



Current knowledge on Mexican tardigrades with a description of *Milnesium cassandrae* sp. nov. (Eutardigrada: Milnesiidae) and discussion on the taxonomic value of dorsal pseudoplates in the genus *Milnesium* Doyère, 1840

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Abstract

Mexico is a megadiverse country, however its tardigrade fauna is poorly known and to date 44 species have been reported from this region. In the present paper, an update of the reported Mexican tardigrades is presented, increasing the number of recorded tardigrades to 55 species (11 new records). Moreover, we describe *Milnesium cassandrae* sp. nov. from State of Nuevo León in northern Mexico. The new species is most similar to *Mil. krzysztofi* Kaczmarek & Michalczyk, 2007 and *Mil. beasleyi* Kaczmarek, Jakubowska & Michalczyk, 2012, but it differs from them mainly by details of the dorsal sculpture and some morphometric characters. We also discuss the taxonomic value of a recently described feature, ‘pseudoplates’, for differentiating the taxa within the genus *Milnesium* Doyère, 1840. [Zoobank URL: urn:lsid:zoobank.org:act:0684AE18-0510-4F7B-B75D-AE5177FBF2A2]

Key words: Coahuila, new records, new species, Nuevo Leon, Tamaulipas, Tardigrada, water bears

Introduction

Mexico is considered a megadiverse country, containing 9–12% of the planet’s biodiversity with currently more than 94,000 species recorded. Although these estimates are considered conservative, there still exist taxonomic groups virtually unknown in Mexico (Martínez-Meyer *et al.* 2014). Martínez-Meyer *et al.* (2014) and Sierra *et al.* (2014) estimated that the real number of species could range between 200,000 and 330,000. According to Martínez-Meyer *et al.* (2014) there are at least 10 invertebrate phyla that are poorly known in Mexico. One such phylum is the Tardigrada, which has never been comprehensively studied in this region. Currently, the phylum Tardigrada consists of ca. 1,300 species (Degma & Guidetti 2007; Degma *et al.* 2018), but in Mexico only 44 species have been reported (May 1948; Schuster 1971; Beasley 1972; McInnes 1994; Claps & Rossi 2002; Pilato 2006; Pilato & Lisi 2006; Beasley *et al.* 2008; Kaczmarek *et al.* 2011, 2014; Meyer 2013; Moreno-Talamantes *et al.* 2015; Pérez-Pech *et al.* 2017); though 16 represent rather doubtful records and need confirmation (Kaczmarek *et al.* 2014).

The genus *Milnesium* Doyère, 1840 is a cosmopolitan taxon, members of which have been reported from all continents (Michalczyk *et al.* 2012a,b). For 150 years after the description of *Milnesium tardigradum* Doyère, 1840, the genus was considered monotypic. Only two subspecies were described in this period, 31 years apart: *Mil. tardigradum trispinosa* Rahm, 1931 and *Mil. tardigradum granulatum* Ramazzotti, 1962. Additional species in the genus *Milnesium* were described sporadically until the first partial revision was conducted by Tumanov (2006). The complete revision of the nominal *Mil. tardigradum* by Michalczyk *et al.* (2012a,b) has aided subsequent taxonomic studies within this group. To date, the genus consists of 36 taxa, including one fossil and two subspecies (Michalczyk *et al.* 2012a,b; Morek *et al.* 2016; Pilato *et al.* 2016, 2017; Pilato & Lisi 2016; Young *et al.* 2016; Schlabach

et al. 2018). Eleven species have been reported from North and Central America (McInnes 1994; Meyer 2013; Kaczmarek *et al.* 2014).

In this paper we describe a new Mexican *Milnesium* species and discuss the taxonomic value of the shape and configuration of the dorsal pseudoplates in differentiating *Milnesium* taxa. We also report ten tardigrade species from seven genera that are new records from Mexico.

Material and methods

Sampling and samples processing. Twenty-three (16 moss and eleven lichen) samples were collected from trees and rocks in various localities in the states of Coahuila, Nuevo Leon and Tamaulipas in Mexico, from November 2013 to December 2016. The samples were collected and examined for terrestrial tardigrades using standard methods (Dastych 1980; Ramazzotti & Maucci 1983; Stec *et al.* 2015).

Microscopy and imaging. For light microscopy, specimens were mounted on microscope slides in a small drop of polyvinyl alcohol with Elvanol® and lacto-phenol (PVA mounting medium from BioQuip Products Inc., catalogue number 6371A), and secured with a cover slip. Dried slides were sealed with transparent nail polish and examined under phase contrast microscopy (PCM) (AmScope T690C-PCT200-PL and Olympus CX31 with digital camera AmScope MU1000) and fluorescent microscopy (FM) (Zeiss Axio Imager M1 with filter DAPI 365 nm excitation, 445/50 nm emission and digital camera AxioCam MR).

Morphometric and morphological nomenclature. All measurements are given in micrometers [μm]. Structures were measured only if they were in the proper orientation. The body length was measured from the mouth to the end of the body excluding the hind legs. The *pt* index is the ratio of the length of the structure to the buccal tube length expressed as a percentage (Pilato 1981), and always presented in [square brackets and in *italics*]. The types of bucco-pharyngeal apparatuses and claws were classified according to Pilato & Binda (2010). The terminology and measurements for *Mil. cassandrae* **sp. nov.** are provided according to Tumanov (2006), Michalczyk *et al.* (2012a,b) and Pilato *et al.* (2016). The terminology of Morek *et al.* (2018) was used for description of changes in claw configuration (CC). Only measurements of adult females were used in differential diagnoses.

Seven exuviae with eggs were placed in the *in vitro* culture, using the methodology described by Morek *et al.* (2016), to observe the configuration of the claws of the hatchling and juveniles in the first and second stages of development (instar I and II). An adult female was also collected in the process of molting and oviposition. The adult, exuviae with empty eggs and hatchlings, and juveniles were mounted permanently on a microscope slide. Genus abbreviations follows Perry *et al.* (2019). Tardigrade taxonomy follows Bertolani *et al.* (2014b) and Guil *et al.* (2018).

Comparative material and literature. Tardigrade species were identified using the taxonomic keys in Ramazzotti & Maucci (1983), Claxton (1998), Tumanov (2006), Fontoura & Pilato (2007), Fontoura *et al.* (2008), Michalczyk & Kaczmarek (2010), Michalczyk *et al.* (2012a,b), Morek *et al.* (2016), and according to the original species descriptions/redescriptions (Pilato & Lisi 2006; Kaczmarek & Michalczyk 2007; Meyer & Domingue 2011; Kaczmarek *et al.* 2012; Meyer & Hinton 2012). Additionally, type specimens of the following were used for comparison: *Doryphoribius quadrituberculatus* Kaczmarek & Michalczyk, 2004, *Mil. krzysztofi* Kaczmarek & Michalczyk, 2007, *Mil. beasleyi* Kaczmarek, Jakubowska & Michalczyk, 2012, *Mil. berladnicorum* Ciobanu, Zawierucha, Moglan & Kaczmarek, 2014 and *Mil. beatae* Roszkowska, Ostrowska & Kaczmarek, 2015.

Results

In total seven lichen and 16 moss samples were analyzed, from which 263 tardigrades, 11 exuviae and 45 eggs of 19 species were extracted, belonging to 6 families and 13 genera (Table 1).

Taxonomic accounts

Phylum: Tardigrada Doyère, 1840

TABLE 1. List of moss and lichen samples and species found in our study.

No.	Date Latitude Longitude	Locality	State	Sample type	Species
1	06/11/2013 25°39'18.63"N 100°20'34.51"W	San Agustin Park, San Pedro Garza García, ca. 605 m asl.	NL	Lichen	<i>Mil. cassandrae</i> sp. nov.
2	01/04/2014 25°43'02.98"N 100°04'18.71"W	Los Manantiales, SE of Dulces Nombres, Pesqueria, ca. 353 m asl.	NL	Moss	<i>Dor. quadrituberculatus</i> Kaczmarek & Michalczyk, 2004
3	02/01/2014 25°51'35.37"N 100°31'42.16"W	Arroyo Blanco, 1 Km at SW of La Purisima, Garcia, ca. 873 m asl.	NL	Moss	<i>Mac. cf. acadianus</i> <i>Ram. cf. oberhaeuseri</i>
4	03/30/2014 25°21'03.31"N 100°20'45.18"W	400 m at S of El Venadito, Santi- tiago, ca. 2090 m asl.	NL	Moss	<i>Dor. dawkinsi</i> Michalczyk & Kaczmarek, 2010
5	05/03/2014 24°30'46.62"N 99°59'03.91"W	Las Crucitas, Aramberri, ca. 2499 m asl.	NL	Lichen	<i>Ech. cf. tamus</i> <i>Mac. cf. acadianus</i>
6	07/27/2014 26°22'08.537"N 100°29'11.34"W	3.3 km at SW of La Higuera, Sierra Gomas, Villadama, ca. 1264 m asl.	NL	Moss	<i>Hys. cf. convergens</i>
7	08/06/2014 25°18'30.95"N 100°12'37.85"W	Near to Cueva El Infierno, La Camotera, Santiago, ca. 1522 m asl.	NL	Moss	<i>Mil. barbadosense</i> Meyer & Hinton, 2012 <i>Min. cf. intermedius</i>
8	08/06/2014 25°16'17.77"N 100°13'41.86"W	Mesa del Oso Vista Hermosa, Santiago, ca. 2181 m asl.	NL	Moss	<i>Adr. carolae</i> (Binda & Pilato, 1969) <i>Mil. barbadosense</i> Meyer & Hinton, 2012
9	08/07/2014 25°44'55.57"N 100°24'11.19"W	Pied mount of Sierra Las Mitras, Monterrey, ca. 632 m asl.	NL	Lichen	<i>Mac. kazmierskii</i> Kaczmarek & Michalczyk, 2009 <i>Mil. cassandrae</i> sp. nov. <i>Pse. cf. juanita</i>
10	08/30/2014 25°43'02.98"N 100°04'18.71"W	1 Km at S of Puerto Genovevo, Santiago, ca. 1103 m asl.	NL	Lichen	<i>Crn. lobatus</i> Gąsiorek & Degma, 2018
11	11/08/2014 25°44'45.98"N 100°25'27.68"W	Pied mount of Sierra Las Mitras, Monterrey, ca. 700 m asl.	NL	Lichen	<i>Mil. cassandrae</i> sp. nov. <i>Min. continuus</i> Pilato & Lisi, 2006
12	11/08/2014 25°44'38.55"N 100°25'31.65"W	Pied mount of Sierra Las Mitras, Monterrey, ca. 719 m asl.	NL	Lichen	<i>Mil. cassandrae</i> sp. nov.
13	01/17/2015 25°23'11.38"N 100°12'08.10"W	Puerto El Gringo, La Botella, Santiago, ca. 1684 m asl.	NL	Moss	<i>Dor. dawkinsi</i> Michalczyk & Kaczmarek, 2010 <i>Pil. nodulosus</i> (Ramazzotti, 1957) <i>Ram. cf. oberhaeuseri</i>
14	01/10/2015 25°21'54.81"N 100°14'02.27"W	El Vado, Cienega de Gonzalez, Santiago, ca. 1411 m asl.	NL	Moss	<i>Ech. manuelae</i> da Cunha & du Nascimento Ribeiro, 1962
15	02/09/2015 25°21'26.16"N 100°22'08.03"W	La Peñita, Santiago, ca. 2006 m asl.	NL	Moss	<i>Dip. pingue</i> (Marcus, 1936) <i>Pil. nodulosus</i> (Ramazzotti, 1957)

