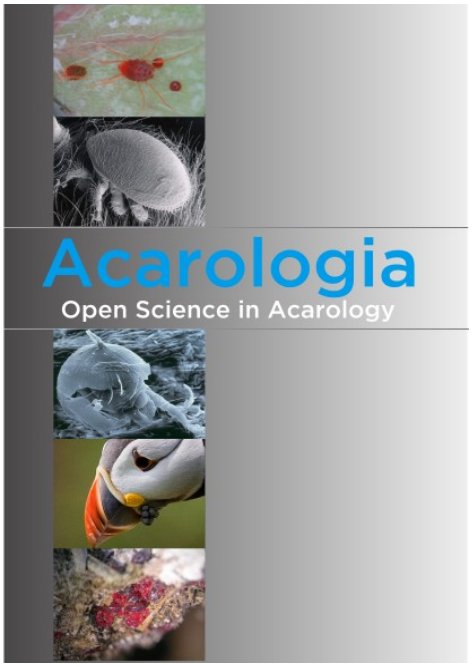

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Hidden treasures – a first study on the unexplored diversity of water mites (Acari; Hydrachnidia) from Belize

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Original research

ABSTRACT

Here we provide first data on the apparently rich water mite fauna of Belize. In this work 27 genera in 14 families were registered at ten sites. The state of knowledge on water mites of El Salvador, Honduras, Guatemala, and Southern Mexico (South of the Isthmus of Tehuantepec) is described and similarities with the presented data are discussed. In total, 23 families, 61 genera are now known from Northern Central America, with one family (Hungarohydracaridae) and three genera (*Santiagocarus*, *Neoaxona* (*Lamellaxona*), *Stygarrenurus*) published for the first time from this region in the present study.

Keywords Neotropics; new records; diversity; water quality assessment

Introduction

Currently over 7500 species of water mites are described worldwide (Smit 2020), and about 1500 species are known from the Neotropical region (Goldschmidt & Ramírez-Sánchez 2020). With 175 described genera from the Neotropics, worldwide this region represents the highest diversity of water mites at the genus level (Di Sabatino *et al.* 2008). Nevertheless, the overall knowledge of the Neotropical water mite fauna is still fragmentary (Di Sabatino *et al.* 2008; Goldschmidt 2006). Whereas Southern Mexico and Guatemala belong to the better (however still rather poorly) known areas within Central America (Böttger 1980; Cook 1980; Marshall 1936; Montes-Ortiz & Elías-Gutiérrez 2020; Otero-Colina 1988; Ramírez-Sánchez & Rivas 2013), no records of freshwater mite findings have been published from Belize. So far the only record of Hydrachnidia from Belize is the finding of the marin pontarachnid *Litarachna belicensis* Montes-Ortiz *et al.*, 2021 in the Corozal Bay, off the northern coast of Belize (Montes-Ortiz *et al.* 2021). Our information on water mites from Honduras and El Salvador is based upon very few records – small samples from three sites in Honduras (Wiles 2005) and one site in El Salvador (K. Viets 1953). Nothing is known about the water mite fauna of Nicaragua.

Overall, it is likely that only a quarter of the Neotropical water mite fauna has been described so far (Goldschmidt 2002), especially in neglected habitats like springs and the hyporheic interstitial water where many undescribed species can still be expected (Di Sabatino *et al.* 2008).

On the other hand, it has been observed that already genus level data of water mite assemblages can be powerful tools in the evaluation of water quality and different anthropogenic contaminations (Growns 2001; Miccoli *et al.* 2013; Goldschmidt 2016). In the only study water mites have been used as bioindicators in the Neotropics, 15 Panamanian streams at three

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different levels of contamination were clearly distinguished by their water mite assemblages, identified to genus level (Goldschmidt *et al.* 2016).

The availability of a recently published key to neotropical water mite genera (Goldschmidt & Ramírez-Sánchez 2020) as well as the publication of a new manual "Water mites of the world" (Smit 2020) are now giving access to this interesting indicator group.

Aquatic macroinvertebrate assessment has been on-going within Belize for about 25 years. When Carrie *et al.* (2015) reviewed the literature on aquatic macroinvertebrates reported for Belize, insects dominated the list and water mites were not mentioned. Most taxonomic literature used to identify aquatic macroinvertebrates was from other Neotropical regions and the United States. The recent release of Thorp and Covich's Freshwater Invertebrates, Volume III, Keys to Neotropical Hexapoda (Hamada *et al.* 2018) advances work in this area for aquatic insects, but not for water mites. However, this current work and subsequent research promises to highlight the importance of water mites within aquatic systems of Belize and provide taxonomic background to identify families and genera found. The availability of a functional key and a generic list for the country shall promote the inclusion of water mites within aquatic invertebrate surveys used in water quality assessment protocols.

Belize offers a range of aquatic habitats waiting to be fully explored, including watersheds influenced by karst landscapes and systems draining igneous and metamorphic headwaters, blackwater streams, large riverine wetland lagoons, coastal zone lagoons, and submerged river systems. This investigation, along with future ones, shall contribute greatly to the Belize aquatic invertebrate list first compiled by Carrie *et al.* (2015), with water mites representing a growing percentage of taxa confirmed for the country.

Material and methods

Water mite collection and data analysis

The present study is based upon 379 water mite specimens (Table 2) collected in February 2018 at ten sites in three districts of Belize (Table 1). The water mites were collected by hand net (mesh size 250 µm). Samples were washed through a sieve (mesh size ~2 mm), transferred to a white plastic plate and sorted at the spot. Water mites were picked up by eye droppers and fine tweezers and fixed in Koenike's solution (ten parts glycerine, six parts water, three parts acetic acid). For details on the water mite collection process, see Goldschmidt & Ramírez-Sánchez (2020).

The mites were sorted and identified with the aid of a Leica MZ 16 stereomicroscope. Microphotos were taken at the Bavarian State Collection of Zoology, Munich, Germany with a Nikon V1 camera combined with a Leica Z16 Apo and a 2.0 fold objective. Images were stacked with HeliconFocus 5.3 software.

A similarity-matrix of the water mite faunas of Belize and the neighboring areas was generated by calculating the respective Sörensen-quotients:

QS (%) = 2 G (number of the genera in common) / $S_A + S_B$ (sum of the number of genera know from area A and B) x 100.

All genera with an abundance of more than 3.2% are regarded as "dominant" (Engelmann 1978).

Several species discovered in the present study are morphologically similar to already described ones, while others clearly represent new species. However, as most species in the area still wait to be described, and without detailed taxonomic work on their respective genera, none of the species can be determined with certainty. Until published, tentative species names become used without further validation, and that use can create confusion in future studies and therefore we completely abstain from the use of species names in the present publication.

Site Description

Eighteen samples were taken from ten sites, all lotic habitats of different size and velocity (rheocrene and rheopsammocrene springs, spring streams, small streams, large streams, rivers [including backwaters]) at elevations between 17 and 213 m asl (Table 1).

Samples were collected from the Sibun River and from Caves Branch River, a tributary of the Sibun River, both rivers flowing through a karst region and fed in part by karst groundwater discharge.

These streams and rivers draining karst landscape are typically basic, sometimes with slightly acidic, hyporheic upwellings, backwater detritus pools, and similar micro-habitats. Much of the dissolved mineral load of karst filtered water is calcium carbonate, while the bed-load material includes quartz sand and gravel to cobble size granite, metamorphic, and other non-limestone sedimentary rocks, largely from outcrop formations upstream of the karst

