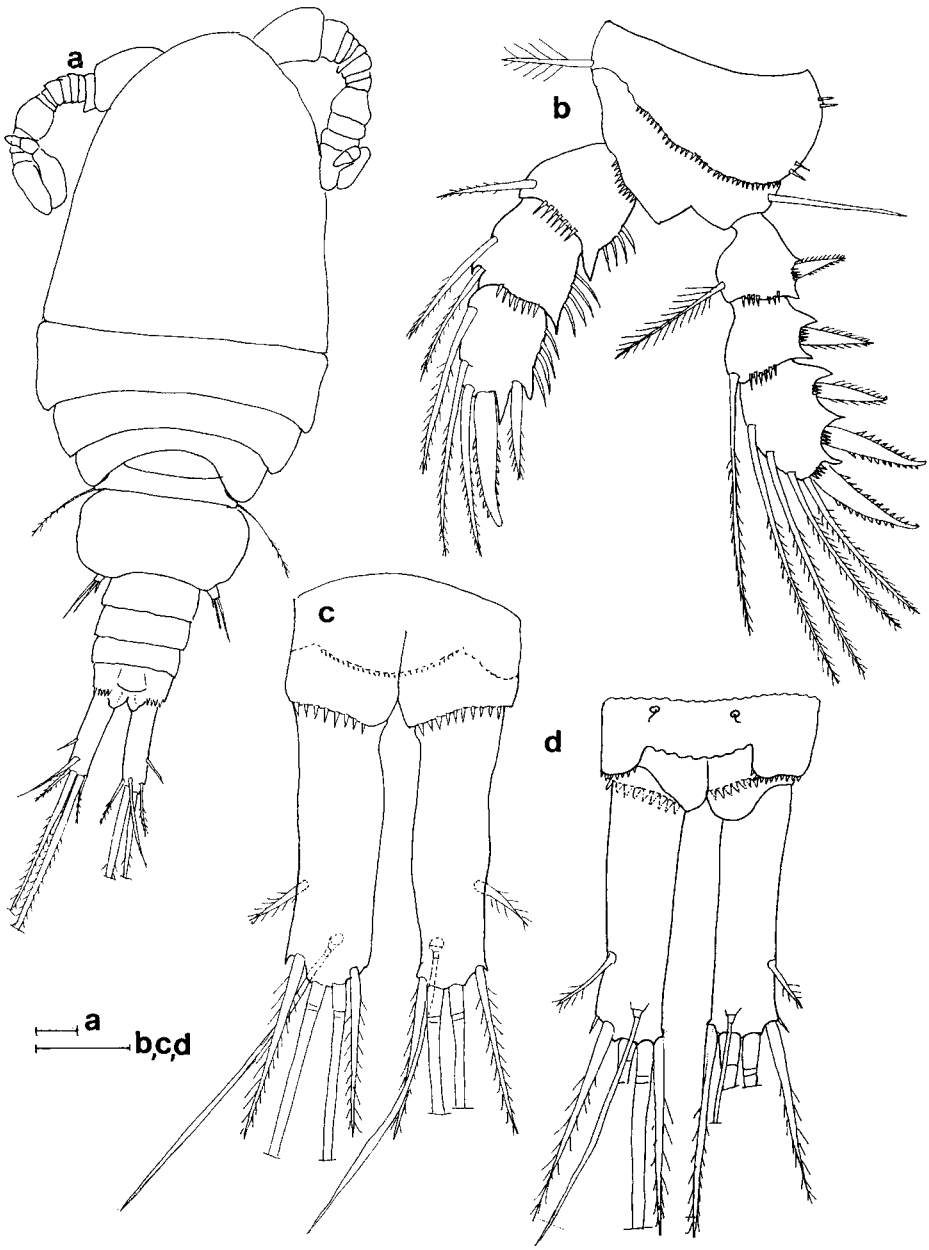

Fig. 13. *Diacyclops nearcticus* Kiefer, 1934. b, female no. 3; c, female no. 1; a, male no. 3; d, male no. 1. a, habitus, dorsal; b, P2; c, last abdominal somite, anal operculum and furcal rami, ventral view; d, anal somite, anal operculum and furcal rami, dorsal view.