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TABLE 1. (Continued)

No.	Date Latitude Longitude	Locality	State	Sample type	Species
16	02/09/2015 25°20'50.79"N 100°22'01.21"W	1 Km at E of La Peñita, Santiago, ca. 2250 m asl.	NL	Moss	<i>Min. continuus</i> Pilato & Lisi, 2006
17	02/09/2015 25°20'44.31"N 100°22'05.22"W	1.2 Km at E of La Peñita, Santiago, ca. 2370 m asl.	NL	Moss	<i>Ast. trinacriae</i> Pilato, Sabella, D'Urso & Lisi, 2017
18	02/09/2015 25°20'27.80"N 100°22'08.61"W	Cerro La Viga, 1.7 Km at E of La Peñita, Santiago, ca. 2543 m asl.	NL	Moss	<i>Dip. pingue</i> (Marcus, 1936)
19	02/09/2015 25°20'23.43"N 100°22'06.42"W	Cerro La Viga, 2 Km at E of La Peñita, ca. 2645 m asl.	NL	Moss	<i>Min. continuus</i> Pilato & Lisi, 2006
20	02/14/2015 25°17'23.13"N 100°30'13.52"W	El Pilar, Arteaga, ca. 2973 m asl.	Coah	Moss	<i>Hys. cf. convergens</i>
21	02/14/2015 25°17'28.52"N 100°30'30.36"W	500 m at E of El Pilar, Arteaga, ca. 2860 m asl.	Coah	Moss	<i>Dip. pingue</i> (Marcus, 1936)
22	12/19/2016 26°00'46.21"N 97°58'59.00"W	La Posta, 2.2 km N of Buenavista, Rio Bravo, ca. 22 m asl.	Tams	Lichen	<i>Mac. anemone</i> Meyer, Domingue & Hinton, 2014 <i>Mil. cassandrae</i> sp. nov.
23	12/19/2016 28°57'42.95"N 102°34'43.22"W	7 km E of Agua de los Frijoles, Sierra Maderas del Carmen, Ocampo, ca. 2263 m asl.	Coah	Moss	<i>Ast. trinacriae</i> Pilato, Sabella, D'Urso & Lisi, 2017 <i>Dip. pingue</i> (Marcus, 1936)

States: Coah = Coahuila, NL = Nuevo Leon, Tams = Tamaulipas

Class: Heterotardigrada Marcus, 1927

Order: Echiniscoidea Richters, 1926

Family: Echiniscidae Thulin, 1928

Subfamily: Echiniscinae Guil, Jørgensen & Kristensen, 2018

Tribe: Echiniscini Guil, Jørgensen & Kristensen, 2018

Genus: *Echiniscus* Schultze, 1840

***Echiniscus manuelae* da Cunha & du Nascimento Ribeiro, 1962**

Terra typica: Madera Island (Portugal, Atlantic Ocean).

Material examined: One specimen: El Vado (25°21'54.81"N, 100°14'02.27"W, ca. 1411 m asl), Cienega de Gonzalez, Santiago, Nuevo Leon, Mexico. Moss on tree (*Quercus* sp.), coll. Mario Alberto Garcia Aranda, 17 January 2015.

Comments: Our specimens correspond well with the original description (da Cunha & du Nascimento Ribeiro 1962). This species has been reported from the type locality, Madera Island (da Cunha & du Nascimento 1962; McInnes 1994), Corrientes Province, Bella Vista in Argentina (Claps & Rossi 1988) and Costa Rica (Kaczmarek & Michalczyk 2010). Kaczmarek & Michalczyk (2010) and Kaczmarek *et al.* (2014) suggest the possibility that the Costa Rican record, found in a big city, was a non-indigenous to the region, but had

been brought to Costa Rica by humans. Our record for this study corresponds to a small town, remote from big cities. This is a new record for Mexico.

Echiniscus cf. tamus

Material examined: One specimen: Las Crucitas (24°30'46.62"N, 99°59'03.91"W, *ca.* 2499 m asl), Aramberri, Nuevo Leon, Mexico. Lichen on tree, coll. Miguel Angel Gonzalez Botello, 3 May 2014.

Comments: *Echiniscus tamus* Mehlen, 1969 was described from North America (Texas, USA). Our single specimen is similar to the Texan specimen (Mehlen 1969; Miller & Mehlen 2007), but differs by having a basal spur on the internal claws. This is possibly a new species, but for final identification a larger number of specimens are required.

Subfamily: Pseudechiniscinae Guil, Jørgensen & Kristensen, 2018

Tribe: Cornechiniscini Guil, Jørgensen & Kristensen, 2018

Genus: *Cornechiniscus* Maucci & Ramazzotti, 1981

***Cornechiniscus lobatus* (Ramazzotti, 1943)**

Terra typica: Italy (Europe).

Material examined: 24 specimens: 1 km S of Puerto Genovevo (25°43'02.98"N, 100°04'18.71"W, *ca.* 1103 m asl), Santiago, Nuevo Leon, Mexico. Lichen on rock, coll. Antonio Moreno-Talamantes, 30 August 2014.

Comments: Our specimens correspond well with to the original description. This species has been reported in many localities in the northern hemisphere (McInnes 1994). This species was reported from Sinaloa, Mexico (Beasley 1972), and this is the second record for Mexico.

Tribe: Pseudechiniscini Guil, Jørgensen & Kristensen, 2018

Genus: *Pseudechiniscus* Thulin, 1911

Pseudechiniscus cf. juanita

Material examined: One specimen: Piedmont of Sierra Las Mitras (25°44'55.57"N, 100°24'11.19"W, *ca.* 632 m asl), Monterrey, Nuevo Leon, Mexico. Lichen (*Physcia stellaris*) on trees (*Parkinsonia aculeata* and *Celtis pallida*), coll. Antonio Moreno-Talamantes, 7 August 2014.

Comments: *Pseudechiniscus juanita* de Barros, 1939 was described from Brazil and later reported from Costa Rica and Mexico (Kaczmarek *et al.* 2014, 2015), but the diagnosis for this species is very unclear, and this is why we report our specimen as *confer* to the nominal taxon.

Class: Apotardigrada Guil, Jørgensen & Kristensen, 2018

Order: Apochela Schuster, Nelson, Grigarick & Christenberry, 1980

Family: Milnesiidae Ramazzotti, 1962

Genus: *Milnesium* Doyère, 1840

***Milnesium barbadosense* Meyer & Hinton, 2012**

Terra typica: Barbados Island (Central America)

Material examined: Eleven specimens: Cueva El Infierno (25°18'30.95"N, 100°12'37.85"W, *ca.* 1522 m asl), La Camotera, Santiago, Nuevo Leon, Mexico. Moss on pine (*Pinus* sp.), coll. Jose Juan Flores Maldonado, 6

August 2014. One specimen: Mesa del Oso (25°16'17.77"N, 100°13'41.86"W, ca. 2181 m asl), Vista Hermosa, Santiago, Nuevo Leon, Mexico. Moss from pine (*Pinus* sp.), coll. Jose Juan Flores Maldonado, 6 August 2014.

Comments: Typical *Mil. barbadosense* was reported from the island country of Barbados (Meyer & Hinton, 2012), but there are also records of *Mil. cf. barbadosense* from Sierra Nevada de Santa Marta, Colombia (Londoño *et al.* 2015). All Mexican and Colombian specimens have the claw configuration [3-3]-[3-3]. Meyer & Hinton (2012) described variability in the presence of spurs on secondary branches of claws on specimens from Barbados. It is possible that the hatchling and juvenile specimens of this species have different number of spurs in comparison with adults. Such a phenomenon has been described in *Mil. variefidum* Morek, Gąsiorek, Stec, Blagden, & Michalczyk, 2016 (Morek *et al.* 2016), *Mil. tar. tardigradum* (Morek *et al.* 2018) and *Mil. cassandrae* **sp. nov.** (present study).

***Milnesium cassandrae* sp. nov.**

(Table 2, Table 3, Figure 1a–e, Figure 2a–e)

Type material: Holotype (female) and 47 paratypes (32 adult females, 13 hatchlings, two juveniles of indeterminate sex), 25 eggs and nine exuviae from piedmont of Sierra Las Mitras (25°44'55.57"N, 100°24'11.19"W, ca. 632 m asl), Monterrey, Nuevo León, Mexico. Lichen (*Physcia stellaris*) on trees (*Parkinsonia aculeata* and *Celtis pallida*), coll. Antonio Moreno-Talamantes, 7 August 2014.

Additional material: Thirteen females from a lichen sample and five eggs in exuviae from San Agustín Park (25°39'18.63"N, 100°20'34.51"W, ca. 605 m asl), San Pedro Garza García Municipality, Nuevo Leon, Mexico. Lichen (*Nephroma* sp.) on trees (*Fraxinus* sp. and *Quercus* sp.), coll. Antonio Moreno-Talamantes, 6 November 2013. Four females from a piedmont of Sierra Las Mitras (25°44'45.98"N, 100°25'27.68"W, ca. 700 m asl), Monterrey, Nuevo Leon, Mexico. Lichen (*Physcia stellaris*) on tree (*Quercus virginiana*), coll. Antonio Moreno-Talamantes, 8 November 2014. Six females from piedmont of Sierra Las Mitras (25°44'38.55"N, 100°25'31.65"W, ca. 719 m asl), Monterrey, Nuevo Leon, Mexico. Lichen (*Physcia stellaris*) on tree (*Quercus virginiana*), coll. Antonio Moreno-Talamantes, 8 November 2014. Four females from La Posta (26°00'46.21"N, 97°58'59.00"W, ca. 22 m asl), 2.2 km N of Buenavista, Rio Bravo, Tamaulipas, Mexico. Lichen on mesquite tree (*Prosopis glandulosa*) coll. Antonio Moreno-Talamantes, 19 December 2016.

