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A new species of *Leptodiaptomus* (Copepoda, Diaptomidae) from Northwestern Mexico with comments on the distribution of the genus

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Abstract. A new species of the freshwater planktonic copepod genus *Leptodiaptomus* is described from a small pond in Northwestern Mexico. *Leptodiaptomus dodsoni* n. sp. can be easily distinguished mainly by the presence of an unusually large sinusoid spine on male antennular segment 13, and by the features of the fifth legs of both sexes. This genus is known to be distributed mainly in North America with 19 recognized species. Of these, six occur in Mexico, and the new species seems to be closely related to most of them. It is probable that this group of species (including the new one) represents the southwards radiation of the genus from North America. Compared to the Caribbean and South American, the North American influence seems to be the most relevant for diaptomid copepods in Mexico. At least two Mexican species of *Leptodiaptomus*, including *L.dodsoni*, are restricted in distributional range to high-altitude temporal ponds, and both could be considered endemics.

Introduction

The freshwater copepod genus *Leptodiaptomus* is one of the most speciose in North America (Dussart and Defaye, 1983). Up to six species of this taxon have been hitherto recorded from Mexico (Reid, 1990; Zamudio-Valdés, 1991; Dodson and Silva-Briano, 1996; Grimaldo-Ortega *et al*., 1998; Suárez-Morales *et al*., 1996; Suárez-Morales and Reid, 1998): *L.novamexicanus* (Herrick, 1895), widely distributed throughout Mexico, recorded even in the southeast lowlands, including the Yucatan Peninsula; *L.mexicanus* (Marsh, 1929), recorded in Mexico City and the adjacent state of Mexico; *L.siciloides* (Lilljeborg, 1889) in Aguascalientes and Coahuila; *L.connexus* (Light, 1938) in Coahuila; *L.assiniboiaensis* (Anderson, 1971) only in the state of Mexico; and *Leptodiaptomus* cf. *signicauda* in Aguascalientes. *Leptodiaptomus cuauhtemoci* (Osorio-Tafall, 1941), described from Morelos State, was synonymized with *L.siciloides* by Wilson, in Wilson and Yeatman (1959), and unfortunately there is no deposited material available.

According to Suárez-Morales and Reid (1998), several states of Mexico have not been surveyed at all for freshwater copepods or have only few records; Jalisco is among these states. Rico-Martínez (personal communication) recorded four species of Copepoda from plankton samples collected at Lake Chapala, in Jalisco. He found a few specimens of an undescribed species of *Leptodiaptomus* which remained with no formal description until now. In January 1996, zooplankton samples collected by us at different localities along the Lerma River Basin, near the border between the states of Jalisco and Michoacán, yielded numerous specimens of a calanoid of the genus *Leptodiaptomus* which turned out to be similar to that previously recorded by Rico-Martínez. We confirm herein that this material represents a new species and a full description is given.

Method

More than 50 male and female specimens of the new species of *Leptodiaptomus* were collected during zooplankton surveys in one pond located near La Barca town, in the state of Michoacán. This locality is close to the border between the states of Jalisco and Michoacán, Northwestern Mexico. Samples were collected using standard plankton nets with 0.06 mm meshes. The material was fixed in a 4% formalin solution. Copepods were sorted and preserved in 70% ethanol. Specimens were processed for examination with a Hitachi S-2460N scanning electron microscope (SEM) with 10–15 kV. Descriptions were made based on SEM and from observations of specimens dissected in glycerin, and drawn with the aid of a camera lucida.

Material examined

Holotype adult female, collected on 24 January 1996, from a small pond in Michoacán, México. Ethanol preserved, with a drop of glycerin, vial deposited at the Natural History Museum, London, catalog number BMNH-1997.1750. Allotype adult male, collected on 24 January 1996, in Michoacán, México, near La Barca (Jalisco). Ethanol preserved, vial deposited at the Natural History Museum, London, catalog number BMNH-1997.1751.

Paratypes

Two adult females, and two adult males from the same locality, deposited at the Muséum National d'Histoire Naturelle, Paris, catalog numbers MNHN-Cp1249 and MNHN-Cp1250. Two adult females, and two adult males from the same locality, deposited at the National Museum of Natural History, Smithsonian Institution, Washington, DC, catalog numbers USNM-277661 and USNM-277662. Two adult females, and two adult males from the same locality, deposited at El Colegio de la Frontera Sur, catalog number ECO-CH-Z00409. Two adult females and two adult males deposited at Universidad Nacional Autónoma de México Campus Iztacala, access number COP-201 and 202. Original samples are deposited at Campus Iztacala, UNAM, Mexico City.