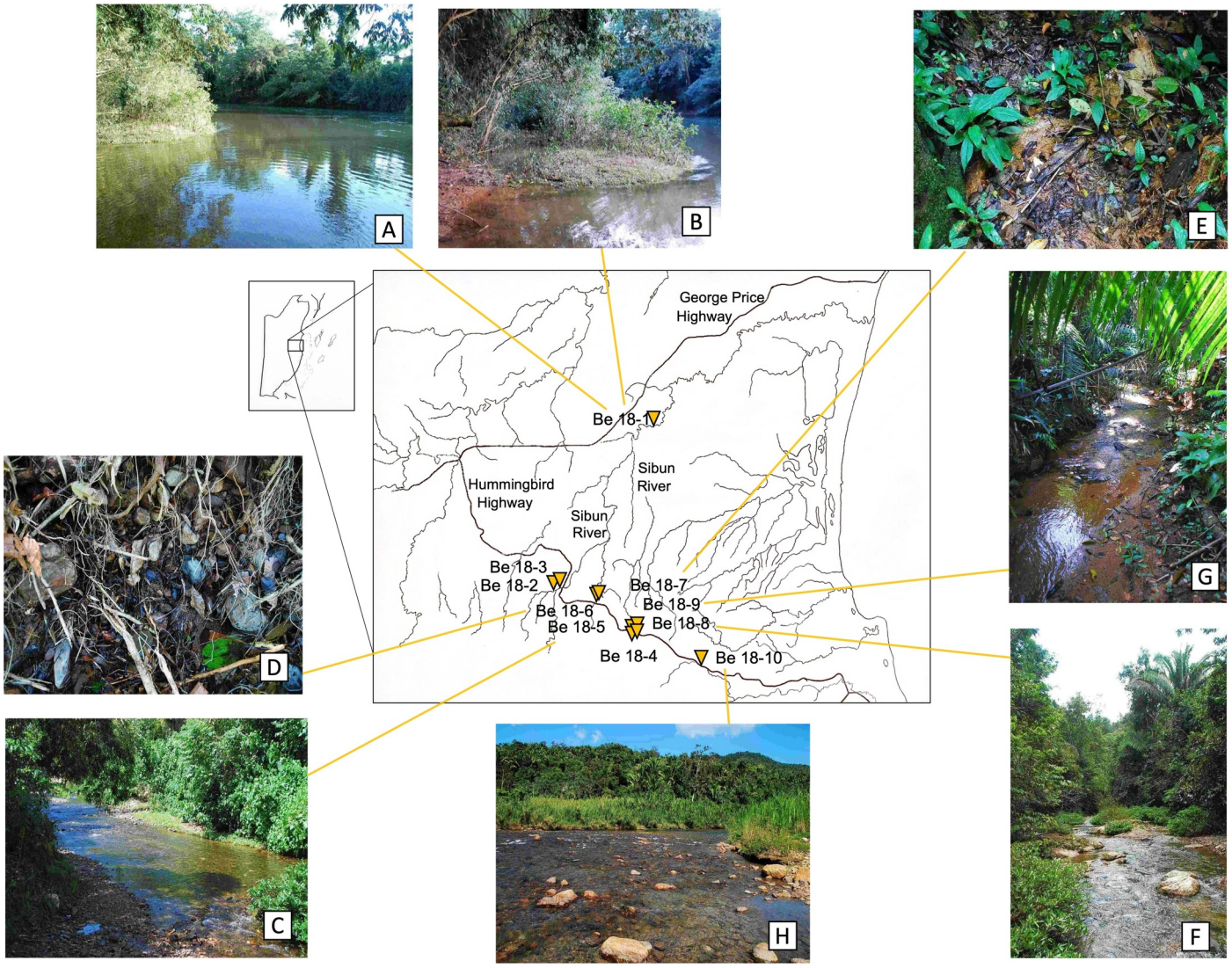

Figure 1 Map of sample sites in Belize, along with inset of Belize, showing the location of the map within the country. A: Monkey Bay, a meander in the Sibun River, sample site Be18-1a, 22 February 2018. B: Monkey Bay, sample site Be18- 1b, 22 February 2018. C: Tributary of the Caves Branch River, sample site Be18-5, 24 February 2018. D: Riparian spring at the edge of the tributary of the Caves Branch River, sample site Be18-6, 24 February 2018. E: Rheopsammocrene spring, sample site Be18-7, 25 February 2018. F: Dry Creek, sample site Be18-8, 25 February 2018. G: Tributary to Dry Creek, sample site Be18-9, 25 February 2018. H: North Stann Creek, sample site Be18-10, 26 February 2018.

Table 1 A – Sample sites; B – Characteristics of sample sites.

A

Site	Date	District	Location		Coordinates	Elevation [m asl]	Habitat type
Be 18 - 1	22-Feb.-2018	Belize	Monkey Bay	Sibun River	17.299953 N 88.5540793 W	17	flowing water
Be 18 - 2	23-Feb.-2018	Cayo	Sleeping Giant	tributary to Sibun River	17.109373 N 88.663335 W	80	flowing water
Be 18 - 3	23-Feb.-2018	Cayo	Sleeping Giant	small tributary to Sibun River	17.107309 N 88.665392 W	80	flowing water
Be 18 - 4	24-Feb.-2018	Stann Creek	TREES	Dry Creek	17.050007 N 88.567293 W	213	flowing water
Be 18 - 5	24-Feb.-2018	Stann Creek	Hummingbird Highway, 8 km W of TREES	tributary to Caves Branch River	17.089366 N 88.618937 W	112	flowing water
Be 18 - 6	24-Feb.-2018	Stann Creek	Hummingbird Highway, 8 km W of TREES	tributary to Caves Branch River	17.089366 N 88.618937 W	112	spring
Be 18 - 7	25-Feb.-2018	Stann Creek	TREES	well trail spring	17.05231 N 88.56528 W	200	spring
Be 18 - 8	25-Feb.-2018	Stann Creek	TREES	Dry Creek	17.03000 N 88.34025 W	161	flowing water
Be 18 - 9	25-Feb.-2018	Stann Creek	TREES	right tributary to Dry Creek	17.05120 N 88.56711 W	180	flowing water
Be 18 - 10	26-Feb.-2018	Stann Creek	Hummingbird Highway, 5 km E of Middlesex	North Stann Creek	17.01790 N 88.48495 W	84	flowing water

B

Site	Habitat	Microhabitat	Substrate	Velocity	Sampled depth [cm]	Shade	Water level
Be 18 - 1a	river	riffle	mesolithal, akal	fast flowing	50	partly	high
Be 18 - 1b	river	backwater pool	macropelal, terrestrial vegetation	fast flowing	50	partly	high
Be 18 - 2a	large stream	pool	akal, macropelal	slow flowing	30	full	high
Be 18 - 2b	large stream	riffle	mesolithal, akal	slow flowing	30	full	high
Be 18 - 3	spring stream	mix	macrolithal, akal, macropelal, roots	fast flowing	5	partly	-
Be 18 - 4	large stream	pool	macropelal, terrestrial vegetation	fast flowing	20	partly	-
Be 18 - 5a	large stream	riffle	mesolithal	fast flowing	30	partly	-
Be 18 - 5b	large stream	riffle at the edge of the stream	mesolithal, akal	fast flowing	10	partly	-
Be 18 - 5c	large stream	pool	psammal, roots	fast flowing	50	partly	-
Be 18 - 5d	large stream	aquatic plants	phytal	fast flowing	20	partly	-
Be 18 - 6	rheocrene	mix	akal, micropelal	fast flowing	5	partly	
Be 18 - 7	rheopsammocrene	mix	psammal, macropelal, roots, akal	fast flowing	5	full	
Be 18 - 8a	large stream	pool	macrolithal, macropelal	fast flowing	40	partly	low
Be 18 - 8b	large stream	fast riffle	mesolithal	fast flowing	30	partly	low
Be 18 - 8c	large stream	slower riffle at the edge	mesolithal, akal	fast flowing	20	partly	low
Be 18 - 9	small stream	mix	psammal, mesolithal, macropelal	fast flowing	10	full	-
Be 18 - 10a	river	riffle	mesolithal, akal, macrolithal	fast flowing	30	no	-
Be 18 - 10b	river	pool	psammal, mesolithal, akal, roots	fast flowing	30	no	-

area. Dry Creek, also a tributary of the Sibun River, and North Stann Creek, a watershed lying along the southern border of the Sibun River Watershed, drain granite outcrop and flow through less karst area.

Results

Faunistic data

The 379 water mite specimens collected represent 27 genera in 14 families (Table 2). By far, the most abundant and prevalent genus is *Torrenticola* Piersig, 1896, present at eleven (out of 18) sample sites, representing 57,3% of all water mite specimens collected. Further dominant genera are *Atractides* (9,8%, eight sites), *Hydrodroma* (6,6%, five sites), *Hygrobates* (5,0%, seven sites) and, *Limnesia* (3,2%, six sites). Six genera are represented as singletons, nine were restricted to one sample site (Table 2).

Representatives of the family Torrenticolidae are typical and abundant inhabitants of the riffle zones in a variety of running waters. Several members of Hygrobatidae are part of the typical assemblages of stream mites as well, being regularly found in the gravel of rivers and streams. In addition to these members of the riffle fauna, the samples include typical representatives of the pool fauna (e.g. *Limnesia*, Unionicolidae, *Arrenurus*), that are found both in standing waters and in the pools of rivers and streams. A third typical group of stream mites is represented by *Tubophorella* and *Neomamersa*. These dorso-ventrally compressed forms are dwellers of the hyporheic or interstitial zone inside the gravel bed of running waters.