Species description. Body white or transparent with light yellow to brownish tones before fixation (Fig. 1a). Eyes present in all living and mounted adults. Hatchling and juveniles without eyes. Adults cuticle sculptured with pseudopores (0.6–1.4 µm in diameter), sparsely distributed and not forming a reticular design. Hatchling and juveniles with reticular design (Figs 1b and 2b). In adults, dorsal side with delineated geometric areas i.e. pseudoplates clearly visible only in FM (Figs 3–4). The row I of pseudoplates situated anteriorly to legs I with four (two small and two large) pseudoplates. The row II situated in line with legs I with two triangular pseudoplates connected in the middle. The row III situated between legs I and II with four connected rectangular pseudoplates forming a large rectangle in the midline of the body. The row IV situated in the line of legs II with six rectangular pseudoplates forming a large rectangle in the midline of the body and two pairs of small oval dorsolateral pseudoplates. The row V situated between legs II and III with two rectangular pseudoplates connected in the middle, and two pairs of small oval dorsolateral pseudoplates. The row VI situated in line with legs III with six rectangular pseudoplates forming a large rectangle in the midline of the body and two pairs of small oval dorsolateral pseudoplates. The rows VII to IX situated between legs III and IV (row VII just behind legs III, row VIII in the middle between legs III and IV, row IX just before legs IV). The row VII with a double rectangular paired pseudoplate (the caudal pair poorly developed) and two pairs of small oval dorsolateral pseudoplates. The row VIII with a complex of ten pseudoplates, eight clustered on the dorsal side and two oval placed dorso-laterally. The row IX with a pair of pseudoplates connected in the middle. The pseudoplates arrangements see *Remarks* below. For pseudoplates in row I and II poorly visible under PCM, but clearly visible in FM. (Fig. 4). The pseudoplates in the hatchlings and juveniles poorly developed.

Buccal apparatus of the *Milnesium* type (Figs 1c and 2c). Buccal tube in adults wide and short (standard width on average 56% of its length) and funnel-shaped, wider anteriorly (posterior diameter on average 89% of the anterior diameter); buccal tube in hatchling and juveniles is more slender (standard width on average 35% of its length) and funnel-shaped, wider anteriorly (posterior diameter on average 80% of the anterior diameter). Six peribuccal

papillae and six peribuccal lamellae (of unequal size, 4+2) around the mouth opening present. Two cephalic papillae positioned laterally. The peribuccal papillae longer than the cephalic one. Pharyngeal bulb elongated and pear-shaped, without placoids or septulum.

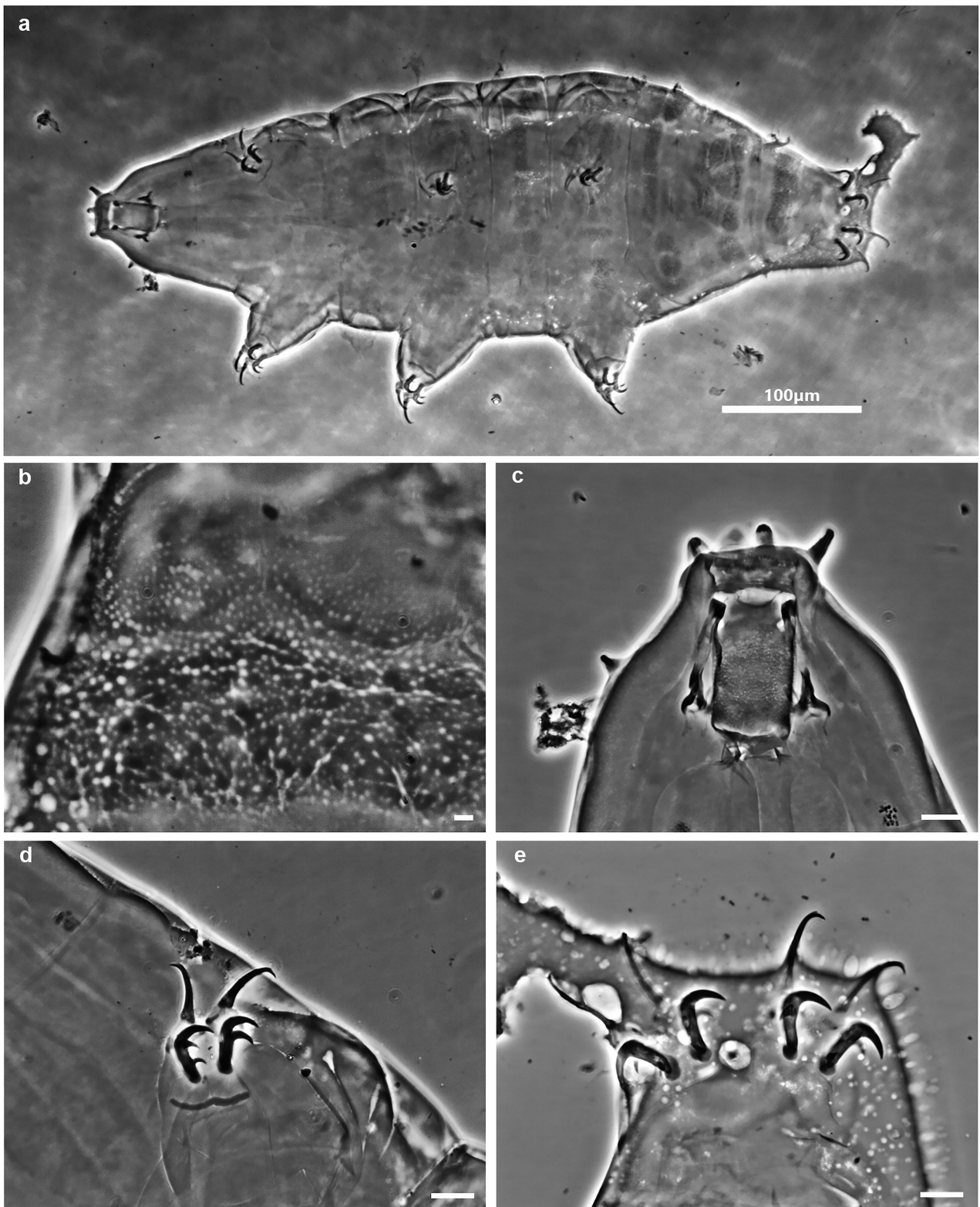


FIGURE 1. Adult of *Milnesium cassandrae* sp. nov. [holotype]. (a) habitus (dorsolateral view); (b) details of dorsal cuticle with pseudopores; (c) buccal tube apparatus; (d) claws I; (e) claws IV (all PCM). Scale bar in a = 100 μm, b = 2 μm, c, d and e = 10 μm.

Claws of the Milnesiidae type (Figs 1d–e and 2d–e). Primary branches on all claws with small accessory points. Secondary branches of all claws with rounded basal thickenings. Transverse cuticular bars present under claws I–III. In adult specimens, internal secondary branches on legs I–III with three points, external with two points. Secondary branches of anterior claw on legs IV with three points, posterior claws with two points. In hatchling and juvenile specimens all secondary branches on all legs with two points. *Milnesium cassandrae* **sp. nov.** exhibits an early positive internal CC (claw configuration [2-2/3]-[2/3-2]); in other words, changes in claw configuration (CC) occur between the hatchling/juvenile stages [2-2]-[2-2], and adults [2-3]-[3-2].

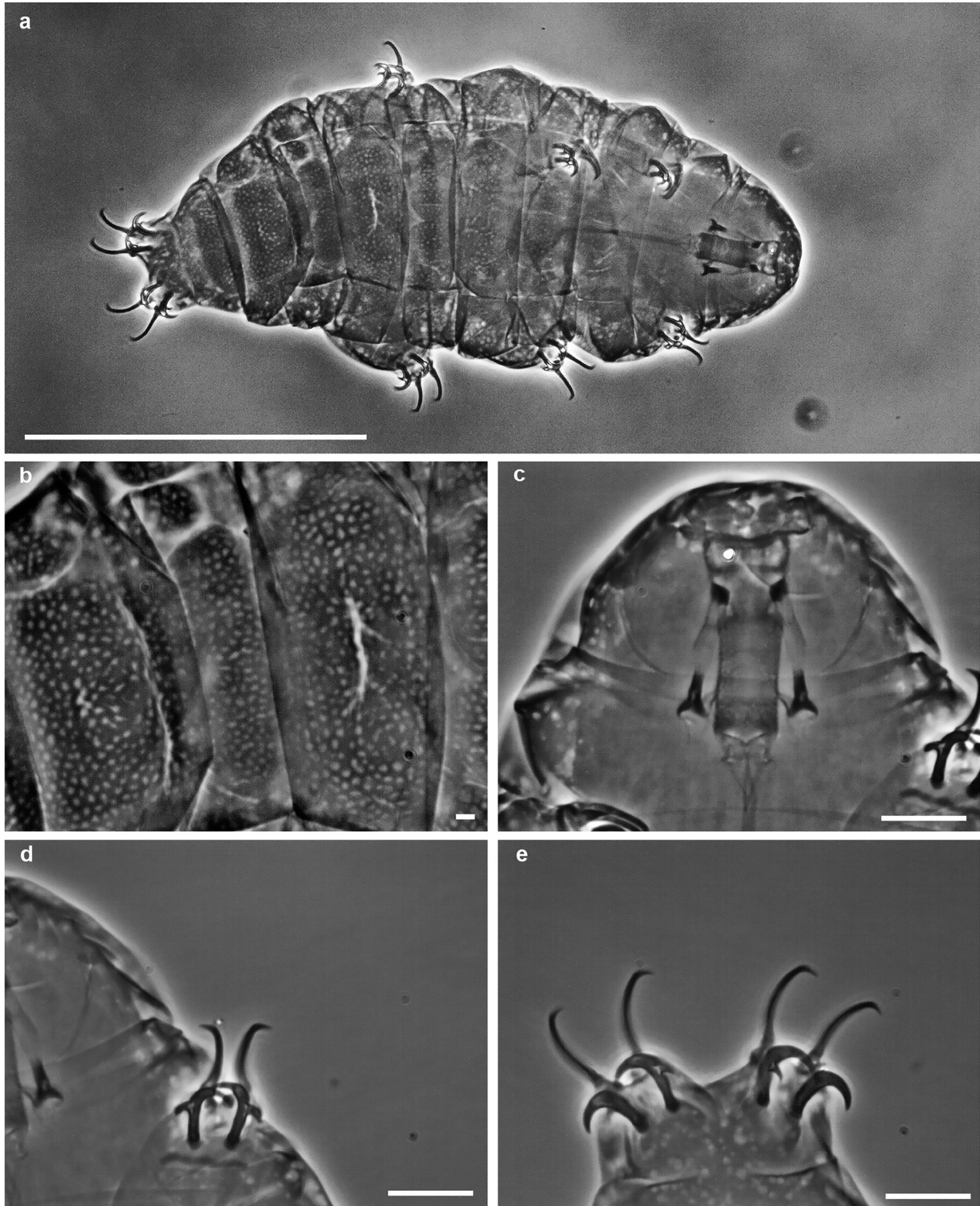


FIGURE 2. Hatchling of *Milnesium cassandrae* **sp. nov.** (a) habitus (ventral view); (b) details of dorsal cuticle with pseudopores; (c) buccal apparatus; (d) claws I; (e) claws IV (all PCM). Scale bar in a = 100 μ m, b = 2 μ m, c, d and e = 10 μ m.

