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Checklist of Water mites in Mexico. Historical background and DNA barcoding perspectives

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Original research

ABSTRACT

Water mites are the most ubiquitous, abundant, diverse, and ecologically important group of arachnids in all freshwater environments. In Mexico, despite being a megadiverse country, only 271 species have been recorded so far since 1873. This is probably due to the scarcity of taxonomists in the country or the inherent complex morphology of this group, which challenges its systematics and its integration into other research studies. Molecular identification has been highly useful for practical applications of these organisms, while taxonomic identification work continues. Until now, a species checklist and reference information about water mites diversity and distribution in Mexico is lacking. In this work, we compiled species described or recorded in Mexico and provided preliminary data for a COI barcode library of the water mites in the country. This checklist includes 271 species from 25 families and 61 genera. In addition, the COI barcode library is supplied in a public dataset from the BOLD database (boldsystems.org); it contains 794 sequences corresponding to 103 BINs or putative species, of which only five of them have been identified to the species. We predict that the discovery of hidden diversity of mites will continue and improve after the use of integrative taxonomy tools. Also, their value as indicators of water quality will be re-evaluated, helping in the conservation of freshwater environments and the evaluation of the global warming impact.

Keywords barcode; catalogue; Hydrachnidia; species; richness

Introduction


Water mites represent the most abundant, diverse, and ecologically important group of arachnids in all freshwater environments (Smith *et al.* 2001; Di Sabatino *et al.* 2008), including interstitial waters, lotic, lentic, and temporary ponds (Di Sabatino *et al.* 2003). Water mites establish significant and multiple biotic interactions within their communities, primarily as parasites of, among others, several aquatic insects groups, such as plecopterans, dipterans, trichopterans, odonates, hemipterans, and also as predators of insect eggs and larvae, cladocerans, ostracods, and copepods (Proctor *et al.* 2015). Several studies have documented the effects of water mites on the survival or longevity of their hosts and the influence on the size and structure of their prey populations (Paterson 1970; Gliwicz and Biesiadka 1975; Proctor and Pritchard 2008). Even more significantly, the viability of water mites as bioindicators of the ecosystems they inhabit has been demonstrated, as a clear and predictable relationship exists between the quality of a water body and the composition of its mite fauna (Goldschmidt 2016). Global warming effects has been studied in semi-terrestrial mites (Zhang *et al.* 2021), but not with hydrachnids. However, some authors affirm that water mites could be a good model for long-term monitoring impacts of freshwater ecosystems including global climate change (Klimov *et*

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al. 2022). Therefore, the group constitutes an important tool for environmental diagnosis and biomonitoring.

Approximately 7,500 species have been described worldwide so far (Smit 2020); but the knowledge of faunal diversity is heterogeneous, with some regions being more explored than others and some not yet even explored (Goldschmidt 2002; Goldschmidt *et al.* 2022). Consequently, some time ago it was estimated that more than 10,000 species could reasonably occur in inland waters (Di Sabatino *et al.* 2003).

In Mexico, despite being a megadiverse country (Morrone 2019) only 271 species have been recorded since the formal study of the group in 1873 to the present. Therefore, it can be considered that historically, the taxonomic knowledge for this group increased recently, but still it is limited here (Cervantes-Martínez *et al.* 2023). Currently, the global trend of integrating molecular information (COI barcoding) for water mite studies seems promising in revealing new species, resolving taxonomic questions, and contributing to biodiversity baselines, and assessments (Blattner *et al.* 2019). This approach could allow their potential use in ecological research or biomonitoring while curatorial work is carried out (Pešić *et al.* 2021; Więcek *et al.* 2020).

For Mexican mite fauna, there are already multiple public COI barcode records and identifications down to the genus and family levels, revealing a potential high diversity of this group (Montes-Ortiz *et al.* 2020, 2022). However, most of these records are not identified to species-level, there is no checklist of water mite species and their distribution in Mexico and COI barcode sequences remain dispersed, challenging a comprehensive integration of data. This paper summarizes the species described in Mexico, their distribution areas, habitat types, and literature sources, and highlights the prospects for the future study of these organisms in the country.

Historical background

A brief summary of the historical background on water mites can be found at Cervantes-Martínez *et al.* (2023). Taxonomic studies in Mexico began formally with the description of two species of the genera *Eylais* and *Limnesia* collected in Guanajuato by the naturalist Alfred Dugés in 1873 and 1884, respectively. Later, in 1936 Ruth Marshall listed three new species (of which *Neumania cenotea* was synonymized) from the Yucatán state. During the decades of the 70's and 80's, the taxonomic knowledge of water mites experienced substantial growth, due to the contributions of Vidrine (1985a, 1985b, 1985c, 1986, 1996), and David Cook. The latter described in 1974 five species for Mexico, and added six years later 166 species more, on his book about neotropical water mites (Cook 1980). However, it is crucial to acknowledge that during this period, several species that were described, or recorded, were based on a small series of individuals, often lacking information on both sexes and assuming a cosmopolitan distribution of the species. Consequently, it is likely that different morphotypes and their variants described in the literature (e.g., *Hydrodroma peregrina peregrina* “The small genital form” and “The large genital form”) or subspecies (e.g., *Unionicola (Unionicola) gracilipalpis tenuis*) pertained in fact to different species.

Simultaneous to new species descriptions, Dr. Ana Hoffmann promoted the studies of mites in Mexico by establishing two laboratories dedicated to acarology, one at the National Polytechnic Institute in 1965 and the other at the National Autonomous University of Mexico in 1977. A year later, one of her students, Dr. Cristina Cramer, made significant contributions in acarology, with the “Taxonomy, Ecology, and Distribution of Water Mites of Mexico” project. This led to the addition of 50 new species descriptions between 1977 and 2000 (Rivas and Hoffmann 2000). In the same decade, Dr. Otero-Colina (1987a, 1987b) described another 11 new species from the southeast of Mexico and redescribed some others previously documented by Cook (1980).

Following this period, research on water mites in Mexico experienced a significant decline, only to be reignited with the addition of four new species of arrenurids in 2013 by Dr. Marcia

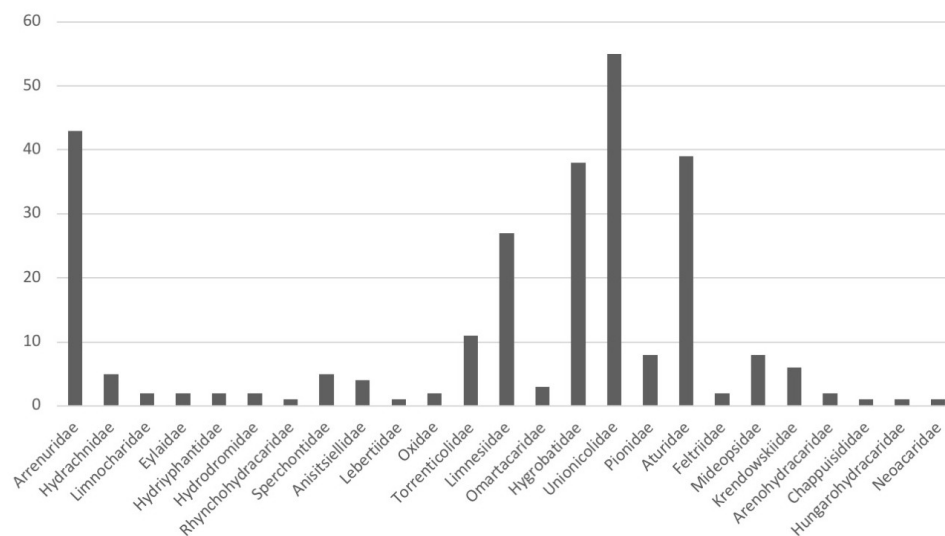


Figure 1 Species richness by family in Mexico.