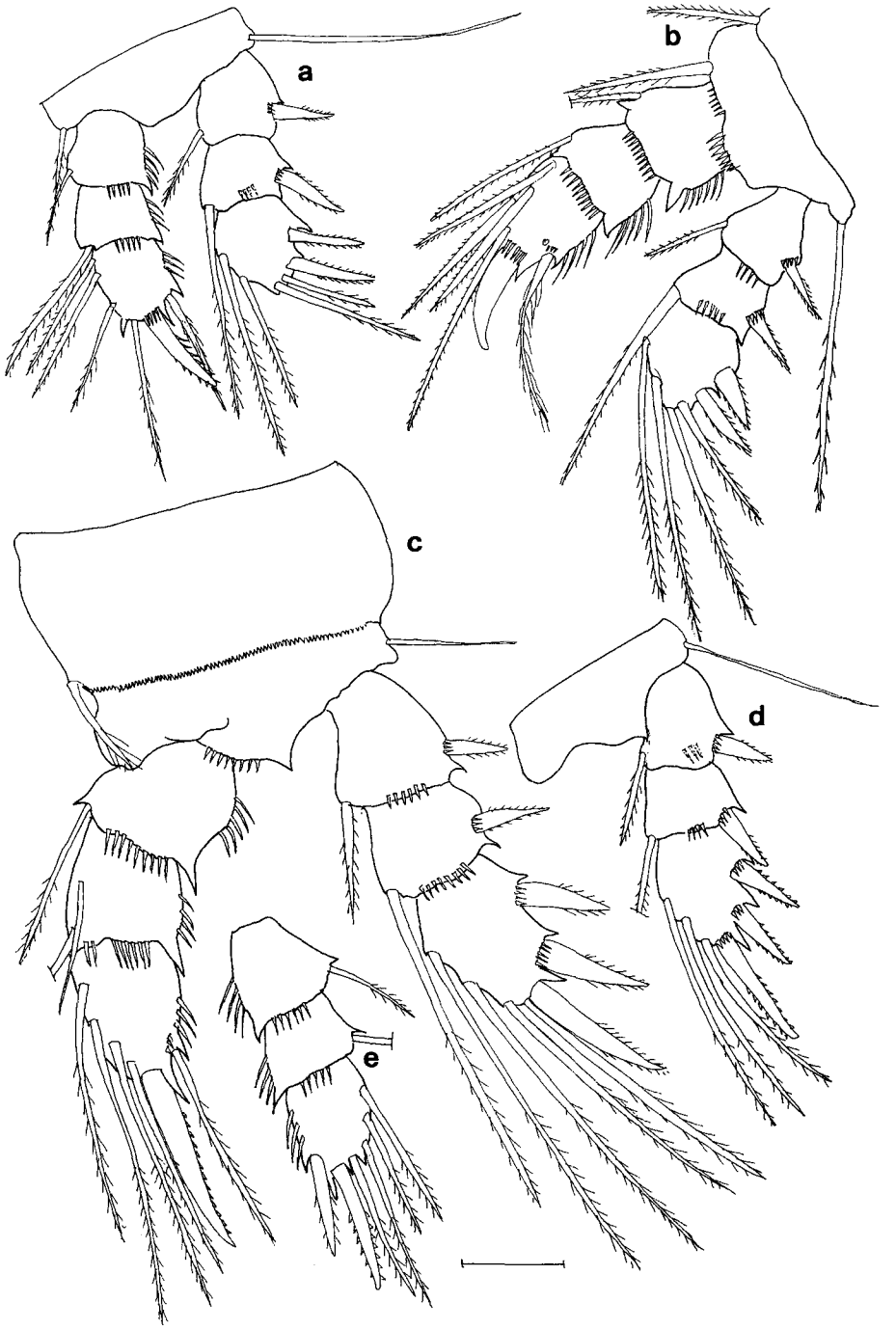

Fig. 14. *Diacyclops nearcticus* Kiefer, 1934. b, female no. 3; a, c, d, e, male no. 2. a, P1; b, P1; c, P2; d, endopodite P3; e, exopodite P3.