Males: not observed.

Eggs: Oval, smooth and deposited in exuvium as in all other known *Milnesium* species.

Type depositories: The holotype (slide ELITE-1/053) and 11 paratypes (slide: ELITE-1/052, ELITE-2/054-055-056-057, ELITE-4/089, ELITE-5/091-092-093, ELITE-30/1068-1069), one exuviae with four eggs (slide ELITE-30/1067) are deposited at Colección Carcinológica-FCB-UANL at Facultad de Ciencias Biológicas, Universidad Autónoma de Nuevo León, San Nicolás de los Garza, Nuevo León, Mexico, nine paratypes (slides ELITE-12/878, ELITE-14/881, ELITE-43/1097-1098-1099, ELITE-44/1100-1101-1102, ELITE-52/1115), one exuviae and eight eggs (ELITE-52/1114) are preserved at the Department of Animal Taxonomy and Ecology, Adam Mickiewicz University, Poznań, Uniwersytetu Poznańskiego 6, Poznań, Poland and 27 paratypes (slides: ELITE-3/058-060, ELITE-13/879-880, ELITE-28/1060, ELITE-29/1065-1066, ELITE-35/1084-1085, ELITE-36/1086-1087, ELITE-37/1089, ELITE-40/1092, ELITE-41/1094, ELITE-42/1096, ELITE-45/1103, ELITE-47/1106, ELITE-49/1108-1109, ELITE-50/1110-1111, ELITE-53/1116, ELITE-54/1119-1120, ELITE-58/1139, ELITE-59/1140-1141), eight exuviae with 13 eggs (slides: ELITE-27/987, ELITE-29/1064, ELITE-36/1088, ELITE-38/1090, ELITE-39/1091, ELITE-53/1117, ELITE-54/1118) are deposited in the collection of first author.

Etymology: The new species is dedicated to Cassandra Moreno Perales, the first author's youngest daughter.

Remarks: To clarify the nomenclature of the pseudoplates arrangement we propose the system which is similar to that used for the numbering of gibbosities in *Doryphoribius* and *Isohypsibius* species by Michalczyk & Kaczmarek (2010). In this system all rows of pseudoplates are named and assigned to a specific place on the dorsal cuticle and the number of pseudoplates is counted:

row I of pseudoplates situated anteriorly to legs I,
row II of pseudoplates situated in line with legs I,
row III situated between legs I and II,
row IV situated in line with legs II,
row V situated between legs II and III,
row VI situated in line with legs III,
row VII situated between legs III and IV (just behind legs III),
row VIII situated between legs III and IV (in the middle between legs III and IV),
row IX situated between legs III and IV (just before legs IV).

The row numbers are always in Roman numerals and the number of pseudoplates is always listed in Arabic numerals. For example, in this system a configuration of pseudoplates (CP) in *Mil. cassandrae* sp. nov. will be: (CP: I:4; II:2; III:4; IV:10; V:6; VI:10; VII:8; VIII:10; IX:2, Figs 3–4).



FIGURE 3. *Milnesium cassandrae* sp. nov. under UV fluorescence, showing dorsal pseudoplates. Scale bar 100 μ m.

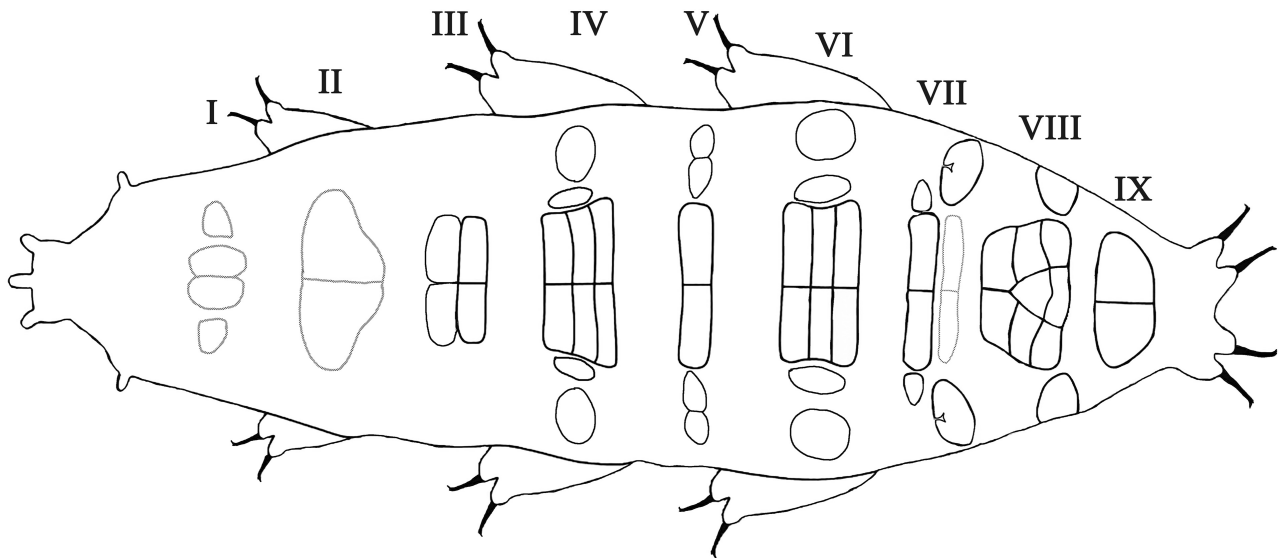


FIGURE 4. Semi-schematic drawing of the dorsal pseudoplates of adult *Milnesium cassandrae* **sp. nov.**, based on PCM and UV fluorescence observation (pseudoplates in anterior segment of leg I and leg I are poorly visible under PCM, but clearly visible under fluorescence microscopy). Roman numbers indicate rows of pseudoplates. Contour of *Milnesium* redrawn and adapted from Morek *et al.* 2016.

Differential diagnosis. Based on having a sculptured dorsal cuticle, *Mil. cassandrae* **sp. nov.** belongs to the *granulatum* group (Michalczyk *et al.* 2012a, b). The new species with claw configuration [2-3]-[3-2] in adults, is most similar to *Mil. krzysztofi* Kaczmarek & Michalczyk, 2007 and *Mil. beasleyi* Kaczmarek *et al.*, 2012, but it differs from:

1. *Milnesium krzysztofi* by: different dorsal sculpture (very dense pseudopores, but not forming a reticular design in adults of *Mil. cassandrae* **sp. nov.** vs. a fine reticular design in *Mil. krzysztofi*), presence of eyes, a higher *pt* of the standard buccal tube width ([41.6–67.2] in *Mil. cassandrae* **sp. nov.** and [33.1–38.4] in *Mil. krzysztofi*), and the presence of pseudoplates (but see Discussion, below).
2. *Milnesium beasleyi* by: presence of eyes, having higher *pt* buccal tube width ([47.4–66.2], [41.6–67.2], [39.9–61.1] anterior, standard and posterior, respectively in *Mil. cassandrae* **sp. nov.** vs. [35.3–41.8], [31.2–39.8], [33.2–39.6] anterior, standard and posterior, respectively in *Mil. beasleyi*), higher standard width/ length ratio of buccal tube (42%–67% in *Mil. cassandrae* **sp. nov.** vs. 31%–40% in *Mil. beasleyi*), smaller lateral papillae (4.0–6.5 in *Mil. cassandrae* **sp. nov.** vs. 7.5–10.3 in *Mil. beasleyi*), and presence of pseudoplates (but see Discussion, below).

In addition, *Mil. cassandrae* **sp. nov.** is similar to other species with the claw configuration [2-3]-[3-2] i.e. *Mil. lagniappe* Meyer *et al.*, 2013, *Mil. reductum* Tumanov, 2006, *Mil. reticulatum* Pilato *et al.*, 2002, *Mil. tardigradum tardigradum* Doyère, 1840, *Mil. tetralamellatum* Pilato & Binda, 1991 and *Mil. vorax* Pilato *et al.*, 2016, but it differs from:

3. *Milnesium lagniappe* by: larger number of peribuccal lamellae (six in *Mil. cassandrae* **sp. nov.** vs. four in *Mil. lagniappe*), different dorsal sculpture (very dense pseudopores, but not forming a reticular design adults of *Mil. cassandrae* **sp. nov.** vs. reticulated pattern of irregular polygons in *Mil. lagniappe*), presence of eyes, stylet supports inserted in less caudal position ([58.7–67.6] in *Mil. cassandrae* **sp. nov.** vs. [69.7–73.4] in *Mil. lagniappe*), and lower *pt* of buccal tube width ([47.4–66.2], [39.9–61.1] anterior and posterior, respectively, in *Mil. cassandrae* **sp. nov.** vs. [68.0–77.5], [61.8–70.8] anterior and posterior, respectively, in *Mil. lagniappe*).
4. *Milnesium reductum* by: sculptured dorsal cuticle, presence of accessory points on primary branches of claws, stylet supports inserted in more anterior position (16.5–26.0 in *Mil. cassandrae* **sp. nov.** vs. 29.2–28.1 in *Mil. reductum*), smaller claws IV (see Table 2 in this work and Table 5 in Tumanov (2006) for the exact differences in dimensions of claws), and presence of pseudoplates (but see Discussion, below).

TABLE 2. Measurements and *pt* values of selected morphological structures of 30 selected adult specimens of *Milnesium cassandrae* **sp. nov.** mounted in PVA medium. Range refers to the smallest and the largest structure among all measured specimens. The *pt* values are provided in italics. N, number of specimens or structures measured; SD, standard deviation.