Type locality

A small pond (surface <1 ha) located in the State of Michoacán at 3 km southeastwards from La Barca town (20°16′47″N, 102°29′20″W), Mexico. The main physical and chemical parameters of the water at the time of collection were: temperature 18°C; depth 0.92 m; Secchi disk 0.45 m; pH 7.45; dissolved oxygen 11.4 mg/l; alkalinity 132 mg $CaCO_3$ l^{-1}; hardness 110 mg $CaCO_3$ l^{-1}.

Etymology

Following a suggestion by Roberto Rico-Martínez from the University of Aguascalientes (Mexico), who was the first to observe this new species, it is named after

Dr Stanley Dodson, for his contributions to knowledge of American freshwater microcrustaceans.

Results

Descriptions

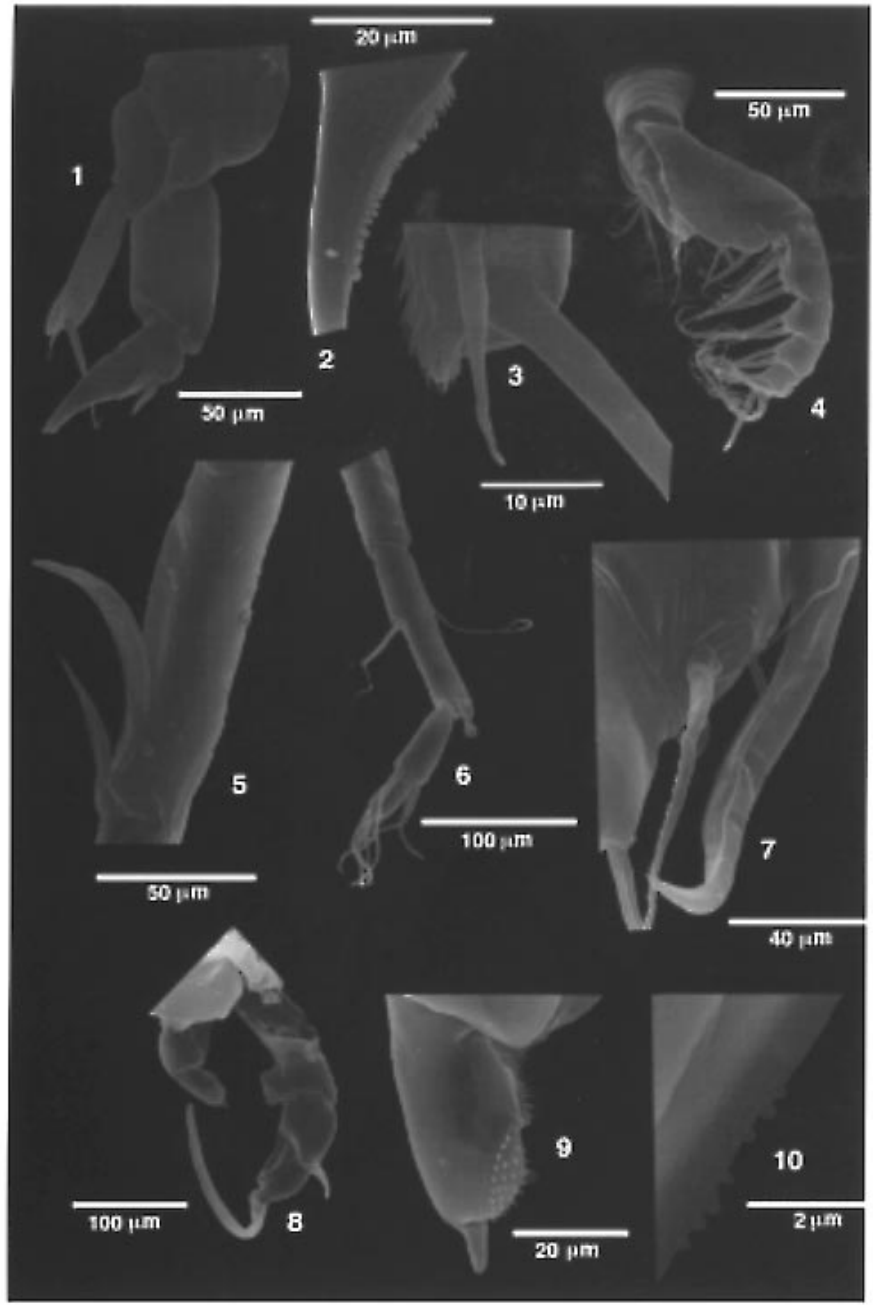
Female. Mean length (mm ± SD) = 1.38 ± 0.06, range = 1.49–1.28 mm. Prosome narrower anteriorly (Figure 18), symmetrical, with slight constriction posterior to cephalic region. Thoracic wings slightly asymmetrical, left shorter than right. Wings each with two posteriorly directed processes ending in a more or less blunt spine-like process. Urosome with two somites, relative lengths: 76.2:23.8 = 100. Genital double-somite asymmetrical, with lateral projection on right side (Figure 18). Genital double-somite ventrally expanded, with one rounded protuberance on genital opening (Figure 16), and with dorsal elongated subtriangular process on right side of distal margin. Anal somite short. Caudal rami about two times as long as wide, lightly haired along distal half of inner margin. Caudal rami with four terminal, one dorsal and one lateral setae, all setae plumose, non-articulated, relatively short, almost twice as long as caudal rami (Figure 18). Rostral points strong, acute (Figure 11). Head with two sensillae on anterior margin and two more above rostrum (Figure 11), all with hairy end, inserted in cuticular depression (Figures 13 and 15).