Ramírez (Ramírez-Sánchez and Rivas 2013) and five more under the paradigm of integrative taxonomy by two of us in 2022 (Montes Ortiz *et al.* 2022).

Material and methods

An exhaustive review of journals and/or books and online literature containing data on water mites in Mexico was carried out. The main reference sources for species described or reported before 1980 were the catalog from Viets (1987) in which the contributions of various authors, such as Müller (1776), Berlese (1888), Piersig (1904), Dugés (1873, 1884) and Marshall (1903, 1908, 1919, 1936) are included. The book “Water mite genera and subgenera” (Cook 1974) was also consulted, it includes five species descriptions. The book “Studies on neotropical water mites” (Cook 1980) contains 166 original descriptions of species from southern and some northern regions of Mexico. All other records after 1980 included in this list were confirmed through the original publications.

The localities from which species were described or reported, accompanied by the habitat type and the reference are included in the checklist.

For DNA sequences, a public dataset, DS-MEXWM was created at Barcode of Life Data System (<https://boldsystems.org>) in which all the sequences from Mexican species available until now are included.

Results and discussion

In total, 271 species of water mites have been described or reported so far in Mexico since 1873. The species belong to 25 families and 61 genera. The families with the greatest species richness were Unionicolidae, Arrenuridae, Aturidae, Hygrobatidae, Limnesiidae, and Torrenticolidae (Figure 1), which together represent more than 75% of the species listed. The richest genera in the list were *Arrenurus* with 43 species described, followed by *Koenikea* with 24 species, *Unionicola* with 18, *Atractides* with 16 species, and *Limnesia* with 15.

This number of species is far from representing the true diversity of water mites in the country. Mexico, with an area of 1,964,375 km², boasts a heterogeneous mosaic of ecosystems

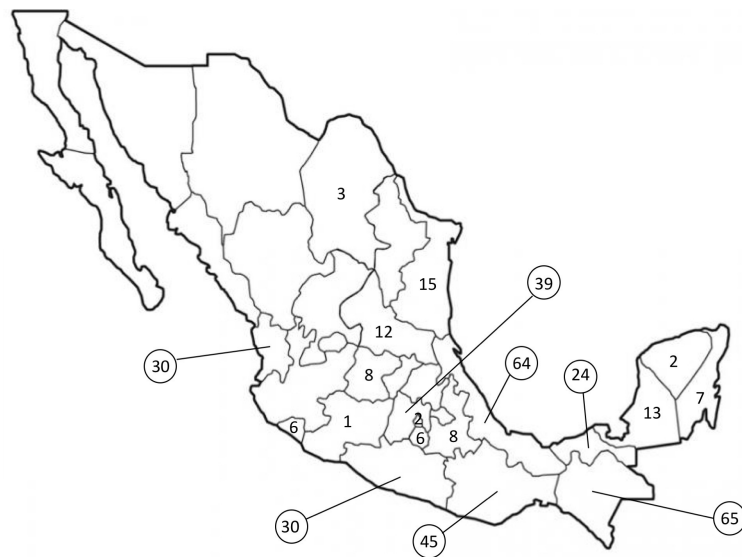


Figure 2 Number of species recorded by state in Mexico.

and complex biogeographic patterns, notably the confluence of the Nearctic and Neotropical regions, making it one of the countries with the highest biodiversity; it occupies second place in the world in species of reptiles and is among the first five as far as species of plants, amphibians, and mammals are concerned (Morrone 2019). Former studies have estimated that there are over 1,000 species of water mites in the Nearctic and over 1,300 in the Neotropical regions (Di Sabatino *et al.* 2008). However, some authors (Goldschmidt 2002) estimated that the true figure could be much higher, reaching up to 5,500 species in the Neotropical regions alone. Similar cases are observable in other aquatic groups, such as cladocerans, for which the taxonomic list is not complete either and clear differentiation between the Nearctic and Neotropical regions as well as restricted distribution patterns (Elías-Gutiérrez *et al.* 2001) are observed.

Politically Mexico is divided into 32 states. Nevertheless, this list cataloged water mites in only 19 states (Figure 2). There is no information available for the remaining 13 states located in Neartic and transition zones, representing over half of the country's unexplored territory.

For the states with records or descriptions, the majority corresponded to a few localities within each region. For example, Mexico state (a region in the Mexican highlands, in which the hydrological systems are located at an average altitude > 1000 above sea level) has 39 listed species (Figure 2). Of those, 21 belong to one location, the Stream Peña Blanca in San Francisco Oxtotilpan town (*Neotorrenticola davecooki*, *Neomamersa temazcala*, *Stygalmiella mexicana*, *Diamphidaxona anitae*, *Neotractides mexicana*, *Torrenticola keesdavitsi*, *T. kurtvietsi*, *T. carlbaderi*, *T. esbelta*, *Aturus matlatzinca*, *A. catoantoni*, *A. guillecrameri*, *A. celiahemkesae*, *A. oxtotilpanensis*, *A. primitivus*, *Kongsbergia antoniocatoi*, *K. cosita*, *K. tigrina*, *K. eterna*, *K. maternal* and *Kawamuracarus iansmithi*) (Cook 1980; Cramer 1987, 2000; Cramer and Smith 1991; Cramer 1992a, 1992b; Cramer and Letechipía 1996), 11 more were described from a stream in the Highway 134 at km 29 (*Bandakia mexicana*, *B. hoffmannae*, *Chappuisides notialis*, *Neoacarus adocetus*, *Eylais mexicana*, *Thyopsella obscura*, *Tyrrelia ovalis*, *Neumania conroyi*, *Mideopsis mexicana* and *Limnesia abenda*) (Cook 1980; Cramer and Smith 1991). Another five were described from Zempoala lagoons (*Sperchon mexicanus*, *Lebertia azteca*, *Atractides tanutus*, *Atractides zempoalus*, *Arrenurus zempoala*) (Cook 1980) and the last two (*Hydrachna leovazquezae* and *Stygarrenurus armoensis*) correspond to a pond in Highway Mexico-Tulancingo and a stream in Avándaro, near Valle de Bravo town (Cramer and Costero 1986; Cramer and Cook 1996). This implies that the water mite diversity in the state of Mexico, a region where three hydrological basins converge and with 11, 859 water reservoirs, mostly

Table 1 Checklist of water mite species in Mexico. * Without data collection.