Character	N	Range				Mean		SD		Holotype			
		μm		<i>pt</i>	μm	<i>pt</i>	μm	<i>pt</i>	μm	<i>pt</i>			
Body length	30	344	–	693	–	560	–	97	–	550	–		
Peribuccal papillae length	25	5.1	–	10.2	<i>19.0</i>	–	<i>29.3</i>	8.5	<i>23.5</i>	1.3	<i>2.9</i>	9.4	<i>27.2</i>
Lateral papillae length	28	4.0	–	6.5	<i>9.3</i>	–	<i>17.2</i>	5.0	<i>13.9</i>	0.6	<i>1.7</i>	4.6	<i>13.2</i>
Buccal tube													
Length	30	26.2	–	42.5	–	36.0	–	4.1	–	34.6	–		
Stylet support insertion point	30	16.5	–	26.0	<i>58.7</i>	–	<i>67.6</i>	22.8	<i>63.5</i>	2.4	<i>2.3</i>	22.5	<i>64.9</i>
Anterior width	30	12.3	–	24.8	<i>47.1</i>	–	<i>66.2</i>	21.0	<i>58.4</i>	2.7	<i>4.9</i>	20.3	<i>58.5</i>
Standard width	30	10.9	–	25.2	<i>41.6</i>	–	<i>67.2</i>	20.0	<i>55.5</i>	2.9	<i>5.6</i>	19.4	<i>56.0</i>
Posterior width	30	10.4	–	22.9	<i>39.9</i>	–	<i>61.1</i>	18.7	<i>51.9</i>	2.6	<i>5.3</i>	18.2	<i>52.6</i>
Standard width/length ratio	30	42%	–	67%	–	55%	–	6%	–	56%	–		
Posterior/anterior width ratio	30	81%	–	96%	–	89%	–	4%	–	90%	–		
Claw 1 lengths													
External primary branch	30	9.3	–	19.0	<i>35.6</i>	–	<i>57.0</i>	15.9	<i>44.4</i>	1.9	<i>4.1</i>	14.8	<i>42.6</i>
External base + secondary branch	30	8.8	–	15.8	<i>33.6</i>	–	<i>52.1</i>	13.9	<i>38.8</i>	1.5	<i>3.8</i>	13.3	<i>38.4</i>
External branches length ratio	29	75%	–	97%	–	87%	–	6%	–	90%	–		
Internal primary branch	30	9.1	–	17.2	<i>34.7</i>	–	<i>52.3</i>	15.3	<i>42.6</i>	1.7	<i>3.5</i>	14.0	<i>40.6</i>
Internal base + secondary branch	30	8.2	–	15.4	<i>31.5</i>	–	<i>50.8</i>	13.0	<i>36.5</i>	1.5	<i>4.1</i>	13.1	<i>37.8</i>
Internal spur	30	2.6	–	5.0	<i>8.6</i>	–	<i>15.8</i>	4.0	<i>11.2</i>	0.6	<i>1.7</i>	4.0	<i>11.5</i>
Internal branches length ratio	30	78%	–	97%	–	86%	–	5%	–	93%	–		
Claw 2 lengths													
External primary branch	29	11.5	–	19.0	<i>40.6</i>	–	<i>59.0</i>	16.8	<i>47.1</i>	1.6	<i>4.0</i>	16.3	<i>47.2</i>
External base + secondary branch	30	8.8	–	17.6	<i>33.6</i>	–	<i>53.9</i>	14.4	<i>40.2</i>	1.7	<i>3.9</i>	13.9	<i>40.2</i>
External branches length ratio	29	77%	–	96%	–	85%	–	5%	–	85%	–		
Internal primary branch	30	11.1	–	18.8	<i>37.8</i>	–	<i>55.6</i>	15.8	<i>44.0</i>	1.8	<i>3.9</i>	14.9	<i>43.2</i>
Internal base + secondary branch	30	8.5	–	15.8	<i>32.2</i>	–	<i>52.3</i>	13.2	<i>36.7</i>	1.5	<i>3.9</i>	12.1	<i>34.9</i>
Internal spur	29	2.2	–	5.8	<i>8.3</i>	–	<i>16.2</i>	4.2	<i>11.8</i>	0.7	<i>1.8</i>	3.9	<i>11.3</i>
Internal branches length ratio	30	76%	–	94%	–	84%	–	5%	–	81%	–		
Claw 3 lengths													
External primary branch	30	10.7	–	23.8	<i>39.3</i>	–	<i>61.2</i>	17.3	<i>48.2</i>	2.2	<i>4.8</i>	16.4	<i>47.5</i>
External base + secondary branch	29	9.2	–	16.4	<i>33.5</i>	–	<i>54.3</i>	14.1	<i>39.3</i>	1.6	<i>4.2</i>	13.8	<i>39.9</i>
External branches length ratio	29	63%	–	98%	–	82%	–	6%	–	84%	–		
Internal primary branch	30	10.9	–	19.2	<i>37.6</i>	–	<i>54.0</i>	16.2	<i>45.1</i>	1.7	<i>3.5</i>	15.3	<i>44.3</i>
Internal base + secondary branch	30	8.8	–	15.6	<i>31.9</i>	–	<i>51.6</i>	13.1	<i>36.6</i>	1.4	<i>3.7</i>	12.4	<i>35.7</i>
Internal spur	30	2.7	–	5.6	<i>7.8</i>	–	<i>15.0</i>	4.1	<i>11.5</i>	0.7	<i>1.5</i>	3.7	<i>10.7</i>
Internal branches length ratio	30	67%	–	96%	–	81%	–	6%	–	81%	–		
Claw 4 lengths													
Anterior primary branch	30	12.6	–	25.0	<i>48.2</i>	–	<i>69.7</i>	20.8	<i>58.1</i>	2.3	<i>5.3</i>	21.0	<i>60.6</i>
Anterior base + secondary branch	30	9.1	–	19.1	<i>34.8</i>	–	<i>51.8</i>	14.8	<i>41.3</i>	1.8	<i>4.2</i>	13.8	<i>39.8</i>
Anterior spur	25	1.2	–	4.6	<i>3.0</i>	–	<i>11.7</i>	2.8	<i>7.6</i>	0.9	<i>2.5</i>	2.1	<i>6.0</i>
Anterior branches length ratio	30	64%	–	83%	–	71%	–	5%	–	66%	–		
Posterior primary branch	30	15.0	–	26.8	<i>53.4</i>	–	<i>77.7</i>	21.9	<i>61.3</i>	2.3	<i>5.6</i>	20.1	<i>58.0</i>
Posterior base + secondary branch	30	9.8	–	19.6	<i>37.2</i>	–	<i>53.2</i>	15.6	<i>43.6</i>	1.9	<i>4.2</i>	15.3	<i>44.3</i>
Posterior branches length ratio	30	64%	–	84%	–	71%	–	5%	–	76%	–		

5. *Milnesium reticulatum* by: larger number of peribuccal lamellae (six in *Mil. cassandrae* **sp. nov.** vs. four in *Mil. reticulatum*), absence of cuticular gibbosities, different dorsal sculpture (very dense pseudopores, but not forming a reticular design in adults of *Mil. cassandrae* **sp. nov.** vs. pseudopores arranged in nine sculptured bands, forming a reticular design in *Mil. reticulatum*), higher *pt* of the standard buccal tube width ([45.6–67.2] in *Mil. cassandrae* **sp. nov.** vs. [30.4–37.4] in *Mil. reticulatum*), and higher *pt* of claws II, III

and IV (see Table 2 in this work and Table 2 in Pilato *et al.* (2002) for the exact differences in dimensions of claws).

6. *Milnesium tardigradum tardigradum* by: having sculptured dorsal cuticle and presence of pseudoplates (but see Discussion, below).

TABLE 3. Measurements and *pt* values of selected morphological structures of 13 hatchling and juvenile specimens (instar I and II) of *Milnesium cassandrae* **sp. nov.** mounted in PVA medium. Range refers to the smallest and the largest structure among all measured specimens. The *pt* values are provided in italics; N, number of specimens or structures measured; SD, standard deviation.

Character	N	Range				Mean		SD		
		μm	μm	μm	μm	<i>pt</i>	μm	<i>pt</i>		
Body length	13	131	–	202	–	179	20			
Peribuccal papillae length	3	3.3	–	4.2	<i>16.2</i>	<i>19.7</i>	3.7	<i>17.9</i>	0.4	<i>1.7</i>
Lateral papillae length	5	2.3	–	3.4	<i>11.3</i>	<i>16.5</i>	3.0	<i>14.6</i>	0.4	2.1
Buccal tube										
Length	13	18.2	–	22.6	–	20.7	–	1.2	–	–
Stylet support insertion point	13	10.3	–	14.8	<i>56.5</i>	<i>70.5</i>	13.8	<i>66.3</i>	1.1	<i>3.4</i>
Anterior width	13	7.2	–	9.6	<i>38.1</i>	<i>47.1</i>	8.8	<i>42.3</i>	0.7	<i>3.2</i>
Standard width	13	6.1	–	7.8	<i>28.2</i>	<i>39.4</i>	7.2	<i>34.6</i>	0.5	<i>3.0</i>
Posterior width	13	6.3	–	7.3	<i>29.6</i>	<i>36.1</i>	7.0	<i>33.6</i>	0.3	<i>2.0</i>
Standard width/length ratio	13	28%	–	39%	–	35%	–	3%	–	–
Posterior/anterior width ratio	13	74%	–	88%	–	80%	–	4%	–	–
Claw 1 lengths										
External primary branch	13	7.4	–	10.4	<i>35.1</i>	<i>52.8</i>	8.9	<i>42.9</i>	0.9	<i>5.7</i>
External base + secondary branch	12	6.5	–	7.9	<i>30.1</i>	<i>39.7</i>	7.3	<i>35.1</i>	0.4	<i>2.6</i>
External branches length ratio	12	72%	–	96%	–	84%	–	10%	–	–
Internal primary branch	13	7.6	–	9.8	<i>35.8</i>	<i>48.4</i>	8.7	<i>42.1</i>	0.7	<i>4.1</i>
Internal base + secondary branch	13	6.2	–	8.2	<i>30.2</i>	<i>39.6</i>	7.1	<i>34.3</i>	0.5	<i>2.9</i>
Internal branches length ratio	13	74%	–	94%	–	82%	–	6%	–	–
Claw 2 lengths										
External primary branch	13	7.6	–	11.0	<i>35.4</i>	<i>60.5</i>	9.3	<i>45.2</i>	0.9	<i>6.5</i>
External base + secondary branch	13	6.7	–	8.1	<i>30.9</i>	<i>40.9</i>	7.5	<i>36.3</i>	0.5	<i>3.5</i>
External branches length ratio	13	65%	–	94%	–	81%	–	7%	–	–
Internal primary branch	12	7.6	–	9.7	<i>37.4</i>	<i>53.5</i>	9.0	<i>43.3</i>	0.6	<i>4.3</i>
Internal base + secondary branch	13	6.4	–	8.9	<i>29.9</i>	<i>40.9</i>	7.2	<i>34.7</i>	0.7	<i>3.4</i>
Internal spur	1	1.8	–	1.8	<i>10.1</i>	<i>10.1</i>	1.8	<i>10.1</i>	?	?
Internal branches length ratio	12	70%	–	96%	–	80%	–	9%	–	–
Claw 3 lengths										
External primary branch	12	8.5	–	10.3	<i>39.4</i>	<i>48.9</i>	9.4	<i>44.7</i>	0.5	<i>3.2</i>
External base + secondary branch	13	6.0	–	8.3	<i>31.3</i>	<i>38.5</i>	7.3	<i>35.1</i>	0.6	<i>2.3</i>
External branches length ratio	12	71%	–	90%	–	79%	–	6%	–	–
Internal primary branch	12	8.6	–	9.7	<i>39.0</i>	<i>47.2</i>	9.3	<i>44.4</i>	0.4	<i>2.8</i>
Internal base + secondary branch	13	6.7	–	7.6	<i>30.4</i>	<i>40.0</i>	7.1	<i>34.2</i>	0.3	<i>2.7</i>
Internal branches length ratio	12	70%	–	83%	–	76%	–	4%	–	–
Claw 4 lengths										
Anterior primary branch	11	8.4	–	11.2	<i>41.5</i>	<i>54.9</i>	10.2	<i>49.7</i>	0.8	<i>3.6</i>
Anterior base + secondary branch	13	5.9	–	8.1	<i>26.1</i>	<i>40.7</i>	7.1	<i>34.4</i>	0.5	<i>3.7</i>
Anterior branches length ratio	11	61%	–	80%	–	71%	–	6%	–	–
Posterior primary branch	11	9.5	–	11.8	<i>45.8</i>	<i>56.7</i>	10.7	<i>52.3</i>	0.7	<i>3.3</i>
Posterior base + secondary branch	13	6.6	–	8.2	<i>30.6</i>	<i>40.9</i>	7.5	<i>36.1</i>	0.5	<i>3.1</i>
Posterior branches length ratio	11	65%	–	77%	–	70%	–	4%	–	–