Antennules long (Figures 12 and 27), 25-segmented, reaching beyond posterior margin of caudal rami by 2–3 segments. Seta on segment 1 very long, stout, reaching the middle of segment 7. Appendages per segment as follows (Arabic numerals = segment, Arabic numerals in parentheses = number of setae, ae = aesthetasc, sp = spine): 1(1+ae), 2(3+ae), 3(1+ae), 4(1), 5(1+ae), 6(1), 7(1+ae), 8(1+sp), 9(2+ae), 10(1), 11(1), 12(1+ae), 13(1), 14(1+ae), 15(1), 16(1+ae), 17(1), 18(1), 19(1+ae), 20(1), 21(1), 22(2), 23(2), 24 (2), 25(4+ae). Antennules with minute spinule-like projections arranged in longitudinal irregular rows along the ventral surface of segments 12–21 (Figures 12 and 14).

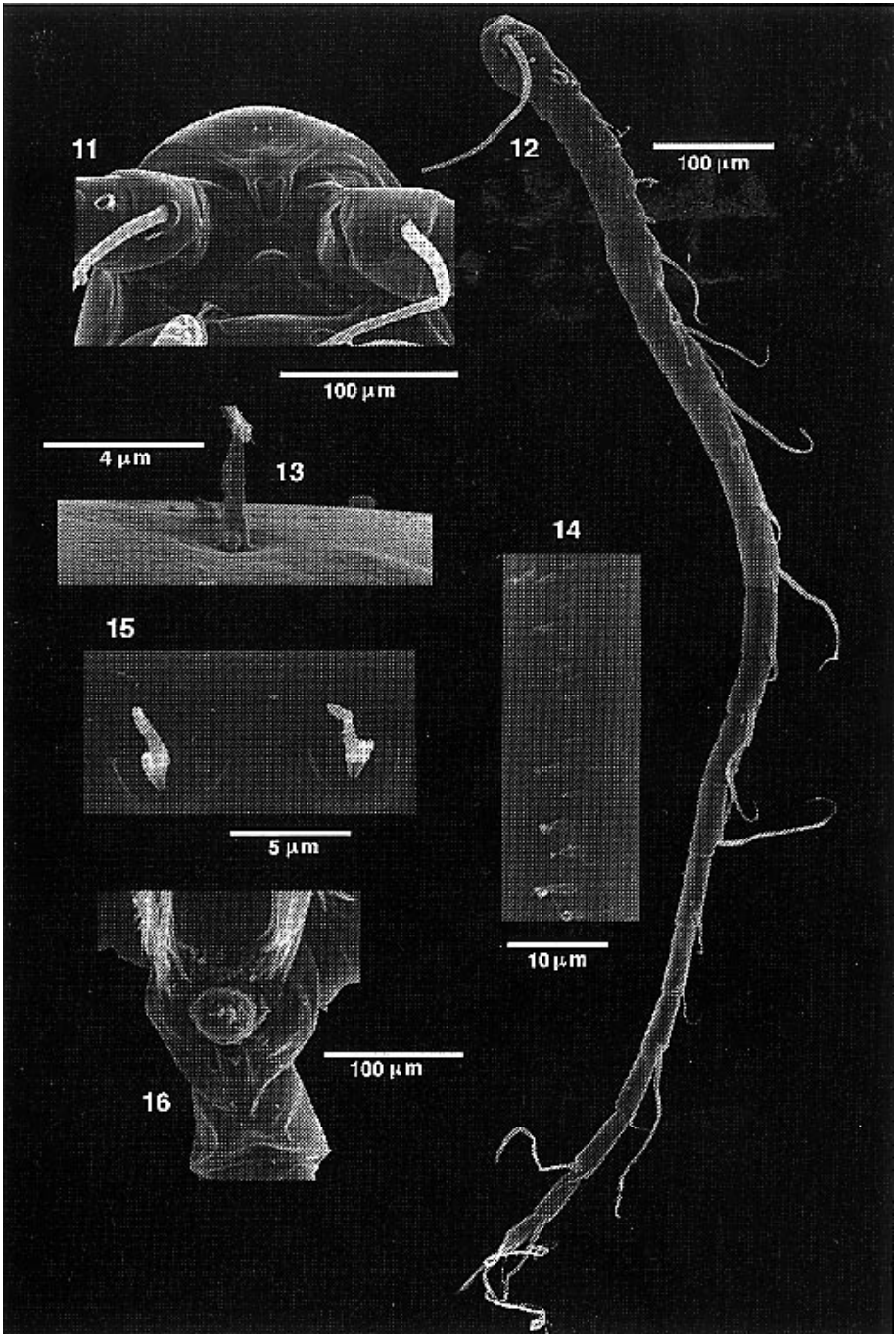
Second antenna with exopod longer than endopod (Figure 25). Coxa with one seta. Basis with two short setae on outer distal margin. Endopod reduced, with two segments, distal portion of terminal endopodal segment with two lobes, internal with one short posterior and seven anterior setae; external lobe with one short and four long setae. Exopod 7-segmented, with one seta on first segment, three on second, and one seta on segments 3–6. Distal segment with one short seta on mid-inner margin, and three long terminal setae subequal in length and breadth.