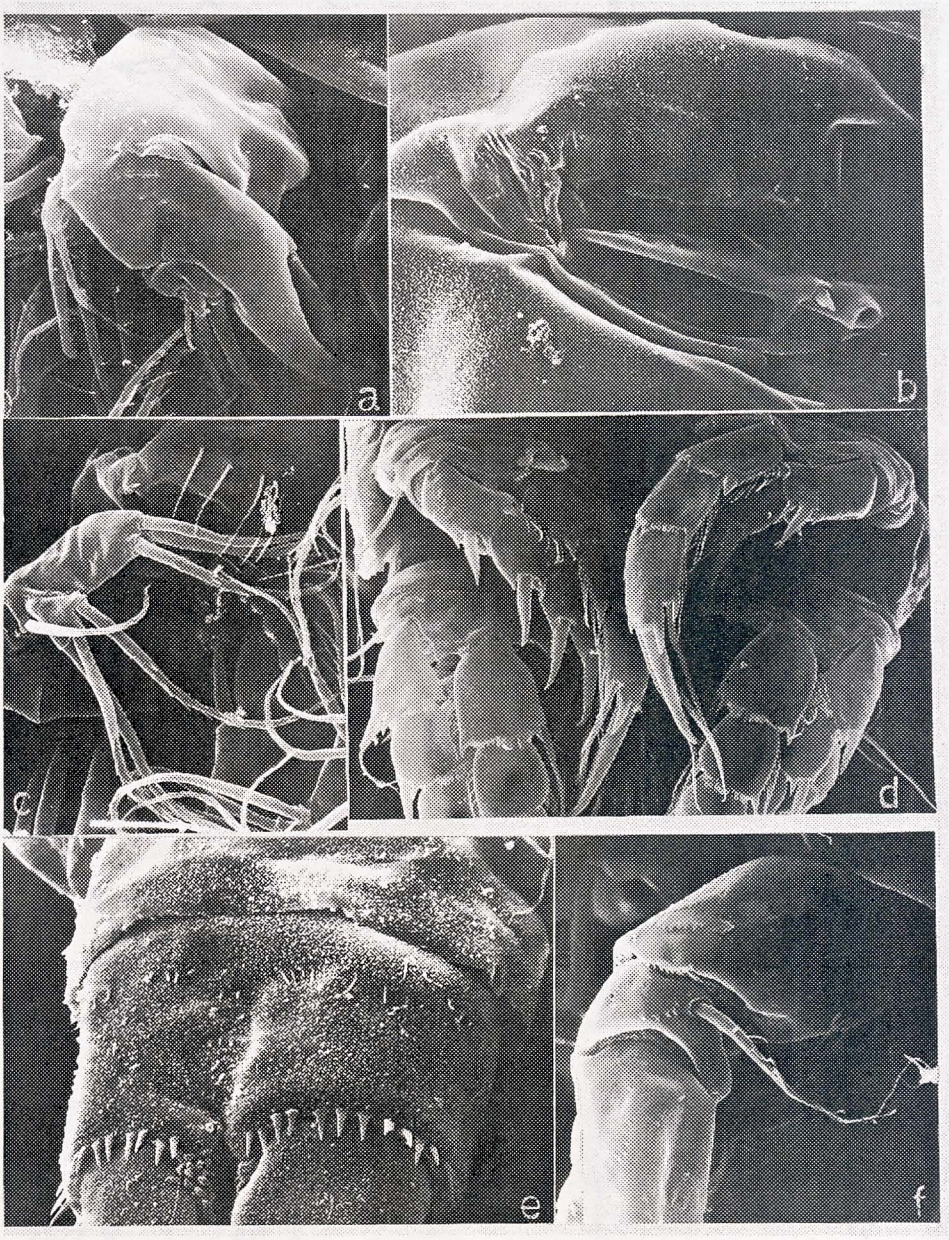

Fig. 15. *Diacyclops nearcticus* Kiefer, 1934. a, b, c, d, f, female; e, male. a, maxillar endopodite (1,500×); b, genital operculum (2,000×); c, maxillular palp (2,000×); d, P3 (750×); e, last two abdominal somites, ventral view (1,500×); f, basipodite P4, outer view (2,000×).