Table 2 Water mite families and genera (systematic following Smit 2020) collected in the present study in eight streams and two springs in Belize.

Family	Genus	Specimens	Sample sites	Abundance [%]
Limnocharidae	*Rhyncholimnochares*	2	5a, 8c	0.5
Hydrodromidae	*Hydrodroma*	25	2b, 5a, c, 8c, 9	6.6
Rhynchohydracaridae	*Clathrosperchon*	2	8b, 10a	0.5
	Santiagocarus	4	8c	1.1
Lebertiidae	*Lebertia*	1	10b	0.3
Limnesiidae	*Limnesia*	12	1b, 2a, 4, 5c, 8a, 10b	3.2
	Tubophorella	3	5a, b, 8c	0.8
	Neomamersa	6	5a, b, 10a	1.6
Sperchontidae	*Sperchon*	3	8b, 10a	0.8
Torrenticolidae	*Monatractides*	2	5c, 9	0.5
	Neoatractides	8	5c, 8b, 8c, 9	2.1
	Torrenticola	217	1a, b, 5a-d, 6, 8b, c, 10a, b	57.3
Aturidae	*Albia*	2	1b	0.5
	Aturus	1	9	0.3
	Neoaxona (Lamellaxona)	1	5c	0.3
	Polyaxonopsella	1	5c	0.3
Frontipodopsidae	*Frontipodopsis*	2	8c	0.5
Hygrobatidae	*Atractidella*	3	5a, c	0.8
	Atractides	37	5a-c, 7, 8c, 10a, b	9.8
	Corticacarus	2	3, 5a	0.5
	Hygrobates	19	1b, 2a, b, 5a-c, 10b	5.0
	Paraschizobates	2	1b, 10b	0.5
Unionicolidae	*Koenikea*	1	8a	0.3
	Recifella	5	1b, 2a, 4	1.3
Arrenuridae	*Arrenurus*	10	1b, 8b, c	2.6
Hungarohydracaridae	*Stygarrenurus*	7	7, 8c, 9	1.8
Mideopsidae	*Neoxystonotus*	1	1b	0.3
14 families	**27 genera**	**379**	**10/18**	**100**

A final group of genera is represented by *Hydrodroma*, a genus with rounded, soft body and legs with swimming hairs. These mites are characteristically inhabiting standing waters but are also regular members of the water mite assemblages in the riffle zones of streams.

The highest number of water mites – 187 specimens – has been collected at sample site 5 (affluent to Caves Branch River), followed by 88 specimens at sample site 10 (North Stann Creek River). The highest number of genera was found at site 5 (affluent to Caves Branch River) and site 8 (Dry Creek) with 14 genera each. Though the highest diversity was found at site 9 (small affluent to Dry Creek), where just seven specimens could be found, that represented five different genera (Tab. 5, appendix).

Ecological and biogeographic characterization of the water mite genera so far known from Belize

Family Limnocharidae Grube, 1859

Genus *Rhyncholimnochares* Lundblad, 1936

A mainly neotropical genus (only one nearctic species) with 22 currently described species (Tuzovskij & Gerecke 2020). These characteristic mites are large and soft, yet are typical inhabitants of running waters, generally found in fast flowing streams, but always in microhabitats protected from the current (pools, leaf litter, fine substrate below or behind large stones).

Family Hydrodromidae K. Viets, 1936

Genus *Hydrodroma* Koch, 1837

Worldwide distribution, with currently ten described neotropical species (Lundblad 1941, 1953; Wiles 2005; Pešić & Smit 2022; K. Viets 1954). There is great need for revision especially of the neotropical species. Typically found in all types of standing waters, as well as pools in streams, streams (especially with groundwater influence) and springs (Figure 2).

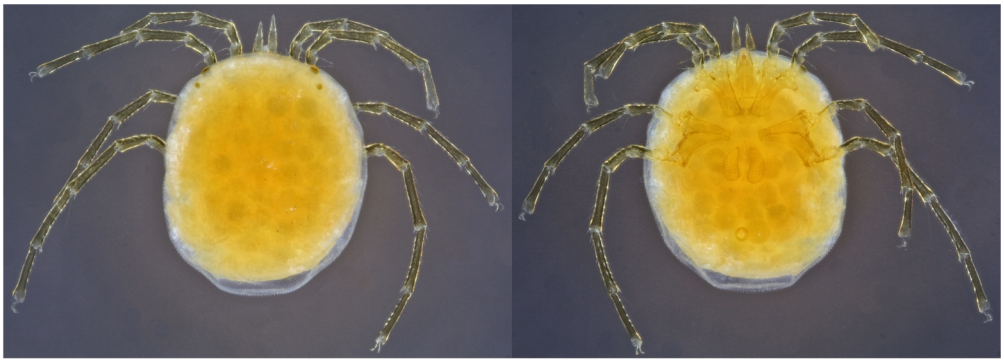

Figure 2 *Hydrodroma* sp., dorsal and ventral view, sample site Be18-5c.

Family Rhynchohydracaridae Lundblad, 1936

Subfamily Clathrosperchontinae Lundblad, 1936

Genus *Clathrosperchon* Lundblad, 1936

A mainly neotropical genus, however as well with two North American species. Currently the genus is under revision. So far four neotropical species are described (Lundblad 1941; Cook 1980; K.O. Viets 1977). Habitat: running waters (Figure 3).

Figure 3 *Clathrosperchon* sp., male, dorsal and ventral view, sample site Be18-10a.

Subfamily Santiagocarinae Valdecasas, 2001

Genus *Santiagocarus* Valdecasas, 2001

One described species, so far only known from the type locality in Panama (Valdecasas 2001). Habitat: streams (Figure 4).

Figure 4 *Santiagocarus* sp., female, dorsal and ventral view, sample site Be18-8c.

Family Lebertiidae Thor, 1900

Genus *Lebertia* Neuman, 1880

Widespread and abundant in the Holarctic, very sparse in the Neotropics, with just two described species from Central America (Cook 1980; K.O. Viets 1977) (Figure 5).

Figure 5 *Lebertia* sp., dorsal and ventral view, sample site Be18-10b.

Family Limnesiidae Thor, 1900

Subfamily Limnesiinae Thor, 1900

Genus *Limnesia* Koch, 1836

Worldwide distribution, with 96 described neotropical species. Habitat: all types of fresh and brackish waters, mainly standing and slow flowing (Figure 6).

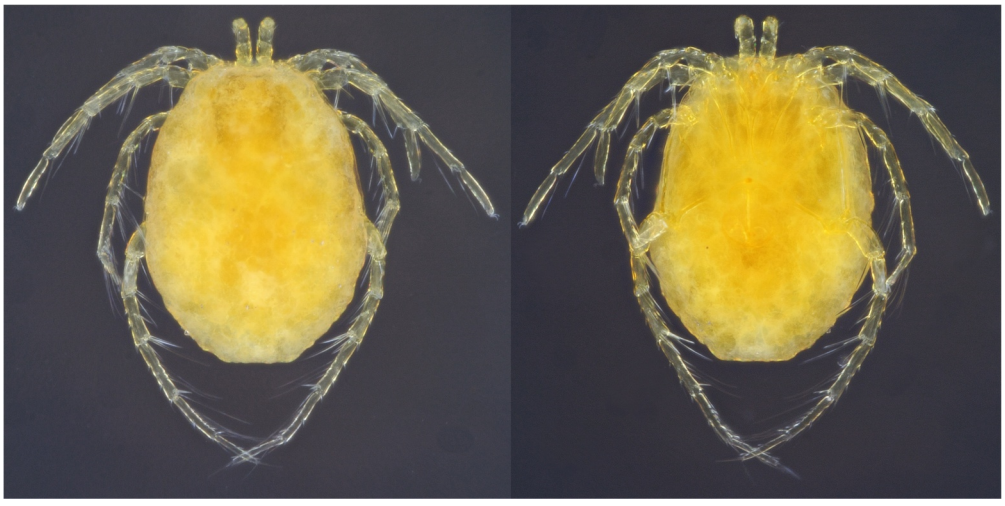

Figure 6 *Limnesia* sp., female, dorsal and ventral view, sample site Be18-8a.