Species	State	Habitat	Reference
Arrenuridae			
<i>Arrenurus (Arrenurus) dentipetiolatus</i>	Oaxaca, Guanajuato	Pond	Marshall 1908
<i>Arrenurus (Arrenurus) valenciis</i>	Campeche, Tabasco	Water-filled roadside	Marshall 1919
<i>Arrenurus (Arrenurus) munovus</i>	Chiapas	Stream	Cook 1980
<i>Arrenurus (Arrenurus) wucabus</i>	Oaxaca	Pond	Cook 1980
<i>Arrenurus (Arrenurus) tamaulipensis</i>	Tamaulipas	Lake	Cook 1980
<i>Arrenurus (Arrenurus) xochimilcoensis</i>	Mexico City	Standing waters	Cramer and Cook 1992
<i>Arrenurus (Megaluracarus) manubriator</i>	Tabasco	Pond	Marshall 1903
<i>Arrenurus (Megaluracarus) birgei</i>	Campeche	Lagoon	Marshall 1903
<i>Arrenurus (Megaluracarus) marshallae</i>	Campeche	Water-filled ditch	Piersig 1904
<i>Arrenurus (Megaluracarus) gricalus</i>	Veracruz	Pond	Cook 1980
<i>Arrenurus (Megaluracarus) hartesus</i>	Tabasco	Pond	Cook 1980
<i>Arrenurus (Megaluracarus) neoexpansus</i>	Tabasco	Pond	Cook 1980
<i>Arrenurus (Megaluracarus) tabascoensis</i>	Campeche	Water-filled ditch	Cook 1980
<i>Arrenurus (Megaluracarus) trassamus</i>	Tabasco	Pond	Cook 1980
<i>Arrenurus (Megaluracarus) zitavus</i>	Campeche	Water filled-ditch	Cook 1980
<i>Arrenurus (Megaluracarus) campechensis</i>	Campeche	Water filled-ditch	Cook 1980
<i>Arrenurus (Megaluracarus) wolardus</i>	Veracruz, Colima	Pond	Cook 1980
<i>Arrenurus (Megaluracarus) costeroae</i>	Tamaulipas	Lake	Cramer and Cook 1992
<i>Arrenurus (Megaluracarus) alloexpansus</i>	Colima	Not specified	Cramer and Cook 1992
<i>Arrenurus (Megaluracarus) apizanus</i>	Tamaulipas	Lake	Cramer and Cook 1992
<i>Arrenurus (Megaluracarus) catoi</i>	Tamaulipas	Lake	Cramer and Cook 1992
<i>Arrenurus (Megaluracarus) champayanus</i>	Tamaulipas	Lake	Cramer and Cook 1992
<i>Arrenurus (Megaluracarus) colitus</i>	Tamaulipas	Lake	Cramer and Cook 1992
<i>Arrenurus (Megaluracarus) anae</i>	Tamaulipas	Lake	Cramer and Cook 1998
<i>Arrenurus (Megaluracarus) anitahoffmannae</i>	Tabasco	Lake, pond, canal	Ramirez-Sánchez and Rivas 2013
<i>Arrenurus (Megaluracarus) olmeca</i>	Tabasco	Lake, pond, canal	Ramirez-Sánchez and Rivas 2013
<i>Arrenurus (Megaluracarus) maya</i>	Yucatán, Quintana Roo	Cenote	Ramirez-Sánchez and Rivas 2013
<i>Arrenurus (Megaluracarus) urbanus</i>	Mexico city	Canal	Ramirez-Sánchez and Rivas 2013
<i>Arrenurus (Megaluracarus) eduardoi</i>	Quintana Roo	Pool (in a stream)	Montes-Ortiz et al. 2022
<i>Arrenurus (Megaluracarus) federicoi</i>	Quintana Roo	Pool (in a stream)	Montes-Ortiz et al. 2022
<i>Arrenurus (Megaluracarus) ecosur</i>	Quintana Roo	Cenote, lagoon, wetlands	Montes-Ortiz et al. 2022
<i>Arrenurus (Megaluracarus) beatrizae</i>	Quintana Roo, Tabasco	Wetland, lagoon	Montes-Ortiz et al. 2022
<i>Arrenurus (Dadayella) zempoala</i>	Mexico state	Small stream	Cook 1980
<i>Arrenurus (Dadayella) adrianae</i>	Colima, Michoacan	Wetland, lagoon	Cramer and Cook 1992
<i>Arrenurus (Dadayella) veracruzensis</i>	Veracruz	Pond	Cramer and Cook 1992
<i>Arrenurus (Dadayella) aztecus</i>	Veracruz	Wetland, lagoon	Cramer and Cook 1992
<i>Arrenurus (Dadayella) colimensis</i>	Colima	Wetland, lagoon	Cramer and Cook 1992
<i>Arrenurus (Dadayella) cristinae</i>	Quintana Roo	Wetland	Montes-Ortiz et al. 2022
<i>Arrenurus (Truncaturus) plevamus</i>	Guerrero	Small stream	Cook 1980
<i>Arrenurus (Truncaturus) zukovus</i>	Chiapas	Gravel-bottom stream	Cook 1980
<i>Arrenurus (Truncaturus) teoceloensis</i>	Veracruz	Stream	Rivas and Cramer 1992
<i>Arrenurus (?Arrenuropopsis) mexicanus</i>	Tamaulipas, Colima	Lagoon	Cramer and Cook 1992
<i>Arrenurus (?) nayaritensis</i>	Nayarit	Small stream	Cook 1980
Hydrachnidae			
<i>Hydrachna miliaria</i>	Oaxaca	Pond	Berlese 1888 in Cook 1980
<i>Hydrachna leovazquezae</i>	Mexico state	Temporal pond	Cramer and Costero 1986
<i>Hydrachna guanajuatensis</i>	Guanajuato	Pond	Cook 1980
<i>Hydrachna mexicana</i>	Veracruz	Pond	Cook 1980
<i>Hydrachna rotunda</i>	Oaxaca, Nayarit, Guanajuato.	Pond	Marshall 1930 in Cook 1980
Limnocharidae			
<i>Rhyncholimnochares (Rhyncholimnochares)</i>	Chiapas	River	Cook 1980
<i>Rhyncholimnochares (Paralimnochares)</i>	Chiapas	River	Cook 1980
Eylaidae			
<i>Eylais guanajuatensis</i>	Guanajuato	*	Dugés 1873
<i>Eylais mexicana</i>	Mexico state	Helocrene spring	Cook 1980
Hydryphantidae			
<i>Hydryphantes (Hydryphantes) ramosus ramosus</i>	Oaxaca	Pond	Daday 1905 in Cook 1980
<i>Thyopsella obscura</i>	Mexico state.	Helocrene spring	Cook 1980
<i>Protzia</i>	Querétaro	Stream	Goldschmidt et al. 2015
Hydrodromidae			
<i>Hydrodroma peregrina peregrina</i>	Campeche, Guanajuato	Pond	Lundblad 1941 in Cook 1980
<i>Hydrodroma (Clavipes) despiciens</i>	Oaxaca, Chiapas, Veracruz, San Luis Potosí.	Stream, river.	Lundblad 1953 in Cook 1980
Rhynchohydracaridae			
<i>Clathrosperchon punctatus</i>	Oaxaca, Chiapas, Veracruz.	Matted roots, bottom of stream	Cook 1980
Sperchontidae			
<i>Sperchon mexicanus</i>	Mexico state	Stream	Cook 1980
<i>Sperchon neotropicus</i>	Oaxaca, Coahuila, Veracruz.	Algae on rocks, stream	Cook 1980
<i>Sperchon (Hispidopershon) gledhilli</i>	Oaxaca, Veracruz, Guerrero.	Stream	Viets 1977
<i>Sperchon (Acadiosperchon) pontifex</i>	Oaxaca	Submerged vegetation	Otero-Colina 1987a
<i>Sperchon (Mixosperchon) oaxacensis</i>	Oaxaca	Submerged vegetation	Otero-Colina 1987a
Anisitsiellidae			
<i>Bandakia hoffmannae</i>	Mexico state.	Spring	Cramer and Smith 1991
<i>Bandakia mexicana</i>	Mexico state.	Spring	Cramer and Smith 1991
<i>Mamersella mesoamericana</i>	Tabasco	Lagoon	Otero-Colina 1987a
<i>Mamersellides costeniis</i>	Veracruz, Colima, Estados Unidos (Florida)	Ponds, Marshes, backwater pools of streams.	Cramer and Smith 1993

Table 1 Continued.