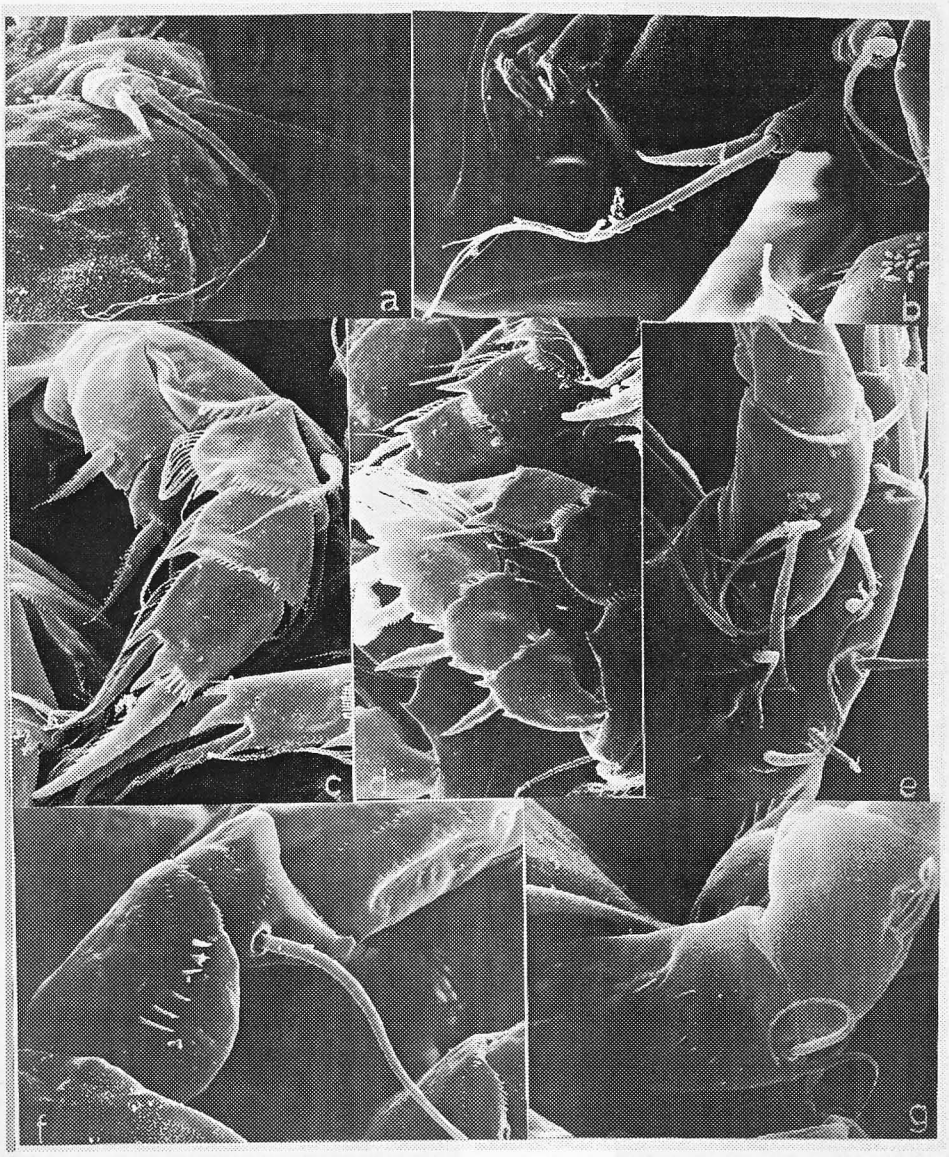

Fig. 16. *Diacyclops nearcticus* Kiefer, 1934. b, c, e, f, g, female; a, d, male. a, P5 (2,000×); b, P5 (2,000×); c, endopodite P1 (1,500×); d, P2 (1,000×); e, antennule (first and second segments) and antenna (first and second segments) (2,000×); f, basipodite P3, outer view (2,000×); g, antenna, first and second segments, caudal side (2,000×).

with one distal pore, and with long spinules at insertion of main apical spine. All setae of endopodite (fig. 16c) pinnate. Coupler (intercoxal sclerite) bare.