Genus *Tubophorella* K.O. Viets, 1978

The genus has an interesting disjunction, an Australian – Neotropical distribution with three described species from Central and South America. Habitat: streams (Figure 7).

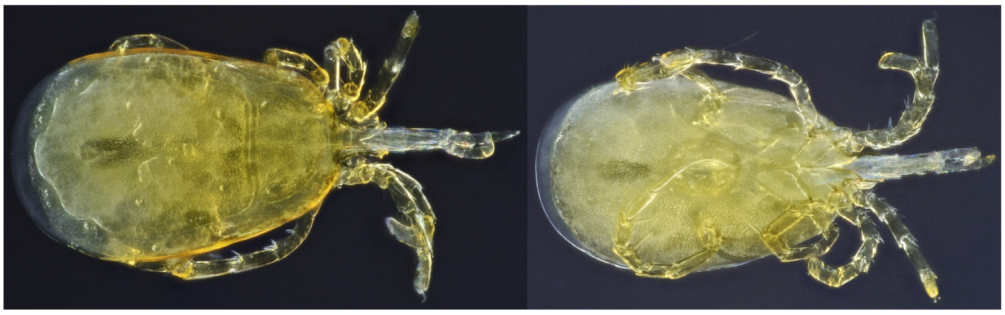

Figure 7 *Tubophorella* sp., dorsal and ventral view, sample site Be18-5a.

Subfamily Neomamersinae Lundblad, 1953

Genus *Neomamersa* Lundblad, 1953

A mainly neotropical genus. However, the distribution reaches north up to the southern states of the US, with 16 described neotropical species. These are characteristic representatives of interstitial habitats, due to their typically dorso-ventrally flattened, slightly elongated, heavily armored idiosoma (Figure 8).

Figure 8 *Neomamersa* sp., dorsal and ventral view, sample site Be18-5a.

Family Sperchontidae Thor, 1900

Genus *Sperchon* Kramer, 1877

The genus is a typical member of the water mite communities of running waters and springs, with a worldwide distribution except for the Australasian region (Smit 2020). Nine described neotropical species (Figure 9).

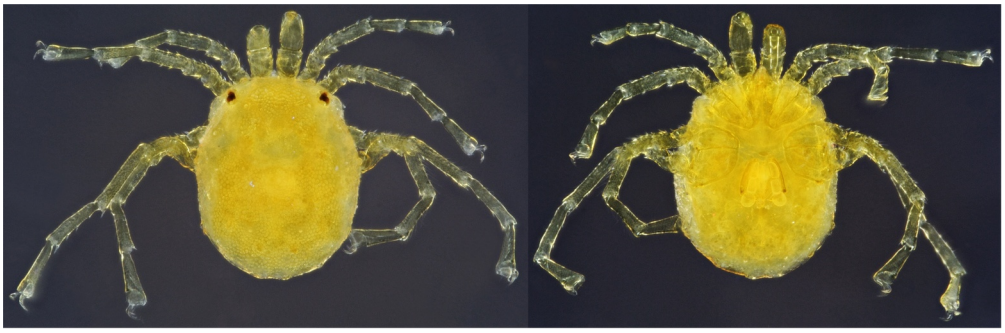

Figure 9 *Sperchon* sp., dorsal and ventral view, sample site Be18-10a.

Family Torrenticolidae Piersig, 1902

The members of the family are very characteristic representatives of stream-inhabiting mites.

Genus *Monatractides* K. Viets, 1926

Worldwide distribution, with eleven described species in Central and Northern South America. Habitat: streams (Figure 10).

Figure 10 *Monatractides* sp., female, dorsal and ventral view, sample site Be18-5c.

Genus *Neoatractides* Lundblad, 1941

The nominate subgenus has a New World (mainly Neotropical) distribution with eleven described species in Central and South America. Habitat: streams, waterfalls (Figure 11).

Figure 11 *Neoatractides* sp., female, dorsal and ventral view, sample site Be18-8c.

Genus *Torrenticola* Piersig, 1896

Nearly worldwide distribution (except Australia and Southern South America), in Central America as well as in the Holarctic very common in fast flowing streams. Fifty-eight described Neotropical species (Goldschmidt 2007a), generally one of the dominant genera in relatively clean, fast flowing running waters. In the present study by far the most abundant genus, represented by several species. Habitat: running waters, springs (Figures 12 and 13).

Figure 12 *Torrenticola* sp. 1, male, dorsal and ventral view, sample site Be18-5b.

Figure 13 *Torrenticola* sp. 2, male, dorsal and ventral view, sample site Be18-8c.

Family Aturidae Thor, 1900

Subfamily Albiinae K. Viets, 1915

Genus *Albia* Thon, 1899

Worldwide distribution, with four described species in the Neotropics. Habitat: streams, standing waters.

Subfamily Aturinae Thor, 1900

Genus *Aturus* Kramer, 1875

Worldwide distribution except Australia, with nine described Neotropical species. Habitat: streams, interstitial (Figure 14).

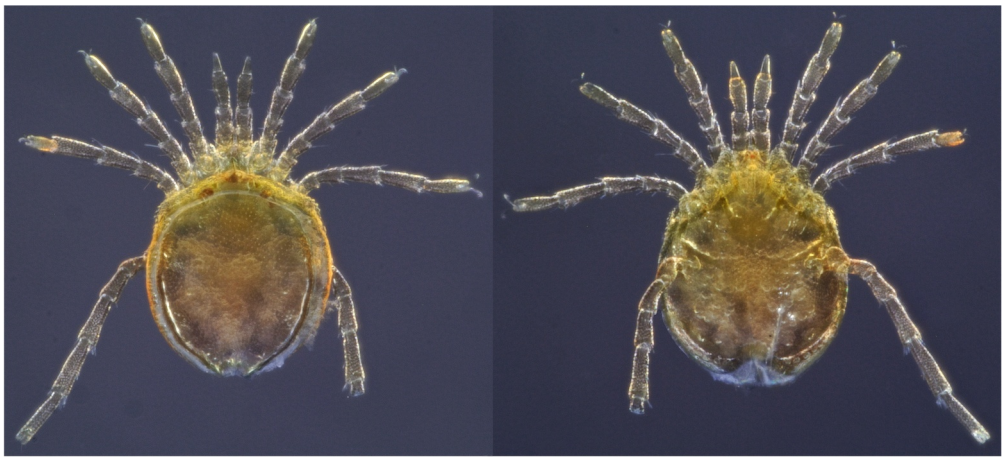

Figure 14 *Aturus* sp., female, dorsal and ventral view, sample site Be18-9.

Subfamily Axonopsinae K. Viets, 1929

Genus *Neoaxona* Lundblad, 1936 (*Lamellaxona*) Lundblad, 1936

Neotropical genus with two species described, one from South America (Brazil, Suriname, Paraguay), one from Central America (Mexico). Habitat: streams (Figure 15).

Figure 15 *Neoaxona* sp., female, ventral view, sample site Be18-5c.

Genus *Polyaxonopsella* Lundblad, 1943

Neotropical genus with four described species (only female). Habitat: streams, interstitial (Figure 16).

Figure 16 *Polyaxonopsella* sp., female, dorsal and ventral view, sample site Be18-5c.

Family Frontipodopsidae Cook, Smith & Harvey, 2000

Genus *Frontipodopsis* Walter, 1919

Four described Neotropical species. Habitat: streams (Figure 17).

Figure 17 *Frontipodopsis* sp., lateral view, sample site Be18-8c.

Family Hygrobatidae Koch, 1842

Genus *Atractidella* Lundblad, 1936

Neotropical genus with 14 species described from Central and South America. Habitat: streams (Figure 18A).

Genus *Atractides* Koch, 1837

Worldwide distribution except Australia, with 33 described Neotropical species. Habitat: running waters, springs, interstitial (Figure 18B).

Genus *Corticacarus* Lundblad, 1936

A very widespread and diverse neotropical genus reaching north into southern states of the US, with 64 described species from Central and South America. Habitat: streams, springs (Figure 18C).

Genus *Hygrobates* Koch, 1837

An abundant, diverse and widespread genus with worldwide distribution, including 37 described Neotropical species. Habitat: running waters, standing waters, springs (Figure 19A).

Genus *Paraschizobates* Lundblad, 1937

An exclusively Neotropical genus with three described species. Habitat: streams (Figure 19B).

Family Unionicolidae Oudemans, 1909

Subfamily Pionatacinae K. Viets, 1916

Genus *Koenikea* Wolcott, 1900

The genus shows an interesting Australian-American disjunction, with 111 described Neotropical species. Habitat: running waters, standing waters, springs (Figure 20A).