Species	State	Habitat	Reference
Lebertiidae			
<i>Lebertia (Pseudolebertia) azteca</i>	Mexico state	Stream	Cook 1980
Oxidae			
<i>Oxus dugesi</i>	Veracruz, Costa Rica	Stream	Cook 1980
<i>Oxus stollii</i>	Guerrero	Tributary river	Cook 1980
Torrenticolidae			
<i>Torrenticola (Monoatractides) lembada</i>	Chiapas, Costa Rica	Stream, river.	Cook 1980
<i>Torrenticola (Monoatractides) gorda</i>	Nayarit, Guerrero, Oaxaca	River	Cook 1980
<i>Torrenticola (Monoatractides) veracruzensis</i>	Veracruz, Chiapas	Stream	Cook 1980
<i>Torrenticola (Torrenticola) rala</i>	Guerrero	River	Cook 1980
<i>Torrenticola (Torrenticola) keesdavidsi</i>	Mexico state.	Stream	Cramer 1992
<i>Torrenticola (Torrenticola) carlbaderi</i>	Mexico state.	Stream	Cramer 1992
<i>Torrenticola (Torrenticola) esbelta</i>	Mexico state.	Stream	Cramer 1992
<i>Torrenticola (Torrenticola) kurtvietsi</i>	Mexico state	Stream	Cramer 1992
<i>Neotorrenticola (Neotorrenticola) davecooki</i>	Mexico state	Stream	Cramer 1987
<i>Pseudotorrenticola (Pseudotorrenticola)</i>	Veracruz	Stream	Cramer and Cook 2000
<i>Pseudotorrenticola (Pseudotorrenticola) boettgeri</i>	Veracruz	Stream	Viets 1977 in Cramer and Cook 2000
Limnesiidae			
<i>Neomamersa (Neomamersa) mexicana</i>	Oaxaca, Guerrero	Bottom deposits of stream	Cook 1980
<i>Neomamersa (Neomamersa) triacebulata</i>	Chiapas	Gravels deposits of stream	Cook 1980
<i>Neomamersa (Neomamersa) temazcala</i>	Mexico state	Stream	Cramer 1987
<i>Meramecia (Meramecia) mexicana</i>	Chiapas, Oaxaca, Puebla	Gravel deposits of stream	Cook 1980
<i>Kawamuracarus (Kawamuracarus) expansipes</i>	Oaxaca, Chiapas	Gravel deposits of stream	Cook 1980
<i>Kawamuracarus (Kawamuracarus) novus</i>	Puebla	Gravel deposits of stream	Cook 1980
<i>Kawamuracarus (Kawamuracarus) iansmithi</i>	Mexico state	Stream	Cramer 1987
<i>Tyrrelia viuda</i>	Puebla	Stream	Cook 1980
<i>Tyrrelia ovalis</i>	Puebla, Mexico state	Stream	Marshall 1940 in Cook 1980
<i>Centrolimnesia (Centrolimnesia) motasi</i>	Chiapas	Pond	Cook 1980
<i>Centrolimnesia (Centrolimnesia) bondi</i>	Veracruz, Campeche	Swam, Pond	Lundblad 1935 in Cook 1980
<i>Limnesia alzatai</i>	Guanajuato	*	Dugés 1884
<i>Limnesia laeta</i>	Oaxaca, Tabasco	Pond	Stoll 1887 in Cook 1980
<i>Limnesia puteorum</i>	Guanajuato	*	Stoll 1987 in Wolcott 1903
<i>Limnesia (Limnesia) abenda</i>	Mexico state	Helocrene spring	Cook 1980
<i>Limnesia (Limnesia) banola</i>	Nayarit, Veracruz	Spring	Cook 1980
<i>Limnesia (Limnesia) canvada</i>	Nayarit	River	Cook 1980
<i>Limnesia (Limnesia) dimorpha</i>	Nayarit	Spring	Cook 1980
<i>Limnesia (Limnesia) dorrera</i>	Veracruz	Stream	Cook 1980
<i>Limnesia (Limnesia) mesoamericana</i>	Guerrero, Oaxaca, Chiapas, Morelos, Nayarit	River, stream	Cook 1980
<i>Limnesia (Limnesia) neodentipalpis</i>	Veracruz	Pond	Cook 1980
<i>Limnesia (Limnesia) setacoxalis</i>	Veracruz, Chiapas, Guerrero	Stream	Cook 1980
<i>Limnesia (Limnesia) trehona</i>	Guerrero	Spring	Cook 1980
<i>Limnesia (Limnesia) zomplina</i>	Nayarit, Veracruz	Pond	Cook 1980
<i>Limnesia (Limnesiella) mexicana</i>	Tabasco	Pond	Cook 1980
<i>Limnesia parafalsificata</i>	Tabasco, Chiapas	Pond	Otero-Colina 1987a
<i>Psammolimnesia (Psammolimnesia) mexicana</i>	Chiapas		Cook 1974
Omartacaridae			
<i>Omartacarus elongatus</i>	Puebla	Interstitial waters	Cook 1963 in Cook 1980
<i>Omartacarus brevipalpis</i>	Chiapas	Interstitial waters	Cook 1974
<i>Omartacarus motasi</i>	Chiapas	Sand and gravel of stream	Cook 1980
Hygrobatidae			
<i>Corticacarus novum</i>	Veracruz	Stream	Cramer and Cook 1998
<i>Corticacarus (Paracorticacarus) mexicanus</i>	Guerrero, Oaxaca, Chiapas	Stream	Cook 1980
<i>Corticacarus (Polycorticacarellus) similis</i>	Guerrero	Stream	Cook 1980
<i>Corticacarus (Polycorticacarellus) mebosus</i>	Chiapas, Veracruz	River	Cook 1980
<i>Neotractides curvispinatus</i>	Tabasco	Gravel in a stream	Otero-Colina 1987a
<i>Neotractides mexicana</i>	Mexico state	Stream	Cramer 1992
<i>Neotractides nayaritensis</i>	Nayarit	Stream	Cramer and Cook 2000
<i>Neotractides abueloi</i>	Veracruz	Stream	Cramer and Cook 2000
<i>Neotractides celiae</i>	Veracruz	Stream	Cramer and Cook 2000
<i>Hygrobates (Hygrobates) boettgeri</i>	Oaxaca, Chiapas, Guerrero, Morelos, Nayarit	Stream	Viets 1975 in Cook 1980
<i>Hygrobates (Hygrobates) plebejus</i>	Oaxaca, Chiapas, Veracruz, Morelos, Nayarit.	River	Lundblad 1930 in Cook 1980
<i>Hygrobates (Hygrobates) amplipalpis</i>	Oaxaca, Veracruz	Stream	Viets 1936 in Cook 1980
<i>Hygrobates (Hygrobates) ampliatus</i>	Veracruz, San Luis Potosí, Morelos	Stream	Viets 1936 in Cook 1980
<i>Hygrobates (Hygrobates) procursor</i>	Guerrero	Stream	Viets 1936 in Cook 1980
<i>Hygrobates (Hygrobates) blatolus</i>	Oaxaca	Tributary river	Cook 1980
<i>Hygrobates (Hygrobates) mexicanus</i>	Nayarit	River	Cook 1980
<i>Atractides (Atractides) crassitarsis</i>	Guerrero	Stream	Lundblad 1942 in Cook 1980
<i>Atractides (Atractides) imitatus</i>	Oaxaca	River	Viets 1978 in Cook 1980
<i>Atractides (Atractides) guatemaltecus</i>	Oaxaca, Chiapas, Guerrero.	Tributary river, stream	Viets 1978 in Cook 1980
<i>Atractides (Atractides) blazonus</i>	Oaxaca	Tributary river	Cook 1980
<i>Atractides (Atractides) mexicanus</i>	Oaxaca	Tributary river	Cook 1980
<i>Atractides (Atractides) neolongitarsus</i>	Coahuila	River	Cook 1980
<i>Atractides (Atractides) prasadi</i>	Chiapas	Stream	Cook 1980
<i>Atractides (Atractides) tanutus</i>	Mexico state	Stream	Cook 1980
<i>Atractides (Atractides) tembolus</i>	Chiapas	Stream	Cook 1980
<i>Atractides (Atractides) tolas</i>	Chiapas	Stream	Cook 1980

Table 1 Continued.