P2 (fig. 13b) basipodite, medial expansion with acute oblique process, sparsely haired, row of spinules along insertion of endopodite. P2 exopodite three-segment-

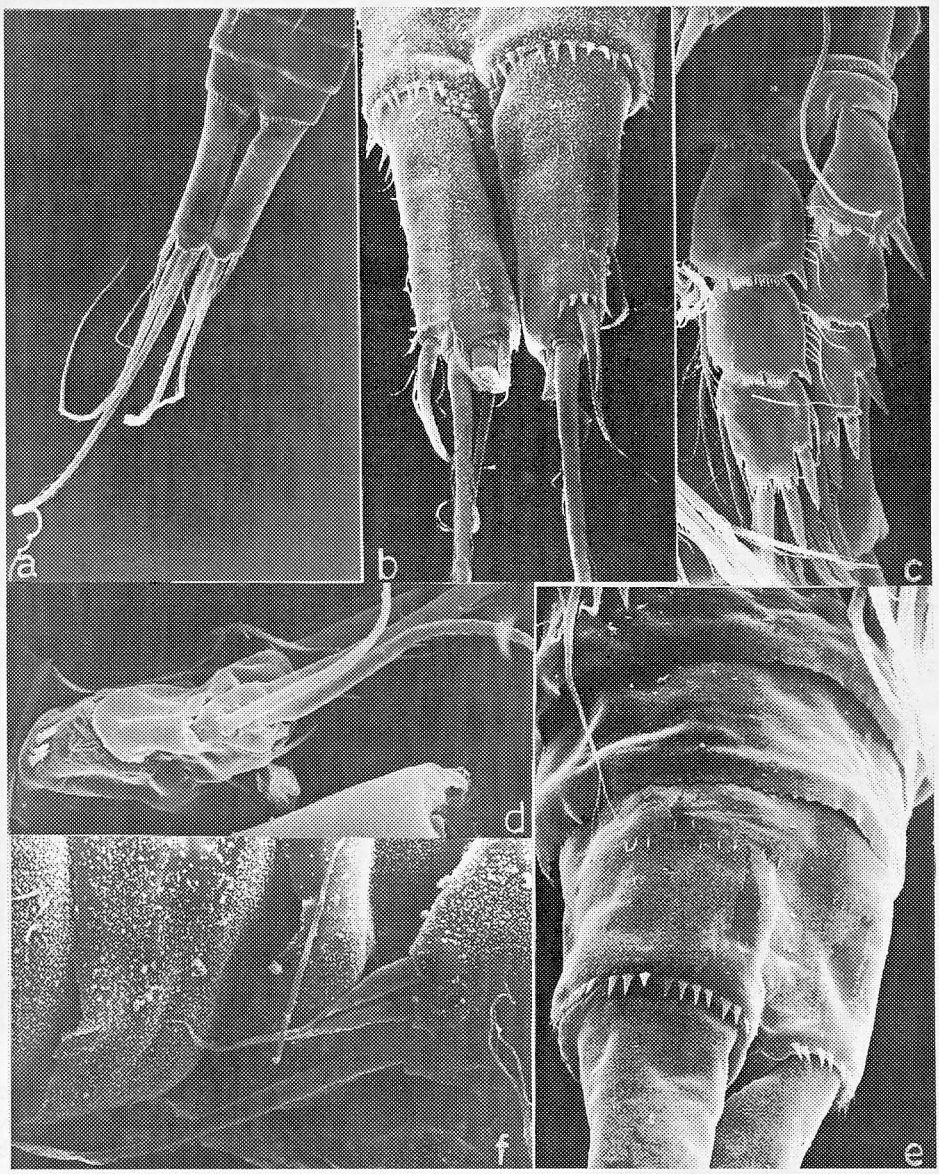

Fig. 17. *Diacyclops nearcticus* Kiefer, 1934. a, c, d, female; b, e, f, male. a, anal somite and furcal rami, ventral view (500×); b, furcal rami, ventral view (1,500×); c, P4 (1,000×); d, maxilla (3,500×); e, last two abdominal somites and anal somite, ventral view (1,500×); f, P6 (3,500×).

ed, first segment with one outer pinnate spine with spines near its insertion, a long inner pinnate seta, and row of spinules along distal margin. Second segment with similar ornamentation, last segment with three strong, pinnate spines with spinules at their insertions, and four long pinnate setae. Endopodite three-segmented, first and second segments with long hairs along outer margin, row of spinules along distal margin, and one pinnate inner seta. Last segment with long lateral hairs, two strong pinnate spines, and three pinnate setae. Coupler (intercoxal sclerite) bare.