7. *Milnesium tetralamellatum* by: larger number of peribuccal lamellae (six in *Mil. cassandrae* **sp. nov.** vs. four in *Mil. tetralamellatum*), sculptured dorsal cuticle, and presence of pseudoplates (but see Discussion, below).

8. *Milnesium vorax* by: sculptured dorsal cuticle, longer % external base + secondary branch/external primary branch I to III in *Mil. cassandrae* **sp. nov.** (see Table 2 in this work and Table 1 in Pilato *et al.* (2016) for the exact differences), and presence of pseudoplates (but see Discussion, below).

Order: Hypsibioidea Pilato, 1969

Family: Hypsibiidae Pilato, 1969

Subfamily: Diphasconinae Dastych, 1992

Genus: *Diphascon* Plate, 1888

***Diphascon pingue* (Marcus, 1936)**

Terra typica: Germany (Europe).

Material examined: Seven specimens: 500 m at E of El Pilar (25°17'28.52"N, 100°30'30.36"W, *ca.* 2860 m asl), Arteaga, Coahuila, Mexico. Moss on tree, coll. Mario Alberto Garcia Aranda, 14 February 2015. One specimen: La Peñita (25°21'26.16"N, 100°22'08.03"W, *ca.* 2006 m asl), Santiago, Nuevo Leon, Mexico. Moss on soil, coll. Mario Alberto Garcia Aranda, 9 February 2015. One specimen: Cerro La Viga (25°20'27.80"N, 100°22'08.61"W, *ca.* 2543 m asl), 1.7 km E of La Peñita, Santiago, Nuevo Leon, Mexico. Moss on soil, coll. Mario Alberto Garcia Aranda, 9 February 2015. Two specimens: 7 km E of Agua de los Frijoles (28°57'42.952"N, 102°34'43.228"W, *ca.* 2263 m asl), Sierra Maderas del Carmen, Ocampo, Coahuila, Mexico. Moss on tree (*Quercus* sp.) coll. Jonas A. Delgadillo Villalobos, 19 December 2016.

Comments: Our specimens correspond well with the redescription given by Pilato & Binda (1998). *Diphascon pingue* has a Holarctic distribution (Pilato & Binda 1998, 1999). This is a new record for Mexico.

Subfamily: Hypsibiinae Pilato, 1969

Genus: *Hypsibius* Ehrenberg, 1848

Hypsibius cf. convergens

Terra typica: Lithuania (Europe).

Material examined: One specimen: Sierra Gomas, 3.3 km SW of La Higuera (26°22'8.537"N, 100°29'11.343"W, *ca.* 1264 m asl), Villaldama, Nuevo Leon, Mexico. Moss on rock, coll. Manuel Nevarez de los Reyes, 27 July 2014. Four specimens: El Pilar (25°17'23.13"N, 100°30'13.52"W, *ca.* 2973 m asl), Arteaga, Coahuila, Mexico. Moss on tree, coll. Mario Alberto Garcia Aranda, 14 February 2015.

Comments: Our specimens correspond well with the characteristics mentioned by Miller *et al.* (2005), however without a redescription of *Hypsibius convergens* (Urbanowicz, 1925), based on type specimens, a correct identification of this taxon is not possible. *Hypsibius cf. convergens* has a cosmopolitan distribution (McInnes 1994), but it is probably a species complex. In Mexico, this species was reported from Creel, Cuiteco and Temoris in the State of Chihuahua (Schuster 1971). This is a new record for the State of Nuevo Leon.

Subfamily: Itaquasconinae Rudescu, 1964

Genus: *Adropion* Pilato, 1987

***Adropion carolae* (Binda & Pilato, 1969)**

Terra typica: Italy (Europe).

Material examined: One specimen: Mesa del Oso (25°16'17.77"N, 100°13'41.86"W, *ca.* 2181 m asl), Vista Hermosa, Santiago, Nuevo Leon, Mexico. Moss on pine (*Pinus* sp.), coll. Jose Juan Flores Maldonado, 6 August 2014.

Comments: Our specimen correspond well with the original description. The species has a disjunct distribution, being reported from Monte Peloritani, Italy (Binda & Pilato 1969), Mont Fuji, Japan (Ito 1995, 1999), and Great Smoky Mountains National Park, North Carolina/Tennessee, USA (Bartels & Nelson 2007; Nelson & Bartels 2007, 2013; Bertolani *et al.* 2014a). Although this is a new record for Mexico, this species does require further study with more specimens.

Genus: *Astatumen* Pilato, 1997

***Astatumen trinacriae* (Arcidiacono, 1962)**

Terra typica: Italy (Europe).

Material examined: 27 specimens: 1.2 km E of La Peñita (25°20'44.31"N, 100°22'05.22"W, *ca.* 2370 m asl), Santiago, Nuevo Leon, Mexico. Moss on soil, coll. Mario Alberto Garcia Aranda, 9 February 2015. One specimen: 7 km E of Agua de los Frijoles (28°57' 42.952"N, 102°34' 43.228"W, *ca.* 2263 m asl), Sierra Maderas del Carmen, Ocampo, Coahuila, Mexico. Moss on tree (*Quercus* sp.) coll. Jonas A. Delgadillo Villalobos, 19 December 2016.

Comments: Our specimens correspond well with the definition of this species proposed by Dastych (1988). *Astatumen trinacriae* has a mainly Holarctic distribution (Kaczmarek *et al.* 2014; McInnes 1994) but can be confused with *Ast. bartosi* (Węglarska, 1959) (Zawierucha *et al.* 2014). This is a new record for Mexico.

Subfamily: Pilatobiinae Bertolani, Guidetti, Marchioro, Altiero, Rebecchi & Cesari, 2014

Genus: *Pilatobius* Bertolani, Guidetti, Marchioro, Altiero, Rebecchi & Cesari, 2014

***Pilatobius nodulosus* (Ramazzotti, 1957)**

Terra typica: USA (North America).

Material examined: Two specimens: Puerto El Gringo (25°23'11.38"N, 100°12'08.10"W, *ca.* 1684 m asl), La Botella, Santiago, Nuevo Leon, Mexico. Moss on tree (*Quercus* sp.), coll. Mario Alberto Garcia Aranda, 17 January 2015. One specimen: La Peñita (25°21'26.16"N, 100°22'08.03"W, *ca.* 2006 m asl), Santiago, Nuevo Leon, Mexico. Moss on soil, coll. Mario Alberto Garcia Aranda, 9 February 2015.

Comments: Our specimens correspond well with the original description. The species has a Nearctic distribution (McInnes 1994). In Mexico, it was reported in the State of Mexico by the Popocatepetl Volcano (Beasley 1972). This is the first record of this species for the State of Nuevo Leon.

Family: Ramazzottiidae Sands, McInnes, Marley, Goodall-Copstake, Convey & Linse, 2008

Genus: *Ramazzottius* Binda & Pilato, 1986

Ramazzottius cf. oberhaeuseri

Terra typica: Germany (Europe).

Material examined: Two specimens and one egg: Arroyo Blanco (25°51'35.37"N, 100°31'42.16"W, *ca.* 873 m asl), 1 km SW of La Purisima, Garcia, Nuevo Leon, Mexico. Moss on tree, coll. Miguel Angel Gonzalez Botello, 1 February 2014. One specimen: Puerto El Gringo (25°23'11.38"N, 100°12'08.10"W, *ca.* 1684 m asl), La Botella, Santiago, Nuevo Leon, Mexico. Moss on tree (*Quercus* sp.), coll. Mario Alberto Garcia Aranda, 17 January 2015.

Comments: Our specimens correspond well with the characteristics mentioned by Pilato *et al.* (2013). McInnes (1994) mentioned that *Ram. oberhaeuseri* (Doyère, 1840) has a cosmopolitan distribution but Pilato *et al.* (2013) reported the need for a revision of the species. Stec *et al.* (2018), suggested that lack of data to complete the identification, should be indicated by reference as *Ram. cf. oberhaeuseri*. In Mexico, it was reported in the States of Michoacán and Mexico (Beasley 1972). This is the third record for Mexico and a new record for the State of Nuevo Leon.

Order: Macrobiotidea Thulin, 1928

Family: Macrobiotidae Thulin, 1928

Genus: *Macrobiotus* C.A.S. Schultze, 1834

Macrobiotus* cf. *acadianus

Material examined: One specimen from Arroyo Blanco (25°51'35.37"N, 100°31'42.16"W, ca. 873 m asl), 1 Km at SW of La Purisima, Garcia, Nuevo Leon. Mexico. Moss on tree, coll. Miguel Angel Gonzalez Botello, 1 February 2014. Five specimens from Las Crucitas (24°30'46.62"N, 99°59'03.91"W, ca. 2499 m asl), Aramberri, Nuevo Leon. Mexico. Lichen on tree, coll. Miguel Angel Gonzalez Botello, 3 May 2014.