Species	State	Habitat	Reference
<i>Atractides (Atractides) toldomus</i>	Coahuila	River	Cook 1980
<i>Atractides (Atractides) travanus</i>	Chiapas, Oaxaca, Guerrero	Stream	Cook 1980
<i>Atractides (Atractides) wevamus</i>	Nayarit	River bottom deposits	Cook 1980
<i>Atractides (Atractides) zempoalus</i>	Mexico state	Stream	Cook 1980
<i>Atractides (Atractides) bassolsae</i>	Oaxaca	Stream	Otero-Colina 1987a
<i>Atractides (Octomegapus) peltatus</i>	Chiapas	River	Viets 1977 in Cook 1980
<i>Atractidella obtusidens</i>	Oaxaca, Chiapas, Veracruz	River, stream	Lundblad 1953 in Cook 1980
<i>Atractidella mesoamericana</i>	Chiapas	Stream	Cook 1980
<i>Paraschizobates scutatus</i>	Nayarit, Chiapas, Oaxaca	River, stream	Cook 1980
<i>Diamphidaxona mexicana</i>	Chiapas	Gravel deposits in stream	Cook 1980
<i>Diamphidaxona anitae</i>	Mexico state	Stream	Cramer and Letechipía 1996
Unionicolidae			
<i>Unionicola gracilpalpis tenuis</i>	Oaxaca, Campeche	Pond, water filled roadside	Lundblad 1935 in Cook 1980
<i>Unionicola (Unionicola) mexicana</i>	Tabasco	Pond	Cook 1980
<i>Unionicola (Pentatax) conjuncta</i>	Chiapas	Stream	Viets 1954 in Cook 1980
<i>Unionicola (Pentatax) furculopsis</i>	Oaxaca	Pond	Cook 1980
<i>Unionicola (Pentatax) aculeata</i>	Tamaulipas, northern and central Mexico	Freshwater mussel <i>Anodonta</i> sp., <i>Cyrtonaias tampicoensis</i> , <i>Disconaias</i> sp., <i>Friersonia</i> sp.	Koenike 1914 in Vidrine 1996
<i>Unionicola (Atacella) neoperforata</i>	Tamaulipas, San Luis Potosí.	Freshwater mussel <i>A. trapesialis glaucus</i>	Vidrine 1985b
<i>Unionicola (Atacella) petita</i>	Veracruz	Freshwater mussel <i>A. trapesialis glaucus</i>	Vidrine 1985b
<i>Unionicola (Atacella) entrerrianensis</i>	Tamaulipas, San Luis Potosí, Veracruz.	Freshwater mussel <i>A. trapesialis glaucus</i>	Rosso de Ferradás 1976
<i>Unionicola (Atacella) fissipes</i>	Western Mexico	Freshwater mussel <i>Anodontites</i>	Koenike, 1891
<i>Unionicola (Berezatax) berezai</i>	Veracruz, San Luis Potosí	Freshwater mussel <i>Nephronaias</i> sp.	Vidrine 1985a
<i>Unionicola (Berezatax) acylindrotarsa</i>	Tamaulipas, San Luis Potosí	Freshwater mussel <i>Popenaias</i> , <i>Nephronaias</i>	Vidrine 1985a
<i>Unionicola (Causeyaxax) hensleyi</i>	San Luis Potosí, Tamaulipas	Freshwater mussel <i>Friersonia iridella</i>	Vidrine 1985c
<i>Unionicola (Clarkatax) serrata</i>	San Luis Potosí, Tamaulipas, Veracruz (Panuco river system)	Friersonia iridella, <i>F. moctezumensis</i>	Wolcott 1898 in Vidrine 1996
<i>Unionicola (Hexatax) laurentiana</i>	San Luis Potosí, Tamaulipas, Veracruz (Panuco river system)	Freshwater mussel <i>Disconaias fimbriata</i> , <i>Nephronaias</i> sp., <i>Popenaias</i> sp.	Crowell and Davids 1979 in
<i>Unionicola (Unionicolides) burchi</i>	Guanajuato	Freshwater mussel <i>Anodonta</i> sp.	Vidrine 1996
<i>Unionicola (Unionicolides) cabnani</i>	Tamaulipas, Veracruz	Freshwater mussel <i>Cyrtonaias tampicoensis</i> , <i>Disconaias discus</i> .	Vidrine 1986
<i>Unionicola (Unionicolides) hoesei</i>	San Luis Potosí, Tamaulipas, Veracruz (Panuco river system)	Freshwater mussel	Vidrine 1986
<i>Unionicola (Neotax) abnormipes</i>	Tamaulipas	Freshwater mussel <i>Cyrtonaias tampicoensis</i>	Vidrine 1986
<i>Neumania (Neumania) conroyi</i>	Mexico state	Reocrene spring	Cook 1980
<i>Neumania (Neumania) diversipalpa</i>	Chiapas	River	Cook 1980
<i>Neumania (Neumania) alticola</i>	Chiapas, Campeche, Oaxaca, Tabasco, Veracruz.	Pond, stream.	Stoll 1886 in Cook 1980
<i>Neumania (Tetraneumania) nondanda</i>	Chiapas, Tabasco, Campeche	River	Cook 1980
<i>Neumania (Tetraneumania) cesateca</i>	Tabasco, Chiapas	River, Pond	Otero-Colina 1987b
<i>Recifella (Recifella) bella</i>	Veracruz, Chiapas	River, stream	Cook 1980
<i>Recifella (Eorecifella?) azteca</i>	Oaxaca	Pond	Cook 1980
<i>Recifella (Eorecifella) cemoba</i>	Chiapas	Stream	Cook 1980
<i>Recifella (Eorecifella) laversi</i>	Chiapas	River	Cook 1980
<i>Recifella (Eorecifella) alpa</i>	Veracruz	Stream	Cook 1980
<i>Recifella (Eorecifella) indistincta</i>	Yucatán	cenote (Sinkhole)	Marshall 1936 in Cook 1980
<i>Recifella (Recifelopsis) mexicana</i>	Chiapas, Veracruz	Stream	Cook 1980
<i>Recifella (Vietsella) veracruzana</i>	Veracruz	Pond	Cramer and Cook 1998
<i>Koenikea (Koenikea) canerma</i>	Tabasco	Pond	Cook 1980
<i>Koenikea (Koenikea) clazona</i>	Veracruz	Stream	Cook 1980
<i>Koenikea (Koenikea) gracilipes</i>	Nayarit, Chiapas, Guerrero	Stream	Cook 1980
<i>Koenikea (Koenikea) tobarana</i>	Nayarit	River, stream	Cook 1980
<i>Koenikea (Koenikea) trocala</i>	Guerrero	Spring	Cook 1980
<i>Koenikea (Koenikea) yenona</i>	Nayarit	Tributary river	Cook 1980
<i>Koenikea (Koenikea) zedima</i>	Chiapas, Tabasco	River	Cook 1980
<i>Koenikea (Koenikea) zolada</i>	Veracruz	River	Cook 1980
<i>Koenikea mesoamericana</i>	Chiapas	Stream	Cook 1980
<i>Koenikea (?Diplokoenikea) bispina</i>	Veracruz	River	Cook 1980
<i>Koenikea (?Diplokoenikea) blepta</i>	Guerrero	Stream	Cook 1980
<i>Koenikea (?Diplokoenikea) beltista</i>	Chiapas, Veracruz, Puebla.	River	Cook 1980
<i>Koenikea (Diplokoenikea) neopectinifera</i>	Campeche, Tabasco	Waterfilled ditch, pond	Cook 1980
<i>Koenikea (Diplokoenikea) clavigera</i>	Chiapas, Oaxaca	Pond	Lundblad 1943 in Cook 1980
<i>Koenikea (Notomideopsis) paragrossa</i>	Oaxaca	Pond	Cook 1980
<i>Koenikea (Notomideopsis) sexmaculata</i>	Oaxaca, Veracruz	Pond	Cook 1980
<i>Koenikea (Notomideopsis) tolima</i>	Veracruz	Stream	Cook 1980
<i>Koenikea (Notomideopsis) veracruzensis</i>	Veracruz	Stream	Cook 1980
<i>Koenikea (Notomideopsis) nayaritensis</i>	Nayarit	Spring	Cook 1980
<i>Koenikea (Notomideopsis) taninulensis</i>	San Luis Potosí	Sulphurous stream	Cramer 1983
<i>Koenikea (Sespekoenikea) chiapasana</i>	Chiapas	Stream	Cook 1980
<i>Koenikea (Sespekoenikea) piotiformis</i>	Nayarit, Guerrero	River	Cook 1980
<i>Koenikea (Tanaognathus) kurtvietsi</i>	Guerrero	River	Cook 1980
<i>Koenikea (Parakoenikea) curvipalpis</i>	Oaxaca	River	Lundblad 1936 in Cook 1980
Pionidae			
<i>Piona bromada</i>	Tabasco, Campeche, Veracruz, Oaxaca.	Pond, waterfilled ditch	Cook 1980
<i>Piona mexicana</i>	Veracruz	Stream	Cook 1980
<i>Piona neoacutidens</i>	Veracruz	Stream	Cook 1980
<i>Piona (Piona) triangularis</i>	*	*	Wolcott 1902 in Marín-Hernández and Cramer-Hemkes 2009

