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**A new North American region colonized by the Australian millipede *Akamptogonus novarae* (Humbert & DeSaussure, 1869) (Polydesmida, Paradoxosomatidae), with a key for the known Paradoxosomatidae species from North and Central America and the Caribbean Islands.**

Introduced species represent one of the most concerning factors in conservation biology, as they may become a threat for native biodiversity and ecosystems' equilibrium. Human activity has become a strong dispersal force for organisms of any kind, either by actively releasing alien species or by passively transporting colonizers into new geographical areas. Although introductions of species have been occurring for thousands of years, their frequency has increased accordingly with the higher intensity of modern worldwide commercial and non-commercial movements

(Hulme 2009). In the majority of cases, introduced species fail to thrive in the new environments and in fact just a small part eventually become invasive and thus a threat for native biota. However, it is important to keep track on introductions, as often we do not fully understand the processes controlling biological invasions, and even small changes in biotic or abiotic factors can turn already established alien species into invasive (Mack et al. 2000).

Among soil organisms, several millipede species are currently established outside their original ranges. It seems that their introductions are frequently associated with the commerce of potted plants, and so it is even possible to find tropical species in green houses in temperate to cold latitudes (Stoev et al. 2010, Decker et al. 2014). Some of these species have been especially successful and are now present in localities all around the world. This is the case of some polydesmid species of the family Paradoxosomatidae, one of the most diverse groups of millipedes.

Paradoxosomatids are naturally present in every continent except Antarctica and North America (Nguyen & Sierwald 2013). They are represented in South America by the tribe Catharosomatini, but have not been very successful dispersing northwards. Only two species are known from Central America, *Iulidesmus isthmianus* (Loomis, 1961) from Panama and *I. moorei* (Hoffman, 1977) from Costa Rica. Another species, *I. semirugosus* (Pocock, 1888) is known from the Caribbean island of Dominica, although this could be the result of an introduction from an unknown source (Hoffman 1977).

Nevertheless, up to this day four species of diverse origin have colonized more or less successfully several North American territories (Hoffman 1999): *Oxidus gracilis* (C. L. Koch, 1847) (Figs. 2A, 3A, 4A), currently widespread from Canada to Mexico; *Orthomorpha coarctata* (DeSaussure, 1860) (Figs. 2B, 3B, 4B), mostly present around the Gulf of Mexico but also in the Mexican Pacific coast (Cupul-Magaña & Bueno-Villegas 2006); *Chondromorpha xanthotricha* (Attems, 1898) (Figs. 2C, 3C, 4C), known from several of the Antilles and a few scattered localities in Mexico and southern Texas (Shelley & Cupul-Magaña 2007). These three species are also known from multiple areas in Central America and the Caribbean islands (Hoffman 1999).

Apparently the most recent addition to this group is *Akamptogonus novarae* (Humbert &



Figure 1. Habitus of *Akamptogonus novarae* male from Mexico City, Mexico.

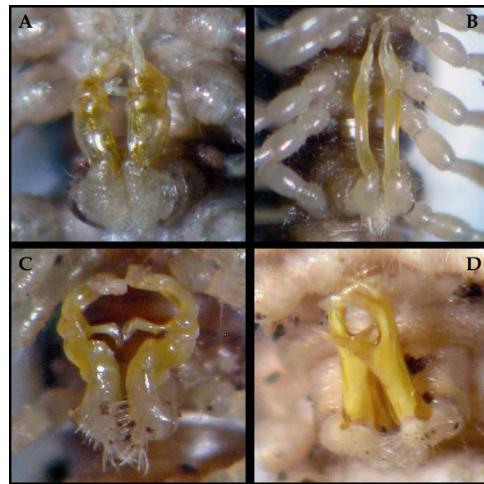
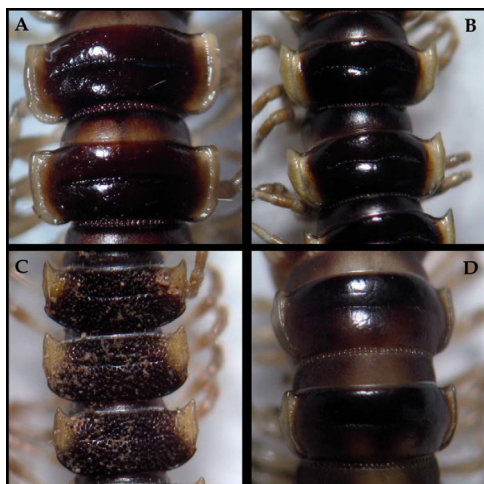