P3 (fig. 15d), coxa with tiny spinules and row of spines along outer margin, basipodite with tiny spinules and one pore on outer margin (fig. 16f), medial expansion with acute, oblique process, row of spinules along endopodite insertion. P3 exopodite three-segmented, first segment with outer pinnate spine with spines near its insertion, one long inner pinnate seta, and row of spinules along distal margin. Second segment with same ornamentation, last segment with three strong pinnate spines with spinules at their insertion and four long pinnate setae. Endopodite three-segmented, first segment with long hairs along outer margin, row of spinules along distal margin, one pinnate inner seta. Second segment with one pinnate inner seta, last segment with long lateral hairs, two strong pinnate spines, four pinnate setae.

P4 (fig. 17c), coxa with row of spinules on outer distal margin, scattered spinules, and transverse row of spinules on distal side. Basipodite (figs. 15f, 17c) with row of spinules along endopodite insertion, one lateral pore, and rows of spinules. P4 exopodite with spinules on each outer corner and near each outer spine, plus rows of comblike spinules on anterior sides of first and second segment, near inner distal corner. All setae and spines pinnate. P4 endopodite, last segment with rows of spinules near insertion of each seta and spine. All setae and spines pinnate. Coupler (fig. 11j) bare.

P5 (figs. 12c, 16b), lateral terminal seta about 2.3 times as long as medial terminal spine, i.e., about 1.2 times longer than article 2. Lateral seta on first article about 2.8 times length of terminal spine.

Male. — Lengths of males number 1, 2, 3, measured from rostrum to distal apex of furcal ramus: 500, 460, 440 μm, respectively.

Habitus in fig. 13a. Body ornamentation, anal somite, and anal operculum (figs. 13d, 15e, 17e), antenna (fig. 12d), and mouthparts (fig. 11c, d, f), P1 (fig. 14a), P2 (figs. 14c, 16d), P3 (fig. 14d, e), P4 (fig. 12g, h) similar to corresponding structures in female. Furcal ramus (fig. 17b) shorter than in female, with same shape, length/width: 3.0-3.5. Each ramus with scattered hairs, row of spinules near outermost seta insertion, all terminal setae pinnate.

Antennule (fig. 12e) geniculate, 17-segmented, first, eighth, and ninth segments with respectively three, one, and one aesthetascs. Segment 10 with rectangular protrusion (fig. 12f), with two short lateral setae, with pinnate apical tip bearing a subapical short seta.

P5 (figs. 11h, 16a), lateral terminal seta about 3 times as long as medial terminal spine, i.e., about 1.2 times longer than segment 2. Lateral seta on segment 1 about 3.6 times length of terminal spine.

P6 (figs. 11h, 17f) consisting of small, subtrapezoidal plate with small ventral spine and two dorsal setae of unequal lengths, both setae reaching past posterior margin of succeeding somite.

Variability. — In both sexes the ratio between the length of the furcal ramus and the lengths of its setae showed minor variations that are not reported here. The P4 coupler is bare in female no. 1, with a row of few spines on the posterior side in females no. 4 and 5 (fig. 11i), and with two rows of spinules on the posterior side in female no. 3.

REMARKS

The specimens in hand and other material confirm the supposition of Reid (1992a) that *Diacyclops nearcticus* has two inner (medial) setae on P2 enp-2, and one inner seta on P3 enp-2: this arrangement was not apparent from the fully dissected type specimen.

The distributional range of *D. nearcticus* is extended to extreme southern Florida by the present records. Other records since Reid's redescription (1992a) from the single type specimens from Massachusetts include: Ohio, Virginia, Tennessee, Alabama (Strayer & Reid, 1999); Kentucky (Reid, 1998); the Laurentian Great Lakes (Hudson et al., 1998); and Tennessee (Reid, 1999).

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