Table 1 Continued.

Species	State	Habitat	Reference
<i>Piona (Tetrapiona) rotunda sudamericana</i>	*	*	Viets 1910 in Marín-Hernández and Cramer-Hemkes 2009
<i>Piona alzatei</i>	*	*	Dugés 1884
<i>Piona pearsei</i>	*	*	Marshall 1936
<i>Piona amimili</i>	Mexico city	Stream	Marín-Hernández 2009
Aturidae			
<i>Aturus matlatzinca</i>	Mexico state	Stream	Cramer 1991
<i>Aturus catoantoni</i>	Mexico state	Stream	Cramer 1991
<i>Aturus güillecrameri</i>	Mexico state	Stream	Cramer 1992
<i>Aturus celiahemkesae</i>	Mexico state	Stream	Cramer 1992
<i>Aturus oxtotilpanensis</i>	Mexico state	Stream	Cramer 1992
<i>Aturus primitivus</i>	Mexico state	Stream	Cramer 1991
<i>Neoturus kurtvietsi</i>	Oaxaca, Chiapas, Veracruz, Guerrero	River, stream	Cook 1980
<i>Neoturus projectus</i>	Veracruz	River	Lundblad 1936 in Cook 1980
<i>Adelaxonopsella pallida</i>	Veracruz	Interstitial water stream	Cook 1974
<i>Albia (Anchistalbia) iantha</i>	Nayarit	Spring	Cook 1980
<i>Albia (Anchistalbia) ianthopsis</i>	Quintana Roo	Lagoon	Otero-Colina 1987b
<i>Axonopsella (?) mesoamericana</i>	Guerrero, Morelos, Nayarit	River	Cook 1980
<i>Axonopsella (Neaxonopsella) nayaritensis</i>	Nayarit	Cataracts	Cook 1980
<i>Axonopsella (Neaxonopsella) vicina</i>	Veracruz	Stream	Cook 1980
<i>Axonopsis (Brachypodopsis) columbicola</i>	Chiapas, Oaxaca, Puebla, Nayarit	River, stream	Lundblad 1953 in Cook 1980
<i>Axonopsis (Brachypodopsis) cemoba</i>	Veracruz	Stream	Cook 1980
<i>Axonopsis (Brachypodopsis) cerucha</i>	Veracruz, San Luis Potosí	River, Stream	Cook 1980
<i>Axonopsis (Brachypodopsis) mesoamericana</i>	Veracruz, Chiapas	Stream	Cook 1980
<i>Axonopsis (Brachypodopsis) trocala</i>	Chiapas	Chiapas	Cook 1980
<i>Polyaxonopsella mexicana</i>	Oaxaca	Stream	Otero-Colina 1987b
<i>Frontipodopsis mesoamericana</i>	Chiapas	Bottom deposits of stream	Cook 1980
<i>Kongsbergia antoniocatoi</i>	Mexico state	Gravel deposits of stream	Cramer 2000
<i>Kongsbergia cosita</i>	Mexico state	Gravel deposits of stream	Cramer 2000
<i>Kongsbergia tigrina</i>	Mexico state	Stream	Cramer 2000
<i>Kongsbergia eterna</i>	Mexico state	Stream	Cramer 2000
<i>Kongsbergia (Kongsbergia) mexicana</i>	Oaxaca	River	Cook 1980
<i>Kongsbergia glopipalpis</i>	Chiapas and Veracruz	Stream	Lundblad 1953 in Cook 1980
<i>Kongsbergia materna</i>	Chiapas, Mexico state, Oaxaca, Veracruz.	Tributary river	Thor 1899 in Cramer 2000
<i>Submiraxona (Submiraxona) bella</i>	Nayarit	Stream	Cook 1980
<i>Submiraxona (Submiraxona) lundbladi</i>	Guerrero, Chiapas	River	Cook 1980
<i>Submiraxona (Submiraxona) stollii</i>	Guerrero	River	Cook 1980
<i>Miraxona (Miraxona) expansipes</i>	Guerrero	River	Cook 1980
<i>Miraxona (Miraxona) mexicana</i>	Guerrero	River	Cook 1980
<i>Miraxonides (Miraxonidella) similis</i>	Nayarit, Veracruz	River	Cook 1980
<i>Miraxona (Miraxonides) geronimoi</i>	Nayarit	Stream	Cramer and Cook 1991
<i>Stygialbiella mexicana</i>	Mexico state	Spring	Cramer 1992
<i>Neoaxona (?Lamellaxona) mexicana</i>	Nayarit	Stream	Cook 1980
<i>Woolastookia gretae</i>	Nayarit	River, stream	Viets 1978 in Cook 1980
<i>Forelia mesoamericana</i>	Chiapas	Lagoon	Otero-Colina 1987b
Feltriidae			
<i>Feltria (Tropifeltria) neotropica</i>	Chiapas	Waterfalls	Otero-Colina 1987b
<i>Feltria (Feltriella) anahoffmannae</i>	Mexico state	Mountain spring	Cramer 1986
Mideopsidae			
<i>Mideopsis (Mideopsis) cartesa</i>	Nayarit, Veracruz	Stream	Cook 1980
<i>Mideopsis (Mideopsides) beta</i>	Chiapas	Gravel deposits of stream	Cook 1980
<i>Mideopsis (Mideopsis) magna</i>	Veracruz, Morelos	River	Cook 1980
<i>Mideopsis (Neoxystonotus) nobilis</i>	Tabasco	Pond	Cook 1980
<i>Mideopsis orbicularis</i>	Yucatán	Cenote	Müller 1776
<i>Mideopsis (Neoxystonotus) mexicana</i>	Mexico state	Helocrene spring	Cook 1980
<i>Mideopsis (Neoxystonotus) gemada</i>	Chiapas	River	Cook 1980
<i>Mideopsis (Neoxystonotus) canzolla</i>	Guerrero	Tributary river	Cook 1980
Krendowskiidae			
<i>Krendowskia (Krendowskiella) azteca</i>	Guerrero	Tributary river	Cook 1980
<i>Krendowskia (Krendowskiella) moyara</i>	Chiapas	River	Cook 1980
<i>Krendowskia (Krendowskiella) trodroma</i>	Veracruz, Nayarit	Stream	Cook 1980
<i>Krendowskia (Krendowskiella) vicina</i>	Tabasco	Pond	Cook 1980
<i>Geayia (Geayia) amacuzaca</i>	Morelos	River	Cook 1980
<i>Geayia (Geayia) mitchelli</i>	Tabasco, Chiapas	Pond	Cook 1980
Arenohydracarinae			
<i>Arenohydracarus eremitus</i>	*	*	Cook 1974
<i>Arenohydracarus minimus</i>	Oaxaca, Guerrero	Intertitial waters	Cook 1974
Chappuisididae			
<i>Chappuisides notialis</i>	Mexico state	Spring	Cramer and Smith 1991
Hungarohydracarinae			
<i>Stygarrenurus armoniensis</i>	Mexico state	Interstitial deposits of spring.	Cramer and Cook 1996
Neocaridae			
<i>Neocaracus adocetus</i>	Mexico state	Spring	Cramer and Smith 1991