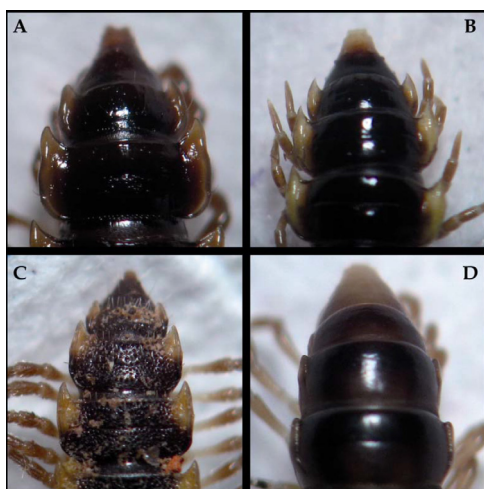
Figure 2. In situ view of gonopods from: A) *Oxidus gracilis*, B) *Orthomorpha coarctata*, C) *Chondromorpha xanthotricha*, D) *Akamptogonus novarae*.

DeSaussure, 1869) (Figs. 1, 2D, 3D, 4D), an Australian species sparsely reported along the coast of California (Hoffman 1979, Shelley 2002). *Akamptogonus* is a small genus in the tribe Australiosomatini currently comprising two species, *A. novarae* and *A. caragoon* Rowe & Sierwald, 2006. Both seem native to New South Wales, Australia, but the former is currently widespread and found in several Australian territories and also in New Zealand, Hawaii and, as mentioned before, California (Nguyen & Sierwald 2013), indicating a strong potential as an invasive species.

During separate visits into urban green areas in central Mexico along 2013 and 2014 we observed several individuals of *A. novarae*, and so it is hereby reported for the first time for this region. Sampling was performed by active search under stones and logs, under the bark of fallen



**Figure 3.** Segments 9 and 10: A) *Oxidus gracilis*, B) *Orthomorpha coarctata*, C) *Chondromorpha xanthotricha* (segment 11 also shown), D) *Akamptogonus novarae*.



**Figure 4.** Body end: A) *Oxidus gracilis*, B) *Orthomorpha coarctata*, C) *Chondromorpha xanthotricha*, D) *Akamptogonus novarae*.

logs, among leaf litter and other vegetal debris and inside decayed wood. Collected specimens were preserved in 95% ethanol.

Additional information was gathered from material deposited at the Colección Nacional de Acarología (CNAC), Instituto de Biología, Universidad Nacional Autónoma de México. Part of the observed material was collected and deposited in the CNAC or kept in ER personal collection.

Pictures were taken with a Canon Ixus 70 digital camera coupled to a Leica EZ4 stereo microscope. Illustrated specimens are currently held in ER personal collec-

tion, with codes ERG2955 (*O. gracilis*), ERG2909 (*O. coarctata*), ERG2956 (*C. xanthotricha*) and ERG2836 (*A. novarae*).

The species was observed in several localities in the south-western part of Mexico City, in habitats with moderate to high anthropogenic disturbance, at altitudes between 2322 to 2495 meters above sea level (masl). Another population was located in the State of Tlaxcala, in an urban forest with mixed native scrub vegetation and *Eucalyptus* trees at an elevation of 2311 masl. The precise data for each population is:

Mexico City: Jardín Botánico IBUNAM, 19°19'07"N 99°11'36"W, 2326 masl, found under stones and logs in areas of exposed volcanic rock and scrub vegetation in several visits, 20-IX-2013 (1 ♂, 1 immature), 22-I-2014 (1 immature), 20-V-2014 (4 ♂♂, 3 ♀♀, 4 immatures), 29-VII-2014 (4 ♂♂, 1 ♀); Ciudad Universitaria, 19°19'17"N 99°11'34"W, 2322 masl, found in a sidewalk by a recently mowed meadow, 7-XI-2013 (1 ♂); Bosque de Tlalpan, 19°17'46"N 99°12'02"W, 2389 masl, found under stones and vegetal debris in scrubland and *Eucalyptus* plantation on volcanic soil in several visits, 7-XII-2013 (1 ♂), 13-VII-2014 (1 ♂, 2 ♀♀), 22-VIII-2014 (1 ♂, 2 immatures); Colonia Ampliación Miguel Hidalgo, found in a small flower bed, inside a large piece of partially decayed *Yucca* log, 19°16'59"N 99°12'38"W, 2495 masl, 4-XII-2014 (4 ♂♂, 1 ♀, 32 immatures); CNAC-DI000386, "Km. 5.5 antigua carretera México-Cuernavaca", C. Beutelspacher leg., 15-VIII-1983 (4 ♂♂, 5 ♀♀).