Mandible (Figure 29) with 5–6 multi-pointed teeth on gnathobase; ventral outermost tooth higher and wider, with short spine-like projection on tip. Distal end of inner margin with short setulated seta-like projection. Basis with four setae; endopod with two segments, proximal segment with four setae; distal segment longer with seven setae. Exopod 4-segmented, with normal 1, 1, 1, 3 setation pattern.

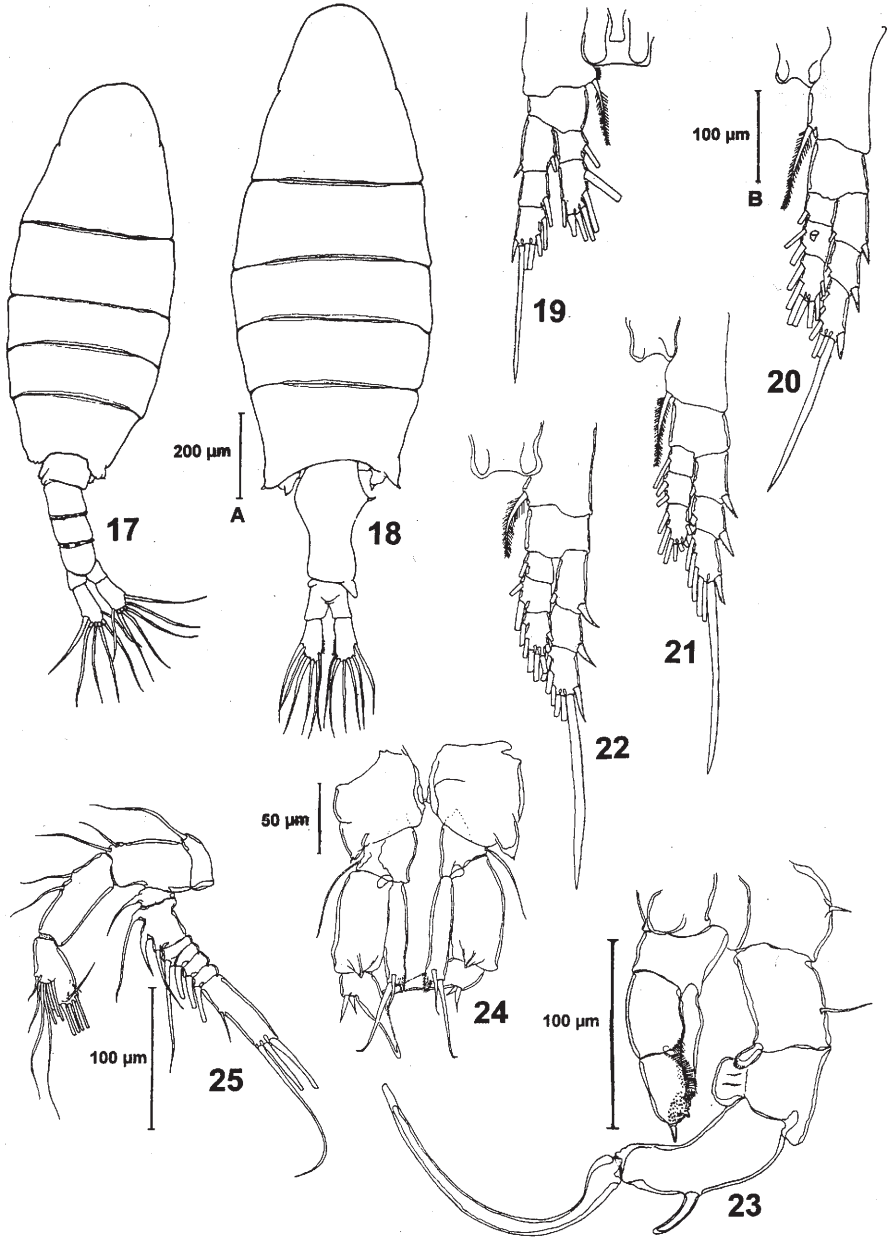
Maxillule (Figure 28) with praecoxal arthrite with 14 spiniform setae, 10 of which are apical, arranged in two rows with five setae each, plus four posterior