dams and lakes, but also wetlands (Gobierno del Estado de México 2024), is represented here by only five sampling locations.

Similarly, a study conducted in Queretaro state, a region with high climatic heterogeneity and complex physiogeography characterized by mountainous elevations between 2000 and 3000 above sea level, highlights the limited knowledge of water mite diversity across most of Mexico. In 2014, during a workshop at the Latin American Congress of Freshwater Macroinvertebrates some collections were made for educational purposes at a single sampling point in the “La Barranca” stream. This effort yielded 112 specimens from 7 families and 10 genera, including the first record of the genus *Protzia* in the country. This revealed that Queretaro, for which no prior information was available, now stands as one of the states with more significant water mite diversity in terms of genera (Goldschmidt *et al.* 2015).

In the Neotropical region of Mexico, the tendency is similar to the transition zone. In Quintana Roo state, which lies adjacent to the Caribbean Sea, seven species have been described out from five localities and the diversity in these environments reaches two families and two genera (Table 1). For this area, Montes-Ortiz and Elías-Gutiérrez (2020) found a richness of 77 putative species in 24 sites using COI barcodes, some of which have been already described (Montes-Ortiz *et al.* 2022) while the rest are still in the process of identification or description. In recent years, molecular analyses of water mites have demonstrated a consistent increase in relevance for species delimitation. It has been possible to pair sexes of a single species when sexual dimorphism challenges their association and match different stages of their life

Table 2 Unidentified species with a DNA barcode in BOLD database. BINs indicate putative species. * Unique BINs this database.

<i>Taxa</i>	BIN	<i>Taxa</i>	BIN	<i>Taxa</i>	BIN
Arrenuridae		Limnesiidae		Pionidae	
<i>Arrenuridae</i>	AEA4828*	<i>Limnesiidae</i>	AEA4382*	<i>Pionidae</i>	AEA4809*
<i>Arrenurus cristinae</i>	AEA7842*	<i>Centrolimnesia</i>	AEA3914*	<i>Piona</i>	AEA5358*
<i>Arrenurus eduardoi</i>	AEA7844*	<i>Limnesia</i>	AEA6471*	<i>Piona</i>	AEE5501*
<i>Arrenurus federicoi</i>	AEB7095*	<i>Limnesia</i>	ACX7759	<i>Piona</i>	AEN6046*
<i>Arrenurus ecosur</i>	ACX8463	<i>Limnesia</i>	ACY7380	<i>Piona</i>	AEO7290*
<i>Arrenurus marshallae</i>	ACL2521	<i>Limnesia</i>	AEA5595	<i>Piona</i>	AER1599*
<i>Arrenurus</i>	ACX8462*	Hygrobatidae		<i>Piona</i>	AER1600*
<i>Arrenurus</i>	ACX8788*	<i>Hygrobatidae</i>	AEA5236*	<i>Piona</i>	AER1601*
<i>Arrenurus</i>	ACX8789*	<i>Hygrobatidae</i>	AEA4089*	Mideopsidae	
<i>Arrenurus</i>	ACY6809*	<i>Atractides</i>	ACX7786*	<i>Mideopsidae</i>	AEB4633*
<i>Arrenurus</i>	ADI3752*	<i>Hygrobates</i>	AEA3689*	<i>Mideopsis</i>	ACY7169*
<i>Arrenurus</i>	ADI4458*	<i>Hygrobates</i>	AEA3690*	<i>Mideopsis</i>	AEA6512*
<i>Arrenurus</i>	AEA3972*	<i>Hygrobates</i>	AEA3924*	<i>Mideopsis</i>	ACX8679
<i>Arrenurus</i>	AEA7182*	<i>Hygrobates</i>	ACX7887	Krendowskiidae	
<i>Arrenurus</i>	AEA7843*	<i>Hygrobates</i>	ADO7098	<i>Krendowskia</i>	ACX8435*
<i>Arrenurus</i>	AEA8234*	Unionicolidae		<i>Geayia</i>	ACT6195
<i>Arrenurus</i>	AEF1989*	<i>Unionicolidae</i>	AEA6658*	Hydrachnidia	AEA3823*
<i>Arrenurus</i>	AEF8444*	<i>Unionicolidae</i>	ACY7381		AEA4343*
<i>Arrenurus</i>	ACL2418	<i>Unionicolidae</i>	AEB1594*		AEF3494*
<i>Arrenurus</i>	ACX8464	<i>Unionicolidae</i>	AEA7951*		AEF8255*
Limnocharidae		<i>Unionicolidae</i>	AEA6062*		AEF0324*
<i>Limnocharidae</i>	AEA4515*	<i>Unionicolidae</i>	AEA4829*		AEI2293*
<i>Limnochares</i>	ACY6840*	<i>Unionicolidae</i>	AEA3726*		AEI2954*
<i>Limnochares</i>	ADI4862*	<i>Unionicolidae</i>	AEA4514*		AEI4296*
<i>Eylaidae</i>		<i>Unionicola</i>	ACX8035*		AEI4327*
<i>Eylaidae</i>	AEA4696*	<i>Unionicola</i>	ADM7936*		AEI4328*
<i>Eylaidae</i>	AEA5669*	<i>Unionicola</i>	AEB4634*		AEI4329*
<i>Eylais</i>	ADD9174*	<i>Unionicola</i>	AEE0841*		AEI8266*
Hydryphantidae		<i>Unionicola</i>	ACX9008		AEI8707*
<i>Hydryphantae</i>	AEA5005*	<i>Unionicola</i>	AEF2345		AEI9124*
Hydrodromidae		<i>Unionicola</i>	ACX8034		AEJ2119*
<i>Hydrodroma</i>	ADF3732	<i>Neumania</i>	AEA8101*		AEN6047*
Anisitsiellidae		<i>Neumania</i>	ACY6829		AEN8226*
<i>Mamersellides</i>	AEA6955*	<i>Koenikea</i>	ACY7384*		AEN8227*
<i>Mamersellides</i>	AEA6956*	<i>Koenikea</i>	ACB9299		AE05260*
<i>Torrenticolidae</i>		<i>Koenikea</i>	ADI2928		AER2566*
<i>Torrenticolidae</i>	AEA4395*	<i>Koenikea</i>	ADI3114		AEB1898
<i>Torrenticola</i>	AEA7372*				