Comments: Our specimens correspond well with the original description (Meyer & Domingue 2011), but we did not find the eggs in our material and therefore the final identification is not possible. Meyer & Domingue (2011) described *Mac. acadianus* from Louisiana, USA, and the species has been reported from Louisiana and Texas, U.S.A. (Meyer 2013; Hinton *et al.* 2014; Kaczmarek *et al.* 2014; Meyer *et al.* 2014). Further samples with eggs are required to confirm whether this is a new species or new record for Mexico.

***Macrobiotus anemone* Meyer, Domingue & Hinton, 2014**

Terra typica: USA (North America).

Material examined: Five specimens and three eggs: La Posta (26°00'46.21.00"N, 97°58'59.00"W, ca. 22 m asl), 2.2 km N of Buenavista, Rio Bravo, Tamaulipas, Mexico. Lichen on mesquite tree (*Prosopis glandulosa*), coll. Antonio Moreno-Talamantes, 19 December 2016.

Comments: Our specimens and eggs correspond well with the original description. This species had only been reported from Louisiana, U.S.A. (Meyer *et al.* 2014; Kaczmarek *et al.* 2016). This is a new record for Mexico.

***Macrobiotus kazmierskii* Kaczmarek & Michalczyk, 2009**

Terra typica: Argentina (South America).

Material examined: 24 specimens and 19 eggs (two embryonated): Piedmont of Sierra Las Mitras (25°44'55.57"N, 100°24'11.19"W, ca. 632 m asl), Monterrey, Nuevo Leon, Mexico. Lichen (*Physcia stellaris*) on trees (*Parinsonia aculeata* and *Celtis pallida*), coll. Antonio Moreno-Talamantes, 7 August 2014.

Comments: Our specimens and eggs correspond well with the original description and type material. This species has only been reported from Rio Negro Province, Nahuel Huapi National Park, Ventisquero Negro in Argentina (Kaczmarek & Michalczyk 2009; Kaczmarek *et al.* 2015; Roszkowska *et al.* 2016). This is a new record for Mexico.

Genus: *Minibiotus* R.O. Schuster, 1980

***Minibiotus continuus* Pilato & Lisi, 2006**

Terra typica: Mexico (Central America).

Material examined: 15 specimens and one egg: Piedmont of Sierra Las Mitras (25°44'45.98"N, 100°25'27.68"W, ca. 700 m asl), Monterrey, Nuevo Leon, Mexico. Lichen (*Nephroma* sp.) on tree (*Quercus virginiana*), coll. Antonio Moreno-Talamantes, 8 November 2014. Five specimens and three eggs: 1 km E of La Peñita (25°20'50.79"N, 100°22'01.21"W, ca. 2250 m asl), Santiago, Nuevo Leon, Mexico. Moss on soil, coll. Mario Alberto Garcia Aranda, 9 February 2015. Three specimens and five eggs: Cerro La Viga (25°20'23.43"N, 100°22'06.42"W, ca. 2645 m asl), 2 km E of La Peñita, Santiago, Nuevo Leon, Mexico. Moss on soil, coll. Mario Alberto Garcia Aranda, 9 February 2015.

Comments: Our specimens and eggs correspond well with the original description. *Minibiotus continuus* has been reported in several localities in Costa Rica and Mexico (Pilato & Lisi 2006; Kaczmarek *et al.* 2011, 2014; Meyer 2013), and probably has a wider Neotropical distribution. This is a new record for the State of Nuevo Leon.

Minibiotus cf. intermedius

Material examined: Six specimens: near to Cueva El Infierno (25°18'30.95"N, 100°12'37.85"W, ca. 1522 m asl), La Camotera, Santiago, Nuevo Leon, Mexico. Moss on pine (*Pinus* sp.), coll. Jose Juan Flores Maldonado, 6 August 2014.

Comments: McInnes (1994) mentioned that *Min. intermedius* (Plate, 1888) has a cosmopolitan distribution. However, modern taxonomy has shown that it is species complex (Claxton 1998). It is possible that the North American records belong to other species. Kaczmarek *et al.* (2016) suggested that all North American reports should be considered questionable and needed further examination. In Mexico, *Min. cf. intermedius* it was found in Barranca del Cobre, Chihuahua (Schuster 1971). In our material we did not find the eggs and therefore the final identification is not possible.

Order: Isohypsibioidea Sands, McInnes, Marley, Goodall-Copestake, Convey & Linse, 2008

Family: Isohypsibiidae Sands, McInnes, Marley, Goodall-Copestake, Convey & Linse, 2008

Genus: *Doryphoribius* Pilato, 1969

***Doryphoribius dawkinsi* Michalczyk & Kaczmarek, 2010**

Terra typica: Costa Rica (Central America).

Material examined: One specimen: 400 m S of El Venadito (25°21'03.31"N, 100°20'45.18"W, ca. 2090 m asl), Santiago, Nuevo Leon, Mexico. Moss on soil, coll. Oscar Ballesteros Medrano, 30 March 2014. Four specimens: Puerto El Gringo (25°23'11.38"N, 100°12'08.10"W, ca. 1684 m asl), La Botella, Santiago, Nuevo Leon, Mexico. Moss on tree (*Quercus* sp.), coll. Mario Alberto Garcia Aranda, 17 January 2015.

Comments: Our specimens correspond well with the original description. The species has been found in Costa Rica (Michalczyk & Kaczmarek 2010), and Kansas, USA (Spiers *et al.* 2013). This is a new record for Mexico.

***Doryphoribius quadrituberculatus* Kaczmarek & Michalczyk, 2004**

Terra typica: Costa Rica (Central America).

Material examined: 13 specimens: Los Manantiales (25°43'02.98"N, 100°04'18.71"W, ca. 353 m asl), SE of Dulces Nombres, Pesqueria, Nuevo Leon, Mexico. Moss on tree (*Ehretia anacua*), coll. Miguel Angel Gonzalez Botello, 4 January 2014.

Comments: Our specimens correspond well with the original description and type material. The species is known in Costa Rica (Kaczmarek & Michalczyk 2004; Kaczmarek *et al.* 2014), and Saint Paul parish, Commonwealth of Dominica, (Hinton *et al.* 2013). *Doryphoribius quadrituberculatus* probably has a wide Neotropical distribution and this is a new record for Mexico.

Discussion

Distribution. Kaczmarek *et al.* (2016) reported 274 species of tardigrades from North America, of which 35 (12.77%) were also reported from Mexico. In South America, 235 species were reported (Meyer 2013; Kaczmarek *et al.* 2015, 2017 and literature cited therein; Londoño *et al.* 2017; Roszkowska *et al.* 2015, 2016, 2017, 2018; Daza *et al.* 2017; Stec *et al.* 2018), of which 32 (13.62%) were reported from Mexico. Approximately 104 species have been reported for Central America, including Mexico (Kaczmarek *et al.* 2014; Moreno-Talamantes *et al.* 2015; Pérez-Pech *et al.* 2017), of which 48 (46.15%) occur in Mexico.

Compared at the country level, the species richness of tardigrades found in Mexico (55 species) is lower than larger North American countries such as the USA (224 species) and Canada (120 species), or countries of South America like Argentina (119 species), Brazil (61 species), and Chile (63 species) (Kaczmarek *et al.* 2014, 2015, 2016; Kaczmarek & Roszkowska 2016; Roszkowska *et al.* 2016). However, the Mexican species richness is higher than countries like Colombia (43 species), Bolivia (36 species), Peru (29 species), Uruguay (26 species) and Venezuela (21 species), and all countries of Central America, with the exception of Costa Rica (63 species) (Kaczmarek

et al. 2014, 2015; Londoño *et al.* 2017; Melo *et al.* 2015; Kaczmarek & Roszkowska 2016; Stec *et al.* 2018). The disparity in species richness is likely affected by sampling intensity and biodiversity of habitats and the size (area) of the countries sampled.

Mexican flora and fauna is highly diverse, due to the convergence of the Nearctic and Neotropical biogeographic regions, as well as the complex relief, wide variation of climatic conditions, and its geological history (Sierra *et al.* 2014). Therefore, the small number of tardigrade species reported, so far, from this region is rather surprising. The main reason of this situation is the low number of studies conducted on this group in Mexico, which mostly corresponds to the occasional collection. The number of reported tardigrade species would increase rapidly if more studies aimed at understanding this group were to be conducted. This is becoming obvious when the present study has increased number of species from 44 to 55; representing a 25% increase. When considering that the geographical area covered by this study is rather small (parts of the states of Coahuila, Nuevo Leon, and Tamaulipas in north-eastern Mexico, which represents only 3% of the country), it is highly probable that further studies conducted in other regions of Mexico would increase the total number of species.

In present study we reported ten new records for the tardigrade fauna of Mexico from seven genera (*Ech. manulae*, *Mil. barbadosense*, *Adr. carolae*, *Ast. trinacriae*, *Dip. pingue*, *Dor. dawkinsi*, *Dor. quadrituberculatus*, *Mac. cf. acadianus*, *Mac. anemone*, *Mac. kazmierskii*), and one species new for science (*Mil. cassandrae* **sp. nov.**). Eight species, from eight genera, are endemic or have only been reported from Mexico (*Ech. siegristi* Heinis, 1911, *Pse. gullii* Pilato & Lisi, 2006, *Mil. cassandrae* **sp. nov.**, *Doryphoribius mexicanus* Beasley, Kaczmarek & Michalczyk, 2008, *Dor. chetumalensis*, *Haplomacrobotus hermosillensis* May, 1948, *Mesobiotus contii* (Pilato & Lisi, 2006), *Mac. ocotensis* Pilato, 2006).

With the information provided in this study, the diversity of tardigrades by states in Mexico (Table 4) is as follows: Chiapas (9 taxa), Chihuahua (15 taxa), Coahuila (3 taxa), State of Mexico (8 taxa), Michoacán (2 taxa), Morelos (6 taxa), Nuevo Leon (20 taxa), Oaxaca (8 taxa), Quintana Roo (1 taxa), Sinaloa (2 taxa), Sonora (1 taxa) and Tamaulipas (2 taxa). It should be noted that for 20 of the 32 Mexican states there are no records of tardigrades.