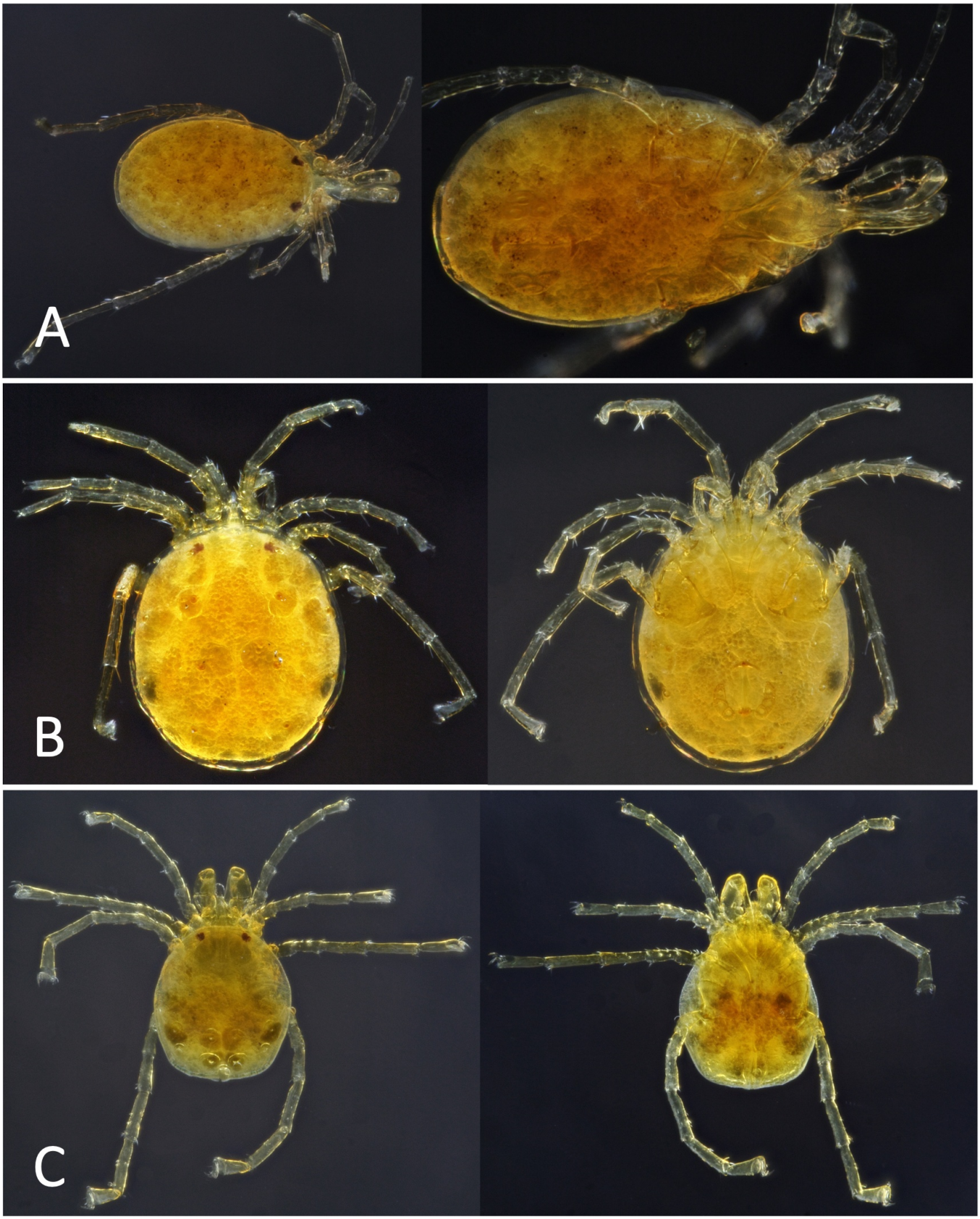

Figure 18 A – *Atractidella* sp., female, dorsal and ventro-lateral view, sample site Be18-5c; B – *Atractides* sp., female, dorsal and ventral view, sample site Be18-5b; C – *Corticacarus* sp., female, dorsal and ventral view, sample site Be18-3.

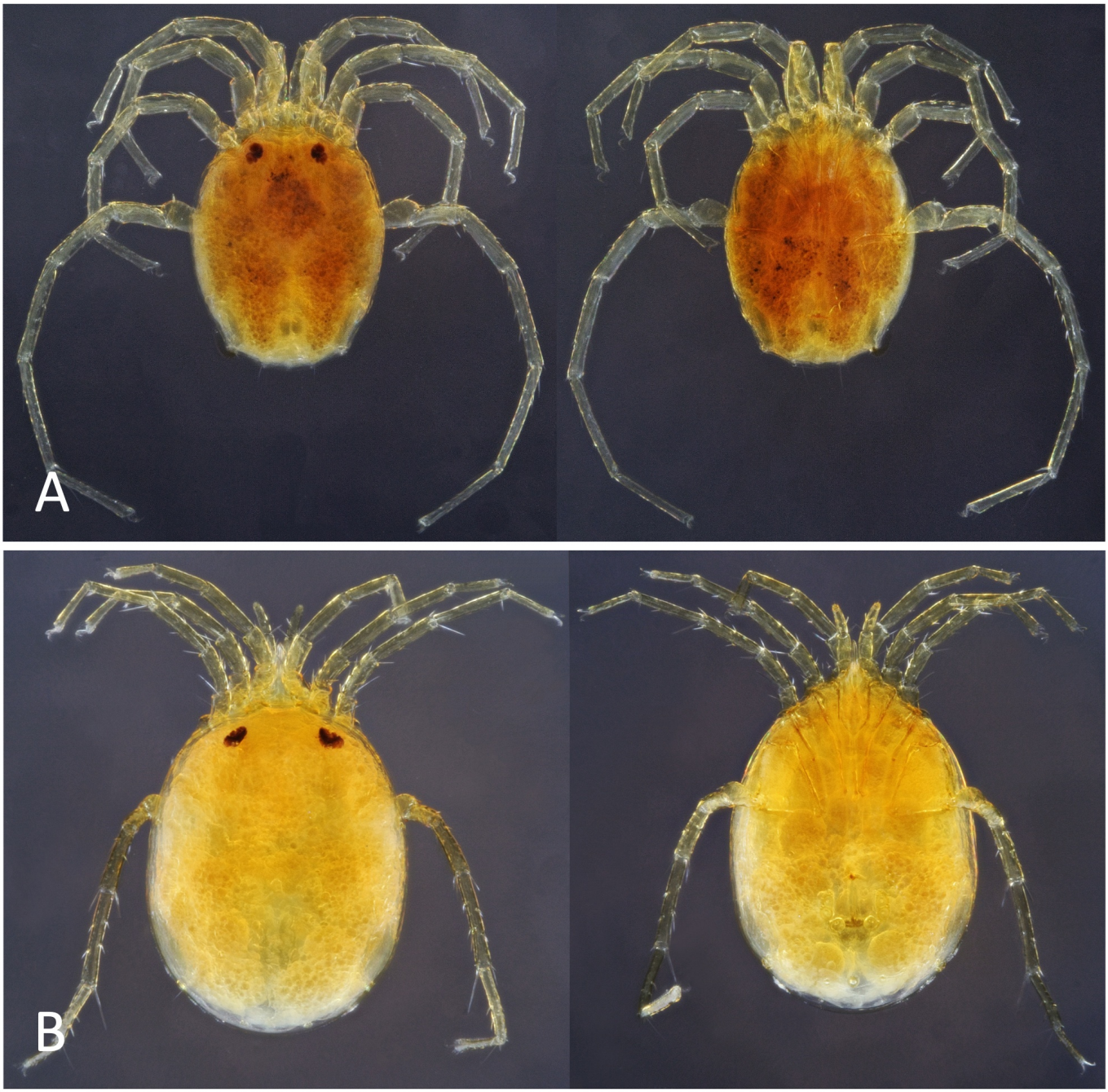

Figure 19 A – *Hygrobates* sp., female, dorsal and ventral view, sample site Be18-5c; B – *Paraschizobates* sp., female, dorsal and ventral view, sample site Be18-1b.