Tlaxcala: Parque de la Amistad, San Diego Metepec, 19°17'58.9"N 98°14'41.4"W, 2311 masl, found under vegetal debris in scrubland and *Eucalyptus* plantation on sandy soil, 5-VII-2014 (2 ♂♂, 2 ♀♀).

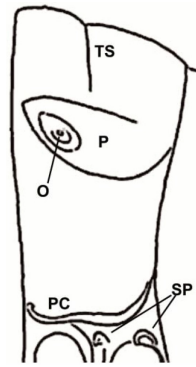
Additionally, another specimen with no locality data but undoubtedly from somewhere in Mexico, is deposited at the CNAC: CNAC-DI000251, C. V. Castelo leg., 20-VIII-1998 (1 ♂).

*Akamptogonus novarae* is readily identifiable and distinguishable from the rest of the paradoxosomatids already established in North America. Detailed diagnosis can be found in Shelley & Lehtinen (1998) and Rowe & Sierwald (2006). As usual in most Diplopoda, the best identification method is checking the structure of male gonopods (Fig. 2, see also illustrations in Shelley & Lehtinen 1998), but there are also other non-gonopodal characters that seem reliable for that purpose, as shown in the following key. Non-gonopodal characters use-

ful for identification are important, as collections often do not include adult males. To make the key useful at a larger geographical scale, we included all naturalized species and also *Iulidesmus* species known from Central America and the Caribbean islands (characters taken from the literature):

1. Reduced paranota (Figs. 3D, 4D)..... 2  
 – Paranota well developed, even in segments 18-19 (Figs. 3A-C, 4A-C).....5
2. Pleurosternal carinae absent; only known in America from California and Central Mexico .....  
*Akamptogonus novarae*  
 – Pleurosternal carinae (Fig. 5) well-marked.....3
3. Dorsal surface irregularly roughened; known only from Dominica .....*Iulidesmus semirugosus*  
 – Dorsal surface smooth .....4
4. Coloration generally dark brown with a narrow yellow/whitish, moniliform, middorsal band; transverse sulcus (Fig. 5) in metazonites shallow; known only from Costa Rica ...*Iulidesmus moorei*  
 – Coloration generally dark brown with a broad yellow/whitish middorsal band; transverse sulcus (Fig. 5) in metazonites strongly impressed; known only from Panama .....*Iulidesmus isthmiannus*
5. Metazonites with granular surface and with three transverse rows of setae; setae from the posterior side are especially conspicuous as they are directed backwards, overlapping the following prozonite (Figs. 3C, 4C) .....  
*Chondromorpha xanthotricha*  
 – Metazonites with smooth surface (Figs. 3A-B, 4A-B) .....6
6. Posterior angles of paranota acute and clearly extending beyond metazonites' posterior margin (Figs. 3B, 4B).....*Orthomorpha coarctata*  
 – Posterior angles of paranota not acutely produced caudad in most of the segments, being so only in segments 16 to 19 (Figs. 3A, 4A).....  
*Oxidus gracilis*

Even if the presence of this Australian invader in Mexico has remained unnoticed until now, it seems that, as indicated by the material deposited in the CNAC collection, *A. novarae* has been established in the region at least since the early 80's, not much later than the first report in California (Hoffman 1979). This species has been found in two different areas in central Mexico, distant by almost 100 km. Further sampling will determine whether this population areas are isolated (suggesting at least two introduction events) or if the species has been able to spread over this distance from a sin-



**Figure 5.** Schematic representation of a metazonite of *Iulidesmus semirugosus* showing the main structures. TS: transverse sulcus; O: ozopore; P: paranotum; PC: pleurosternal carina; SP: spiracles.

gle introduced population.

As usual in this kind of organisms, it is likely that the arrival of *A. novarae* in Mexico was unintentional. Curiously, all localities where it has been found are characterized by the presence of *Eucalyptus* plantations. It is a possibility that its introduction was associated with the original stocks for any of these plantations, either seeds or seedlings. However, with the current information at hand it is not possible to determine neither how it arrived in Mexico nor where it came from. Further studies using molecular markers and a full sampling of the species could clarify some of these points. This species has been found in strict sympatry with both native (*Cleidogona*, *Parajulus*, *Peridontodesmus*) and introduced (*Cylindroiulus*, *Polydesmus*, *Oxidus*) millipedes. Detailed studies are necessary to evaluate its effects on native local communities of soil organisms.

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