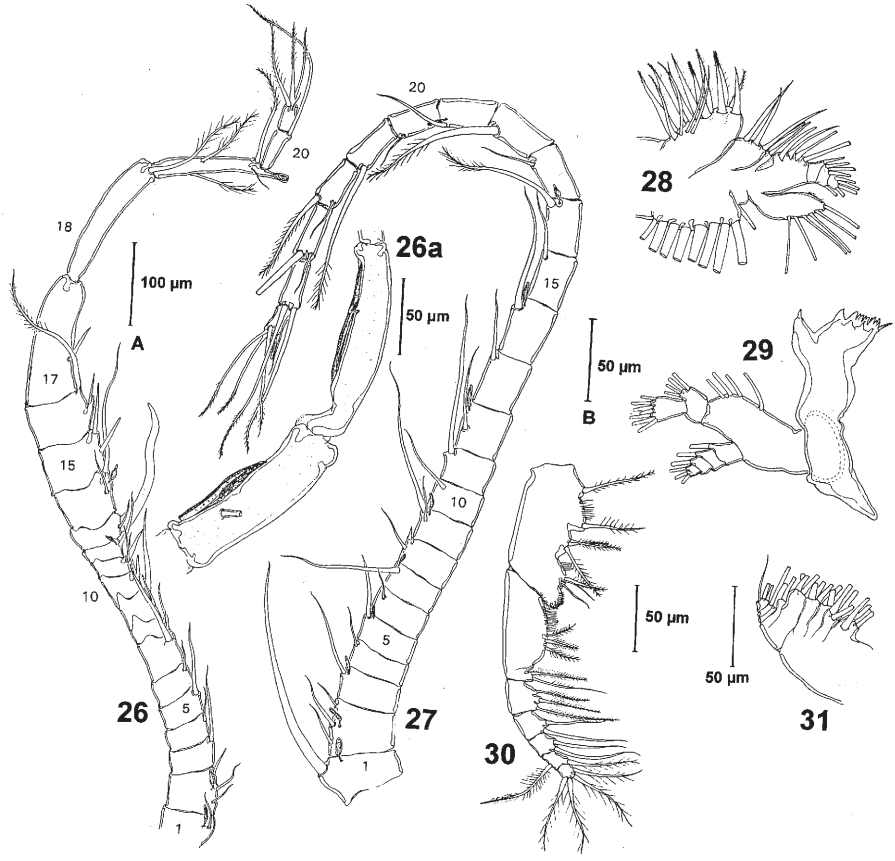
Figs 1–4. *Leptodiaptomus dodsoni* n. sp., female. **Fig. 1.** Left fifth leg. **Fig. 2.** Fifth leg, detail of second exopod. **Fig. 3.** Fifth leg, tip of the endopod. **Fig. 4.** Maxilliped.
Figs 5–10. *Leptodiaptomus dodsoni* n. sp., male. **Fig. 5.** Right antennule, detail of spiniform process on segment 18. **Fig. 6.** Right antennule, detail of last three segments. **Fig. 7.** Spine of antennular segment 13. **Fig. 8.** Fifth leg, posterior view. **Fig. 9.** Left fifth leg, detail of second exopod. **Fig. 10.** Vesicle-like cuticular projections on spine of antennular segment 13.



Figs 11–16. *Leptodiaptomus dodsoni* n. sp., female. **Fig. 11.** Rostral points, ventral view. **Fig. 12.** Right antennule. **Fig. 13.** Detail of sensilla on anterior margin of head. **Fig. 14.** Detail of armature on antennular segment 14. **Fig. 15.** Sensilla above rostrum. **Fig. 16.** Genital somite, ventral view.