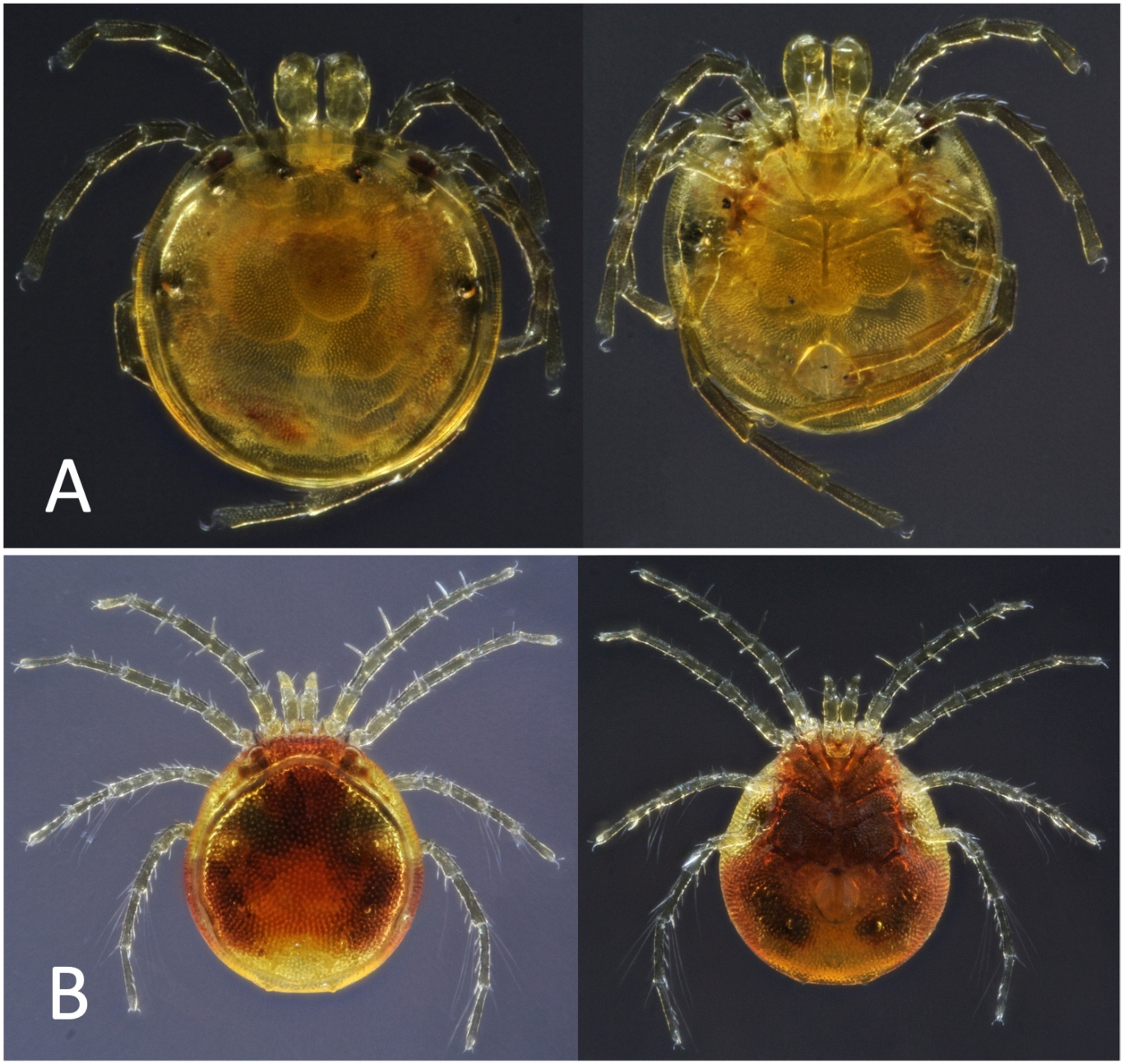

Figure 20 A – *Koenikea* sp., female, dorsal and ventral view, sample site Be18-8a; B – *Recifella* sp. 1, female, dorsal and ventral view, sample site Be18-2a.

Genus *Recifella* K. Viets, 1935

The genus has an Australian-Neotropical disjunction, with 33 species described from Central and South America. Habitat: running waters, standing waters, springs.

Even though not very abundant in the present study, represented by at least two different species (Figures 20B, 21A, and 21B).

Figure 21 A – *Recifella* sp. 2, female, dorsal and ventral view, sample site Be18-4; B – *Recifella* sp. 2, male, dorsal and ventral view, sample site Be18-1b.

Family Arrenuridae Thor, 1900

Genus *Arrenurus* Dugès, 1834

This genus is the most diverse and wide-spread water mite genus with almost 1000 described species worldwide (Smit 2020), and 212 Neotropical species. Habitat: temporary and permanent standing waters (lakes, pools, ponds, ditches, marshes), slow flowing streams, springs.

In the present study represented by at least two different species (Figure 22A, B, C).

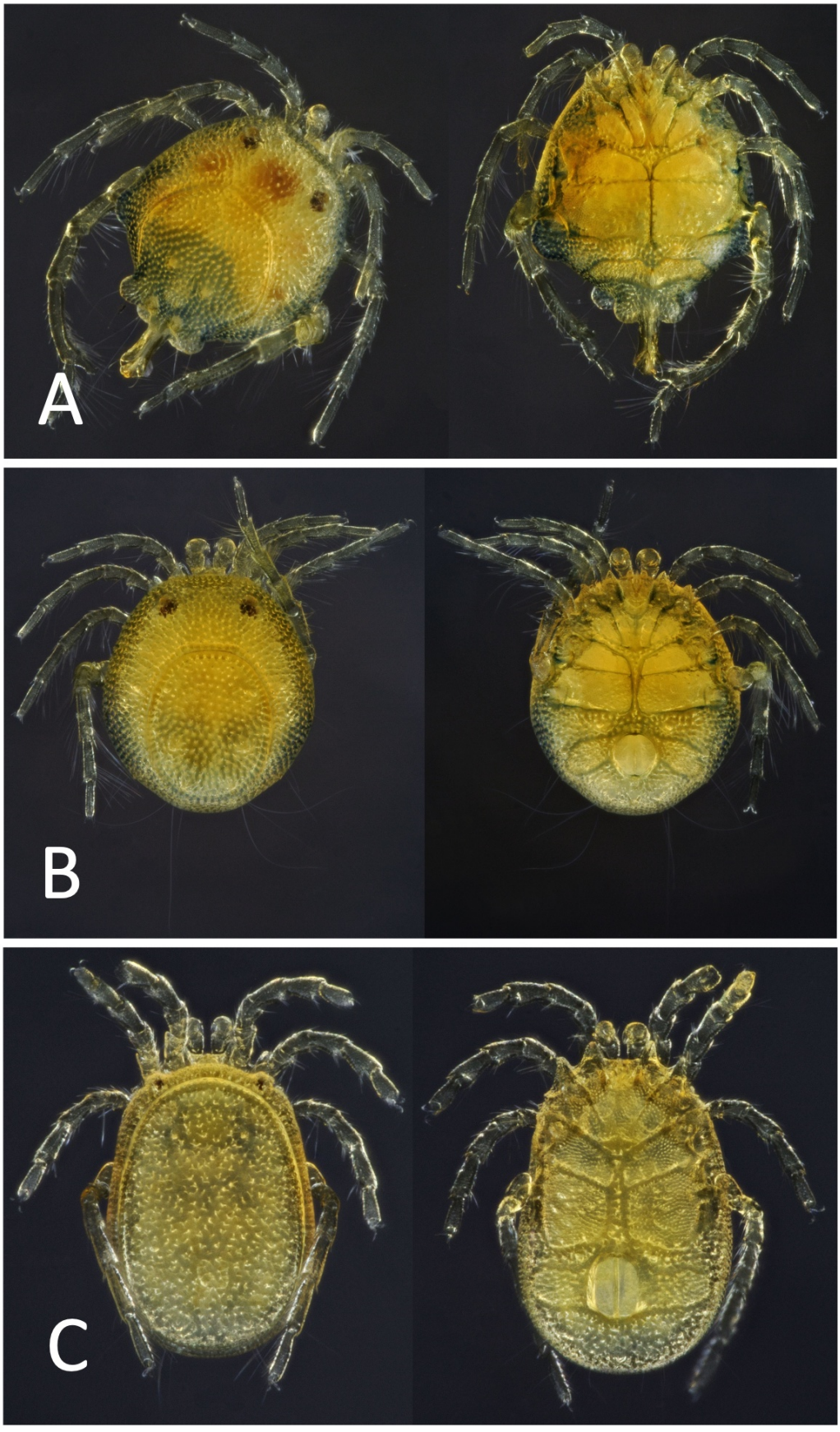

Figure 22 A – *Arrenurus* sp. 1, male, dorsal and ventral view, sample site Be18-1b; B – *Arrenurus* sp. 1, female, dorsal and ventral view, sample site Be18-1b; C – *Arrenurus* sp. 2, female, dorsal and ventral view, sample site Be18-8c.