cycle (Alarcon-Elbal *et al.* 2020; Montes-Ortiz *et al.* 2022), reveal species assemblages, infer ecological similarities between water mite communities, and recognize seasonality (Montes-Ortiz *et al.* 2020; Vasquez *et al.* 2020; Klimov *et al.* 2022). Pešić *et al.* (2021) emphasized the significance of creating COI barcode libraries for water mites.

Currently, from Mexico there are 794 sequences of 898 specimens exclusively from the Yucatán Peninsula (southern Mexico). These sequences corresponded to 103 BINs (Barcode

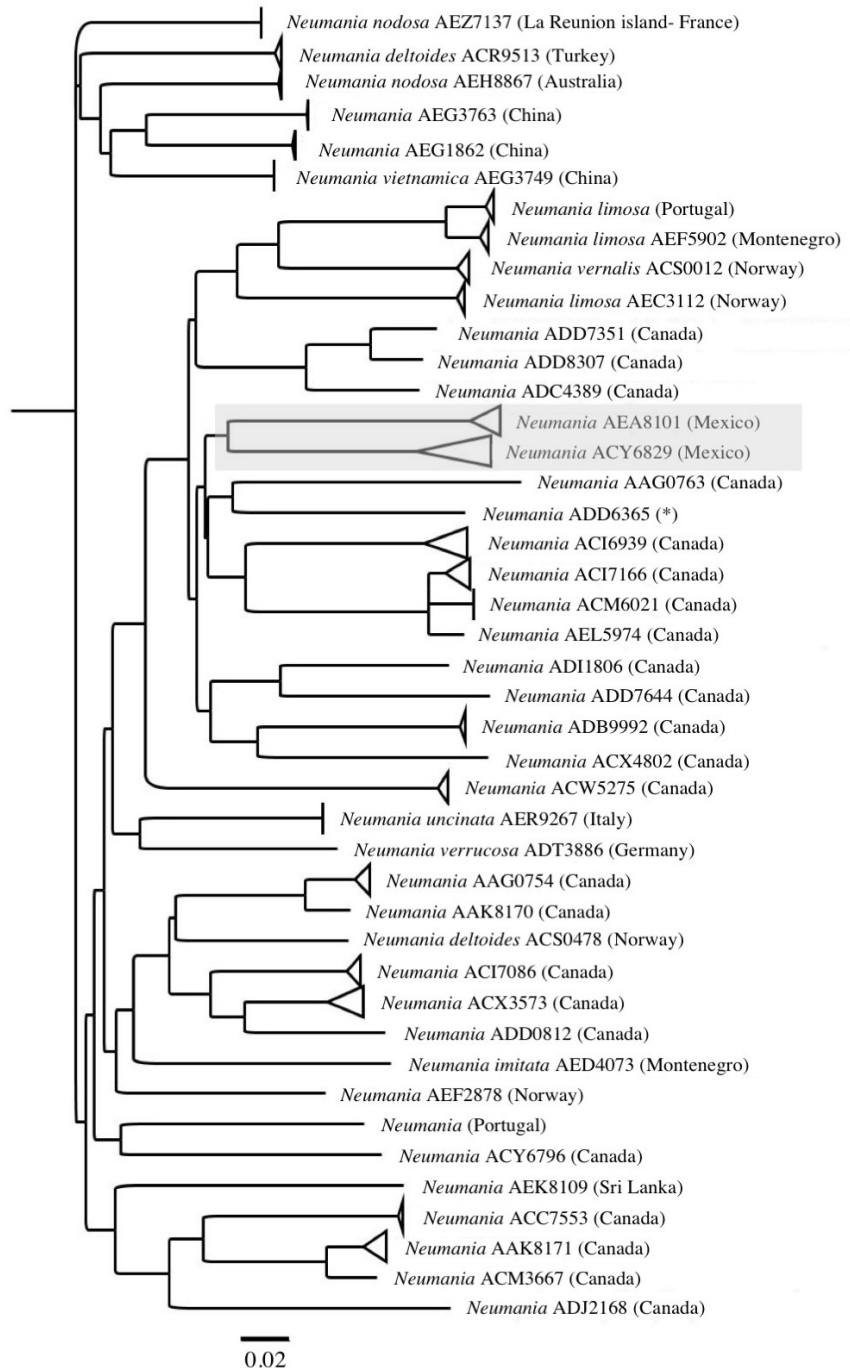


Figure 3 Neighbor joining tree based on all worldwide *Neumania* COI sequences. The name is followed by the barcode index number (BIN). * Without data collection.

Index Numbers) or putative species, of which 82 are unique in the BOLD database. It means that these sequences are novel in the system and there are no genetically identical taxa in the database, therefore they could be the indicators of endemism, or limited distribution (Table 2). The families with the most records of COI gene are the Unionicolidae, Arrenuridae, Limnesiidae, Krendowskiidae, Hygrobatidae, Mideopsidae, and Pionidae.

An example of the potential of barcode libraries can be seen in a cosmopolitan genus such as *Neumania*; with publicly available sequences from 12 countries, it was possible to generate an identification tree. This tree shows that clusters in Mexico, represented by the BINs AEA8101 and ACY6829, form a group separate from those in other regions of the world. Additionally, the differentiation of the two *Neumania* putative species is evident (Figure 3). The barcode analysis has been useful in determining species distributions (Więcek *et al.* 2020), and it illustrated that species considered cosmopolitan and recorded in regions far from their type locality are most likely new species. This may be the case of previous identification in Mexico, in which recorded species could originate from different ecoregions from the American continent.

The public barcode database (DS-YUCWM Water Mites Diversity from PY) presented in this work, represents the first reference framework of molecular data of water mites in Mexico. It will allow water mites to be integrated successfully and with certainty as putative species in ecological studies, facilitating a deeper understanding of biotic relationships (Vasquez *et al.* 2021), and their use in assessments of water quality. However, a Linnean name is still pending. It will be assigned after the fine taxonomical study. We must emphasize that BIN number is not a solution for the so-called taxonomic impediment, and taxonomic study of these putative species should be a priority in further studies.

Conclusion

This is the first checklist reporting all species described or recorded in Mexico, and a public project is made available, integrating all barcode sequences from the country. The analysis of Mexican states with records such as Mexico state, Queretaro and Quintana Roo highlighted that the sampling effort has been limited, underscoring the real water mite diversity here. Similarly, molecular data of the COI gene correspond only to species from Yucatán Peninsula, revealing the necessity of adequate studies in the rest of the country.

This manuscript represents the first reference framework of the current knowledge of morphological diversity and molecular data of water mites in Mexico and we propose this integrative approach to minimize the uncertainty of taxonomic determination toward increasing the reliability of ecological studies using water mites, or assessing their value as indicators of change.

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