Figs 17–25. *Leptodiaptomus dodsoni* n. sp., male: **Fig. 17.** Habitus, dorsal view. Female: **Fig. 18.** Habitus, dorsal view. **Fig. 19.** Right leg 1, anterior. **Fig. 20.** Left leg 2, anterior. **Fig. 21.** Left leg 3, anterior. **Fig. 22.** Left leg 4, anterior. Male: **Fig. 23.** Fifth leg, posterior view. Female: **Fig. 24.** Fifth leg, posterior. **Fig. 25.** Antenna. Scale bar A: Figs 17 and 18. Scale bar B: Figs 19–22.



Figs 26–31. *Leptodiaptomus dodsoni* n. sp., male: **Fig. 26.** Right antennule. (**a**) Detail of segments 17 and 18. Female: **Fig. 27.** Left antennule. **Fig. 28.** Maxillule. **Fig. 29.** Mandible. **Fig. 30.** Maxilliped. **Fig. 31.** Maxilla. Scale bar A: Figs 26 and 27. Scale bar B: Figs 28 and 29.

setae. Coxal epipodite with eight setae, inner is wider than the others, coxal endite with three setae. Basis with one internal lobe bearing a single seta. Endopod reduced, 3-segmented, articulating with the basis, distalmost segment with two apical and two subapical setae. Exopod with six setae.

Maxilla (Figure 31) indistinctly segmented, with two praecoxal and two coxal lobes, and a well-developed basal lobe. Setation pattern of five lobes as: 4, 3 (first and second praecoxal endites), 2, 3 (first and second coxal endites), 3 (basal endite); endopod well developed, 4-segmented, with setation pattern: 1,1,1,3.

Maxilliped (Figures 4 and 30) well developed. Coxa fused with praecoxa, with anterior protuberance projecting over next segment, with row of short spinules surrounding process. Coxa with three distinct lobes, proximalmost with one seta, second with two and third with three. Basis with group of three setae on middle of inner margin. Endopod 6-segmented, with first segment partially fused to basis, bearing two subequal setae. Second endopodal segment with three subequal

setae, third with two, fourth with two, fifth with two; terminal segment with four subequal setae.

First leg (Figure 19) with 3-segmented exopod and 2-segmented endopod, coxa with plumose seta on internal margin, reaching middle of first endopodal segment. Second, third and fourth legs (Figures 20–22) with exopods and endopods 3-segmented. Armature formula for swimming legs:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-1	0-0	I-1;0-1;I,3,2	0-1;1,2,3
Leg 2	0-1	0-0	I-1;I-1;I,3,3	0-1;0-2;2,2,3
Leg 3	0-1	0-0	I-1;I-1;I,3,3	0-1;0-2;2,2,3
Leg 4	0-1	0-0	I-1;I-1;I,3,3	0-1;0-2;2,2,3

Leg 5 (Figures 1–3 and 24): coxa with lateral processes on each side; left coxal process smaller than right, both processes with terminal spine. Their distal ends reaching, and the right one surpassing, the distal end of basis. Basis with inner margin straight, with long and slender lateral seta reaching midlength of first exopodal segment. Endopod 1-segmented, long and relatively narrow (5.3 times long as wide), its distal end reaching beyond distal margin of first exopodal segment; armed with one long terminal seta and one short, subterminal seta. Former seta 1.6 times as long as latter, with distal end curved. Inner margin of endopodal tip protruding into a relatively acute process surrounded by short, stout hairs. First exopodal segment nearly as long as second, with smooth, straight lateral margins, distal margin with subtriangular process on mid-part. Claw of second exopod with blunt tip, inner margin armed with row of small teeth on mid-margin. Third exopodal segment reduced, barely distinct from second, represented by short, strong, spiniform process near usual spine of second exopod.

Male. Length (mm) mean ± SD = 1.16 ± 0.08, range = 0.97–1.26 mm. Body slender, with typical diaptomid shape (Figure 17). Pediger 4 wider than succeeding somite; pediger 5 tapering posteriorly, asymmetrical, with reduced lateral 'wings', less developed than in female. Right wing rounded, pointing outwards, posterior end reaching almost to half way along first urosomite. Left wing reduced, with small naked lobe, pointing posteriorly. Urosome (Figure 17) symmetrical, 5-segmented. Relative lengths of urosomites being: 23.3:24.5:22:22:8.2 = 100. First urosomite with rounded process on left margin. Urosomites 2 and 3 with fringe comprising several groups of small spinules on posterior margin. Urosomite 4 slightly produced posteriorly, with smoothly rounded, posterior margin. Anal somite reduced. Caudal rami as for female. Inner and outer margins of caudal rami naked. Rostral points short, acute similar to female.