Family Hungarohydracaridae Motaş & Tanasachi, 1959

Genus *Stygarrenurus* Cook, 1980

An exclusively Central American genus with two described species so far known from Mexico (Cramer & Cook 1996), Costa Rica (Cook 1980) and Panama (Goldschmidt *et al.* 2016). Habitat: interstitial, streams, springs (Figure 23A, B).

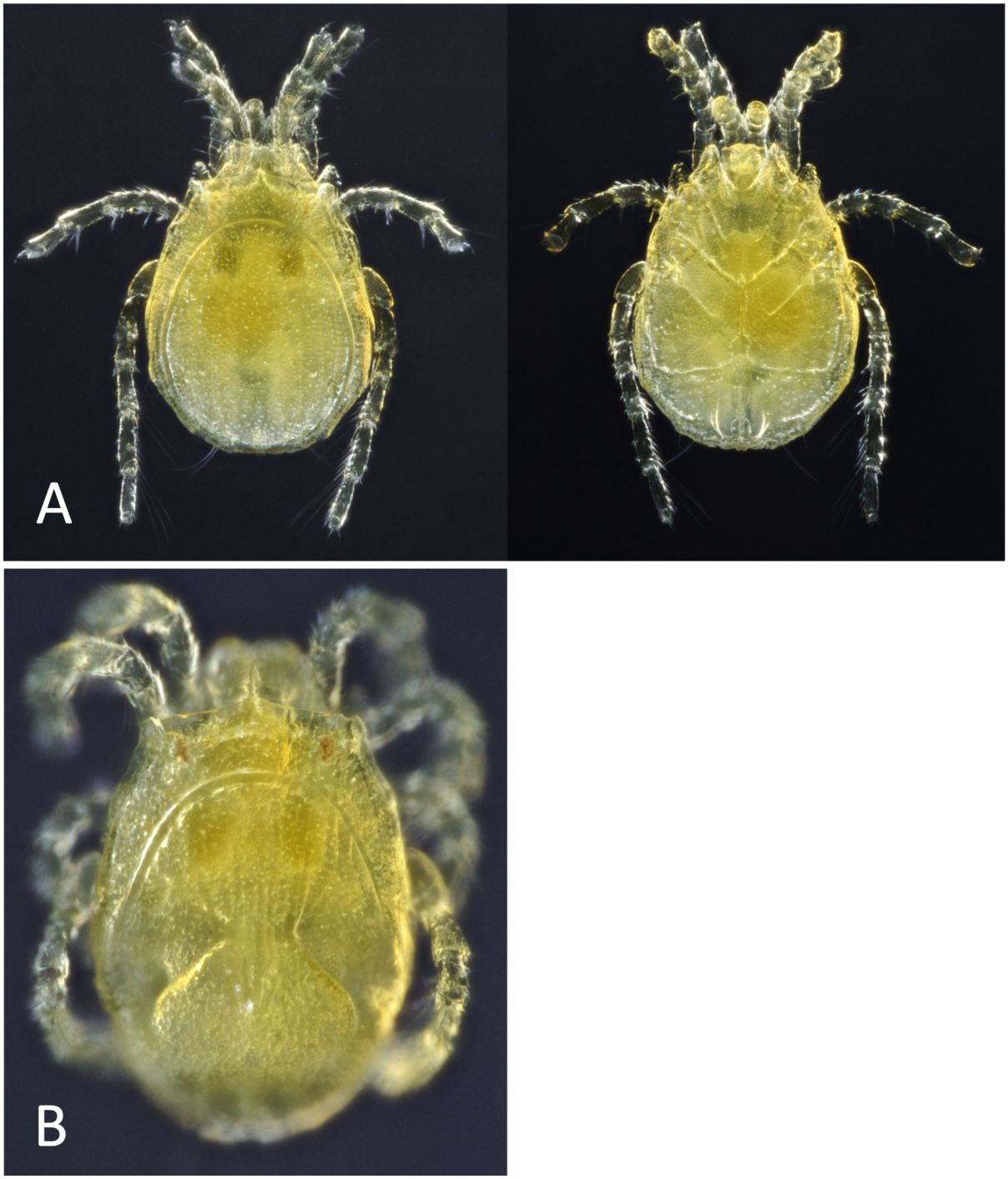

Figure 23 A – *Stygarrenurus* sp., female, dorsal and ventral view, sample site Be18-7a; B – *Stygarrenurus* sp., male, dorsal view, sample site Be18-7a.

Family Mideopsidae Koenike, 1910

Subfamily Mideopsinae Koenike, 1910

Genus *Neoxystonotus* Wolcott, 1900

The genus shows a New World distribution, with some North American and 14 described Neotropical species. Habitat: standing as well as running waters (Figure 24).

Figure 24 *Neoxystonotus* sp., female, dorsal and ventral view, sample site Be18-1b.

Faunistic and biogeographic comparison of the so far known water mite fauna of Belize with neighboring regions

In total, 23 families, 61 genera are known from Central America north of Costa Rica to the south of the Isthmus of Tehuantepec. One of these families (Hungarohydracaridae) and three genera (*Santiagocarus, Neoaxona (Lamellaxona), Stygarrenurus)* in the present study have been found for the first time in this region. Overall, 14 families and 27 genera are now known from Belize. Therefore, with the results of the limited study we are presenting here, the knowledge on the water mite fauna of Belize reaches (or even surpasses) the level of information we have on other areas of the region (Table 3). Out of the 61 genera overall known from the region defined above, six have been registered in all the four areas surrounding Belize (four as well found in the present study); eight are registered from three areas (five in the present study); 13 from two areas (seven in the present study); 16 from one area (five in the present study).

In order to compare the similarity the known water mite fauna of Belize shows with neighboring areas, we calculated the respective Sörensen-quotients. Overall, the highest similarity exists between Southern Mexico and Yucatan (62%) and Guatemala (63%) respectively. The known fauna of Belize is most similar (57%) to the fauna of Guatemala, the lowest similarity (42%) is with the Yucatan Peninsula, probably because most records from Yucatan refer to standing waters, whereas most samples from Belize are from running waters (Table 4).

Table 3 Water mite families and genera known from the area SE of the Isthmus of Tehuantepec / N of Costa Rica (there are no records from Nicaragua, the knowledge on the water mite fauna of El Salvador (K. Viets 1953) and Honduras (Wiles 2005) are very sparse, and the data from Guatemala (Böttger 1980 and further references there are based upon detailed studies of very few sites). Number of published species given in brackets, (-) = genus published without species name. Underlined = known from Belize (present study).