Comments on pseudoplates in the genus *Milnesium*. Tibbs *et al.* (2016) and Morek *et al.* (2016) showed a new morphological trait in *Milnesium* species; the pseudoplates. Tibbs *et al.* (2016) observed and showed these structures using a UV fluorescence microscopy technique for *Mil. beatae*, but did not describe the shape and arrangement of these pseudoplates in detail. Simultaneously, Morek *et al.* (2016) observed these structures in SEM and PCM in two species *Mil. variefidum* and *Mil. berladnicorum*, and proposed that the arrangements of these pseudoplates was a good taxonomic character for differentiating the *Milnesium* species. As was shown by Tibbs *et al.* (2016), and in present study, pseudoplates are much more visible under UV fluorescence microscopy than in PCM or SEM. Additionally, the pseudoplates arranged in the midline and posterior parts of the body are much more visible than laterally situated pseudoplates, which can easily be overlooked. We compared arrangement of pseudoplates (based on original slides, microphotographs and drawings) in all four species, *Mil. beatae*, *Mil. berladnicorum*, *Mil. cassandrae* **sp. nov.** and *Mil. variefidum*, and have found an interesting convergence. In all species the arrangements of the pseudoplates are identical, or almost the same at least in some rows. The main differences reported by Morek *et al.* (2016) were due to the lack of some pseudoplates—mainly on the anterior and lateral sides of the body; but we know already that these are sometimes very barely visible, especially when using only PCM or SEM. Additionally, some differences were also noted in the shape of those pseudoplates. However, the arrangement of pseudoplates in rows VIII and IX is identical in all four species.

In *Mil. beatae* and *Mil. cassandrae* **sp. nov.** the arrangement of pseudoplates is also the same in rows V–VII and probably in rows III–IV. Rows I and II are not clearly visible in the microphotographs nor on slides of *Mil. beatae* (Figs 3–4 and Fig. 1B in Tibbs *et al.* 2016).

In *Mil. variefidum* the configuration of pseudoplates in rows IV–VII is very similar to *Mil. beatae* and *Mil. cassandrae* **sp. nov.** but some of the “lateral” pseudoplates (placed laterally to the main plates situated in the midline of the body) are lacking. In row III only two pseudoplates are present instead of four visible in *Mil. beatae* and *Mil. cassandrae* **sp. nov.** There are no pseudoplates in rows I and II in *Mil. variefidum* (Figs 3–4, Figs 2A–D and 3A–D in Morek *et al.* 2016 and Fig. 1B in Tibbs *et al.* 2016).

In *Mil. berladnicorum* the configuration of the pseudoplates in row VII is very similar to other three species. In rows I–VI, in comparison to other three species, some “central” and “lateral” pseudoplates are lacking, have a different shape, or are poorly visible (Figs 3–4, Figs 2A–D, 3A–D and 6A, D in Morek *et al.* 2016 and Fig. 1B in Tibbs *et al.* 2016).

TABLE 4. Tardigrade species of Mexico with their state distribution (in **bold**—species new for Mexico; *—Endemic species of Mexico; ?—doubtful records and species identification need to be confirmed).

Species	State	Reference
<i>Cornechiniscus lobatus</i> Gąsiorek & Degma, 2018	NL, Sin	Beasley (1972), present study
? <i>Echiniscus kerguelensis</i> Richters, 1904	Mex, Mor	Beasley (1972)
<i>Echiniscus kofordi</i> Schuster & Grigarick, 1966	Chi	Pilato & Lisi (2006)
<i>Echiniscus manuelae</i> da Cunha & du Nascimento Ribeiro, 1962	NL	Present study
* <i>Echiniscus siegristi</i> Heinis, 1911	Oax	Heinis (1911)
<i>Echiniscus</i> cf. <i>tamus</i>	Chih, NL	Schuster (1971), present study
<i>Echiniscus viridis</i> Murray, 1910	Chi	Schuster (1971)
<i>Echiniscus viridissimus</i> Péterfi, 1956	Oax	Kaczmarek <i>et al.</i> (2011)
<i>Pseudechiniscus facettalis</i> Petersen, 1951	Chih	Schuster (1971)
* <i>Pseudechiniscus gullii</i> Pilato & Lisi, 2006	Chi	Pilato & Lisi (2006)
<i>Pseudechiniscus</i> cf. <i>juanitae</i>	Chi, NL	Pilato & Lisi (2006), present study
? <i>Pseudechiniscus suillus</i> (Ehrenberg, 1853)	Oax	Heinis (1911)
<i>Milnesium barbadosense</i> Meyer & Hinton, 2012	NL	Present study
<i>Milnesium cassandrae</i> sp. nov.	NL, Tams	Present study
? <i>Milnesium tardigradum tardigradum</i> Doyère, 1840	Chih, Mex, Mor	Schuster (1971), Beasley (1972), Kaczmarek <i>et al.</i> (2011)
<i>Adropion carolae</i> (Binda & Pilato, 1969)	NL	Present study
<i>Astatumen trinacriae</i> Pilato, Sabella, D'Urso & Lisi, 2017	NL, Coah	Present study
? <i>Diphascon chilense</i> Plate, 1888	Chih	Schuster (1971)
<i>Diphascon pingue</i> (Marcus, 1936)	NL, Coah	Present study
? <i>Hypsibius</i> cf. <i>convergens</i>	Chih, NL, Coah	Schuster (1971), present study
? <i>Hypsibius pallidus</i> Thulin, 1911	Unknown	Ramazzotti & Maucci (1983)
<i>Itaquascon umbellinae</i> de Barros, 1939	Chih	Schuster (1971)
<i>Pilatobius nodulosus</i> (Ramazzotti, 1957)	Mex, NL	Beasley (1972), present study
<i>Ramazzottius baumanni</i> (Ramazzotti, 1962)	Mex, Mich, Mor	Beasley (1972)
<i>Ramazzottius</i> cf. <i>oberhaeuseri</i>	Mex ⁺ , Mich ⁺ , NL	Beasley (1972), present study
* <i>Doryphoribius chetumalensis</i> Pérez– Pech, Anguas– Escalante, Cutz– Pool & Guidetti, 2017	QRoo	Pérez– Pech <i>et al.</i> (2017)
<i>Doryphoribius dawkinsi</i> Michalczyk & Kaczmarek, 2010	NL	Present study
<i>Doryphoribius evelinae</i> (Marcus, 1928)	Chih	Schuster (1971)
? <i>Doryphoribius flavus</i> (Iharos, 1966)	Chi	Pilato & Lisi (2006)
<i>Doryphoribius gibber</i> Beasley & Pilato, 1987	Chi	Pilato & Lisi (2006)
* <i>Doryphoribius mexicanus</i> Beasley, Kaczmarek & Michalczyk, 2008	Oax	Beasley <i>et al.</i> (2008)
<i>Doryphoribius quadrituberculatus</i> Kaczmarek & Michalczyk, 2004	NL	Present study
* <i>Haplomacrobotus hermosillensis</i> May, 1948	Son	May (1948)
<i>Isohypsibius sattleri</i> (Richters, 1902)	Chi	Pilato & Lisi (2006)
<i>Isohypsibius sculptus</i> (Ramazzotti, 1962)	Mor	Beasley (1972)
<i>Dactylobiotus parthenogeneticus</i> Bertolani, 1982	NL	Moreno–Talamantes <i>et al.</i> (2015)
<i>Macrobotus</i> cf. <i>acadianus</i>	NL	Present study
<i>Macrobotus anemone</i> Meyer, Domingue & Hinton, 2014	Tams	Present study
<i>Macrobotus alvaroi</i> Pilato & Kaczmarek, 2007	Chi	Kaczmarek <i>et al.</i> (2011)
? <i>Macrobotus ascensionis</i> Richters, 1908	Unknown	Ramazzotti & Maucci (1983)
? <i>Macrobotus echinogenitus</i> Richters, 1904	Mex	Beasley (1972)
<i>Macrobotus furcatus</i> Ehrenberg, 1859	Mex, Mor	Beasley (1972)

.....continued on the next page

TABLE 4. (Continued)

Species	State	Reference
? <i>Macrobiotus hufelandi hufelandi</i> C.A.S. Schultze, 1834	Chih, Mex, Mor	Heinis (1911), Schuster (1971), Beasley (1972)
<i>Macrobiotus kazmierskii</i> Kaczmarek & Michalczyk, 2009	NL	Present study
* <i>Macrobiotus ocotensis</i> Pilato, 2006	Chih	Pilato (2006)
? <i>Macrobiotus persimilis</i> Binda & Pilato, 1972	Chih	Kaczmarek <i>et al.</i> (2011)
? <i>Macrobiotus rubens</i> Murray, 1907	Oax	Heinis (1911)
<i>Macrobiotus terminalis</i> Bertolani & Rebecchi, 1993	Oax	Kaczmarek <i>et al.</i> (2011)
* <i>Mesobiotus contii</i> (Pilato & Lisi, 2006)	Chi	Pilato & Lisi (2006)
<i>Mesobiotus coronatus</i> (de Barros, 1942)	Chih, Oax	Schuster (1971), Kaczmarek <i>et al.</i> (2011)
? <i>Mesobiotus harmsworthi harmsworthi</i> (Murray, 1907)	Oax, Sin	Heinis (1911), Beasley (1972)
<i>Minibiotus continuus</i> Pilato & Lisi, 2006	Chi, NL	Pilato & Lisi (2006), present study
<i>Minibiotus cf. intermedius</i>	Chih, NL	Schuster (1971), present study
? <i>Paramacrobiotus (Amicrobiotus) areolatus</i> (Murray, 1907)	Chih	Schuster (1971)
? <i>Paramacrobiotus (Paramacrobiotus) richtersi</i> (Murray, 1911)	Chih	Schuster (1971)

States: BCS= Baja California Sur, Chi= Chiapas, Chih=Chihuahua, Coah= Coahuila, Mex= Mexico State, Mich= Michoacan, Mor= Morelos, NL= Nuevo Leon, Oax= Oaxaca, QRoo= Quintana Roo, Sin= Sinaloa, Son= Sonora, Tams= Tamaulipas.

Our conclusion is that the arrangement of the pseudoplates in *Milnesium* taxa is not species specific, but it is rather a constant character connected with the specific structure of the cuticle in entire genus. This is based on the similarities we found in configuration of pseudoplates, and the fact that pseudoplates of *Mil. berladnicorum* and *Mil. variefidum*, were observed only under PCM and SEM, and the pseudoplates in rows I and II in *Mil. beatae* were not very visible in the microphotographs. Those species ‘lacking pseudoplates’ or pseudoplates with different shapes were located in anterior part of the body or laterally to the midline of the body, where we showed the pseudoplates are difficult to observe. This conclusion, however, needs to be confirmed with more detailed studies on a larger number of *Milnesium* species observed under UV fluorescence microscopy. At present we strongly suggest using this feature in the differentiation of *Milnesium* species very carefully or not at all.

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