Antennules slightly longer than in female, last antennular segment surpassing posterior margin of caudal rami. Right antennule (Figures 5–7 and 26) geniculated between segments 17 and 18, with one seta on segments 3–7; seta on segment 7 large. Aesthetascs on segments 1, 2, 12 and 14. Segment 8 with one short spine and one seta; 9 with one long and one short setae; 10 and 11 each with

one stout spine, that on former almost reaching distal end of next segment, that on latter almost reaching midlength of segment 13; segment 12 with one long seta; 13 with short seta and one large sinusoid spine, its base almost as wide as segment and with a row of small papillae in distal two-thirds of internal side (Figure 10), spine reaching beyond mid-point of segment 16. Segment 14 with one short seta plus one long seta reaching midlength of segment 17; segment 15 with one spine and one seta, both subequal in length; 16 with broad-based spiniform process pointing distally on outer margin, with one spine borne near its base, and long seta on distal margin; 17 elongated, with one seta, and with spine-like processes closely adjacent to inner margin of segment (Figure 26a); 18 with one distal seta, a small spine, two spiniform processes on inner margin (Figure 5), and a group of minute spinules on inner proximal protuberance. Segment 19 with elongated knob-like process on distal inner margin, reaching proximal half of next segment, also bearing four setae, two inserted in middle and two distally, one of these small. Segment 21 with one seta. Terminal segment relatively short, with four apical setae. Setation of left antennule, mouthparts and swimming legs as for female.

Left leg 5 (Figures 8–9 and 23) reaching beyond distal margin of right second exopodal segment. Coxa with large rounded anterior process. Basis without lateral seta. First exopodal segment slightly longer and wider than second, with group of short hairs on distal third of inner margin. Second exopodal segment ending in distal process with stout, blunt, smooth terminal digitiform structure, and similar, but shorter subterminal process. Inner margin of second segment rounded, provided with hairs and with small vesicle-like processes on distal third. Endopod 1-segmented, reaching beyond two-thirds second exopodal segment, narrowing at distal third, tip covered with hairs.

Right leg 5 (Figures 8 and 23): coxa with a spinous process on middle of external margin. Basis almost twice as long as first exopodal segment with seta inserted on middle of external margin. Outer margin of first exopodal segment straight and slender, with subquadrate process on outer distal portion; inner margin with squared lateral process. Second exopodal segment about twice as long as first. Lateral spine strong, slightly curved, naked, distal end bluntly rounded, borne just in distal half of segment. Terminal claw relatively slender, curved, tapering gradually from enlarged base, ~1.3 times longer than exopod segments 1 and 2 combined, without teeth on inner margin. Right endopod reduced to lobe, 1-segmented, barely reaching middle of inner margin of first exopodal segment, without suture on posterior surface, with some hair-like structures on tip.

Discussion

A total of 20 species of *Leptodiaptomus* have been described (Wilson, in Wilson and Yeatman, 1959; Dussart and Defaye, 1983). No new species of this genus has been recognized since 1971. The new species, *L.dodsoni*, has been assigned to *Leptodiaptomus* on the presence of one seta on segment 11 of the left male and both female antennules, the very reduced female fifth leg terminal exopod segment (represented only by a small spine and a short seta near the spine of the

second exopodal segment), and the right male antennule with strong spines on segments 10, 11 and 13 (Wilson, 1954; Wilson, in Wilson and Yeatman, 1959; Dussart and Defaye, 1995; Suárez-Morales *et al*., 1996). The new species can be easily distinguished from its congeners by the presence of a strong, sigmoid spine on segment 13 of the right male antennule, and by the structure of the female urosome and the fifth legs in both sexes.

It shows affinities with other species of *Leptodiaptomus*, such as *L.siciloides*, *L.mexicanus*, *L.novamexicanus* and *L.assiniboiensis*. In these species, the long spine on the male antennular segment 13 does not reach the distal margin of segment 14, while in *L.dodsoni* this structure extends beyond the midlength of segment 16, and has a distinctive sigmoid shape. The process of the antepenultimate segment on the right male antennule is distally acute in these other species, while it is clearly knob-like in the new species. The process on the inner margin of the first exopodal segment of the right male fifth leg in *L.dodsoni* is similar to that of *L.assiniboiensis*, but is much wider than that of *L.siciloides*, in which the middle portion of the process tends to be depressed and forms an anvil-shaped structure. The long terminal setae on the endopod of the female fifth leg are similar to those of *L.mexicanus* (redescribed by Grimaldo-Ortega *et al*., 1998), but in this species both setae are equally long. The same structures diverge from the two short subequal setae of *L.assiniboiensis* (Anderson, 1971). However, in all these species, the distal tip of the endopod reaches beyond the distal margin of the first exopodal segment.

Distributional comments

Leptodiaptomus is a North American genus dwelling mostly in cold-temperate regions; 17 of the 20 species currently known are mainly distributed in Canada and the USA, including Alaska (Wilson, 1954; Wilson, in Wilson and Yeatman, 1959; Dussart and Defaye, 1983). Outside the Americas, only two species, *L.angustilobus* (Sars, 1898) and *L.tyrreli* (Poppe, 1888), have been recorded, from Japan (Kiefer, 1938) and Kamchatka (Smirnov, 1931; Wilson, 1954), respectively. The former species was originally described under the genus *Psychrodiaptomus*, which was later synonymized with *Leptodiaptomus* by Wilson (1954). The occurrence of these two species in Eastern Asia could be considered as a result of a relatively recent dispersal of the genus through the Bering Strait link, probably associated with the Miocene bridge. This bridge had a mild climate and an unbroken belt of deciduous forest stretching from North America and along eastern Asia, including Japan (Pielou, 1979).

Several other North American genera, such as *Onychodiaptomus*, *Skistodiaptomus* and *Hesperodiaptomus*, have no southern representatives (Wilson, in Wilson and Yeatman, 1959; Dussart and Defaye, 1983, 1995; Scanlin and Reid, 1996). However, *Leptodiaptomus* does contain forms which probably radiated southwards from North America, a radiation represented by species such as *L.siciloides*, *L.assiniboiensis*, *L.connexus* and *L.signicauda*, which have been recorded in northern and central Mexico (Suárez-Morales and Reid, 1998). The southernmost American record of the genus is *L.novamexicanus* from the

Yucatan Peninsula (Suárez-Morales *et al*., 1996). Another North American genus which has been known to occur in Mexico is *Aglaodiaptomus*, represented by one species recorded in northern Mexico (Suárez-Morales and Reid, 1998). In contrast, radiation of diaptomid copepods from the south appears to have been quite limited; several speciose and widely distributed genera from South America, such as *Notodiaptomus*, *Argyrodiaptomus* and *Rhacodiaptomus*, have no representatives either in Central America or in Mexico.

The north to south trend appears to have had a greater impact on Mexican diaptomid diversity than colonization from Antillean sources by genera such as *Arctodiaptomus* Kiefer, 1932 and *Mastigodiaptomus* Light, 1939, which occur both in the Caribbean and in North America. Each of these genera is represented in Mexico (Suárez-Morales, 1991; Suárez-Morales and Reid, 1998) by one widely distributed species, namely *A.dorsalis* (Marsh, 1907) and *M.albuquerquensis* (Herrick, 1895). The distributional pattern of these two genera coincides with the North American/Caribbean track of Rosen (1975) by which the Antillean and the North American faunas were periodically or temporarily linked (Bânârescu, 1995).

The north to south pattern seems to be the most probable trend, based on the fact that the original Laurasian (North America) paleocontinental unit is older (Late Triassic) than that derived from the link of the 'proto-Antilles' with North America (Early Cretaceous). It is much older than the connection of North and South America during the Pliocene (Pielou, 1979; Bânârescu, 1995).

The new species represents the seventh record of the genus *Leptodiaptomus* in Mexico (Suárez-Morales and Reid, 1998). Only *L.novamexicanus* has been recorded in the southeast lowlands, which represents a true tropical environment. The other species, including *L.dodsoni*, have been recorded in Central and Northern Mexico at higher altitudes (+1500 m above sea level), and are related to more temperate environments. Diaptomid copepods tend to show more restricted distributional ranges when compared with other freshwater copepods and endemism is relatively high (Dussart and Defaye, 1995). *Leptodiaptomus mexicanus* seems to be restricted to a small geographical area within the central plateau of Mexico, and is considered to be an endemic species (Suárez-Morales and Reid, 1998). *Leptodiaptomus dodsoni* also shows an apparent restricted distributional range, and could be considered as a possible endemic.

Leptodiaptomus dodsoni is probably a result of isolation after the genus radiation in the highlands of Central Mexico. This phenomenon is shared with the rare *L.mexicanus*. Further research on mating, breeding and habitat preferences should be carried out to explain the limited distribution of this species.

Rico-Martínez (personal communication) recorded a few specimens of *L.dodsoni* at Lake Chapala, one of the largest permanent systems in Mexico. Our surveys in the same locality were negative for this new taxon. The occurrence of this species at Chapala could be due to passive transport by adjacent land effluents during the rainy season from the type locality. This pond is located near the mouth of the Lerma River, which flows into Chapala, and it has a well-established population of *L.dodsoni*.

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