		Yucatan Peninsula (Mexican States Campeche / Yucatan / Quintana Roo)	**Southern Mexico** (Mexican States Chiapas / Tabasco)	**Guatemala**	**El Salvador / Honduras**	**Belize**
		21 genera	**40 genera**	**33 genera**	**18 genera**	**27 genera**
Eylaidae	*Eylais*	X (-)	X (-)			
Limnocharidae	*Limnochares*	X (-)				
	Rhyncholimnochares		X (2)	X (1)		X
Hydrachnidae	*Hydrachna*	X (-)	X (-)	X (1)		
Hydryphantidae	*Hydryphantes*	X (-)	X (-)			
	Trichothyas				x (1)	
Hydrodromidae	*Hydrodroma*	X (2)	X (2)		X (2)	X
Rhynchohydracaridae	*Clathrosperchon*		X (1)	X (2)		X
	Santiagocarus					X
Anisitsiellidae	*Anisitsiella*	X (-)				
	Mamersella		X (1)			
Lebertiidae	*Lebertia*			X (1)	X (1)	X
Limnesiidae	*Centrolimnesia*	X (1)	X (1)			
	Epallagopus				x (1)	
	Kawamuracarus		X (1)			
	Limnesia	X (1)	X (5)	X (3)		X
	Meramecia		X (1)			
	Neomamersa		X (2)			X
	Psammolimnesia		X (1)			
	Tubophorella			X (1)		X
	Tyrrellia				x (1)	
Oxidae	*Oxus*			X (1)	X (1)	
Sperchontidae	*Sperchon*			X (1)	X (1)	X
Torrenticolidae	*Monatractides*		X (1)	X (4)	X (2)	X
	Neoatractides		X (1)	X (4)		X
	Pseudotorrenticola			X (1)	X (1)	
	Torrenticola	X (-)	X (2)	X (12)	X (1)	X
Aturidae	*Albia*	X (1)				X
	Aturus			X (1)		X
	Axonopsalbia			X (1)		
	Axonopsella		X (1)	X (1)		
	Axonopsis		X (3)	X (3)		
	Kongsbergia		X (1)	X (2)		
	Neoaturus		X (1)			
	Neoaxona (Lamellaxona)					X
	Polyaxonopsella			X (1)		X
	Stygalbiella			X (1)		
	Submiraxona		X (1)			
	Woolastookia			X (1)		
Feltriidae	*Feltria*		X (1)			
Frontipodopsidae	*Frontipodopsis*		X (1)	X (1)		X
Omartacaridae	*Omartacarus*		X (2)	X (1)		
Hygrobatidae	*Atractidella*		X (2)		X (1)	X
	Atractides	X (-)	X (8)	X (6)	X (3)	X
	Corticacarus		X (2)	X (1)	X (1)	X
	Diamphidaxona		X (1)	X (1)		
	Hygrobates	X (-)	X (4)	X (2)	X (2)	X
	Paraschizobates		X (1)			X
Pionidae	*Forelia*		X (1)			
	Piona	X (1)	X (1)	X (1)		
Unionicolidae	*Koenikea*	X (4)	X (10)	X (3)		X
	Neumania	X (4)	X (4)	X (1)		
	Recifella	X (1)	X (5)	X (2)	X (1)	X
	Unionicola	X (3)	X (3)	X (2)	X (2)	
Arrenuridae	*Arrenurus*	X (7)	X (7)	X (4)	X (1)	X
Hungarohydracaridae	*Stygarrenurus*					X
Krendowskiidae	*Geayia*	X (-)	X (1)			
	Krendowskia	X (-)	X (2)			
Mideopsidae	*Mideopsis*	X (1)	X (3)	X (1)	X (1)	
	Mideopsides		X (1)			
	Neoxystonotus	X (1)	X (2)			X

Table 4 Similarity of the known water mite faunas of the areas between the Isthmus of Tehuantepec and the northern border of Costa Rica. Number of genera in common and Sörensen-quotient (QS).

QS	Yucatan Peninsula	Southern Mexico	Guatemala	El Salvador / Honduras	Belize
Number of genera in common	**21 genera**	**40 genera**	**33 genera**	**18 genera**	**27 genera**
Yucatan Peninsula		62%	44%	41%	**42%**
Southern Mexico	19		63%	38%	**51%**
Guatemala	12	23		51%	**57%**
El Salvador / Honduras	8	11	13		**49%**
Belize	**10**	**17**	**17**	**11**	

Discussion

A high diversity of water mites was sampled in a limited, preliminary study from Belize. The data even includes one family and three genera recorded in the region for the first time. These data show the great biodiversity potential of this group for the country. Furthermore, this high diversity emphasizes the great potential of water mites as bioindicators for the ecological integrity of Belizean watersheds (Goldschmidt 2016). This assumption is emphasized by the comparison of our data with a recent study on water mites from streams in Panama (Goldschmidt *et al.* 2016).

Ecological comparison with a biomonitoring study from Panama

In the far more extensive study from Panama, a total of 4371 water mite specimens were collected in 15 streams during two intensive sampling campaigns. The collected material yielded 31 genera and 14 families. In comparison, in the present study eight streams and rivers, as well as two small springs were sampled once, yielding 379 specimens representing 27 genera from 14 families.

Most genera are represented in both studies. Though they are not completely comparable due to the lower number of water mites collected in Belize, there are some interesting similarities and differences.

In both studies *Torrenticola* is the most abundant genus overall three genera (*Torrenticola*, *Atractides*, *Hygrobates*) in both studies are among the five and six dominant genera for Belize and Panama respectively.

The genus *Atractidella* was the second most abundant genus in the Panamanian study, with a clear emphasis at contaminated sites. On the other hand, the genus shows low to moderate abundances at pristine or at least low impacted sites (e.g. Goldschmidt 2004 – study on water mites from Costa Rica). In the present study from Belize, just three specimens of *Atractidella* were found.

The Panamanian study (Goldschmidt *et al.* 2016) revealed a group of taxa characteristic for pristine sites: *Hydrodroma*, *Limnesia*, *Koenikea*, *Torrenticola*, *Monatractides, Pseudotorrenticola* and the family Aturidae. All these taxa (except for the rare genus *Pseudotorrenticola*) are represented in the present study from Belize as well. Furthermore, three of them (*Hydrodroma*, *Limnesia*, *Torrenticola*) are among the dominant genera.

Ecological comparison with data from Guatemala, Costa Rica and Mexico

Thirty-three genera in 15 families are known from Guatemala, mainly from mountain streams, as well as from lakes. According to our present state of knowledge, Belize and Guatemala have 18 genera in common (Belize shows the highest similarity with Guatemala (Table 4)), yet 14 rare genera known from Guatemala have not yet been recorded from Belize. Four of these

genera (*Neumania*, *Hydrachna*, *Piona*, *Unionicola*) have been found in lakes in Guatemala. On the other hand, nine genera known from Belize have not yet been recorded in Guatemala.

Given that the data on the water mite fauna of both countries is based on very few sample sites, these similarities are quite strong.

As in the present study, *Torrenticola* has been the dominant genus in a study on the benthos of mountain streams in Guatemala (Böttger 1980), where the genus represented 61% and 38% of all water mites in the two streams studied.

In a study on the water mite fauna of Costa Rica the genus was present at 56% of all sample sites, representing 19% of all specimens collected (Goldschmidt 2007a). Up to seven different species of the genus were found at an individual sample site in Costa Rican streams (Goldschmidt 2009), and up to eight different species in a stream in Guatemala (Böttger 1980).

A comparison with the water mite fauna of the northern neighbor, the Mexican states of Campeche and Quintana Roo, is rather difficult due to the karstic geology of the Northern Yucatan Peninsula, where most aquatic habitats are standing waters. So far, we do not have any data on the water mite fauna of lentic habitats in Belize.

This was a rapid, opportunistic sampling effort conducted over a short period, and included a limited number of habitat types. However, it indicates that Belize potentially harbors an impressive diversity of water mite fauna. It encourages a more intense survey of other watersheds, many different types of lentic and lotic aquatic habitats, hyporheic waters, and estuarine and coastal zone habitats. This is particularly of interest given the potential use of water mites as another biological assessment tool that can be used to help assess the quality and potential impacts of aquatic units. Currently there is growing interest in the use of aquatic macroinvertebrates for water quality assessment and monitoring by non-government agencies and community-based organizations involved in overseeing management of local aquatic resources.

Water mites are often encountered during sampling efforts and may be counted and recorded as a group, but no effort has been invested in identifying specimens to family or genus level due to lack of taxonomic keys and expertise. This project has underscored not just the importance of isolating and preserving mite specimens in separate vials during these field efforts, but to add a requirement to macroinvertebrate assessment protocols to conduct searches specifically for mites within a range of available habitats while on site. A collective sampling effort of this nature could greatly increase our knowledge of the diversity and distribution of water mites of Belize.

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Appendix

Table 5 Similarity of the known water mite faunas of the areas between the Isthmus of Tehuantepec and the northern border of Costa Rica. Number of genera in common and Sörensen-quotient (QS).

Sample	Genus	Specimens	Habitat	Microhabitat
Be 18 - 1a	*Torrenticola*	7	river	riffle
Be 18 - 1b	*Torrenticola*	3	river	backwater pool
	Arrenurus	7		
	Paraschizobates	1		
	Hygrobates	4		
	Limnesia	1		
	c.f. Recifella	3		
	Neoxystonotus	1		
	Albia	2		
Be 18 - 2a	*c.f. Recifella*	1	large stream	pool
	Hygrobates	1		
	c.f. Limnesia	1		
Be 18 - 2b	*Hydrodroma*	3	large stream	riffle
	Hygrobates	1		
Be 18 - 3	*Corticacarus*	1	spring stream	mix
Be 18 - 4	*Limnesia*	4	large stream	pool
	c.f. Recifella	1		
Be 18 - 5a	*Torrenticola*	58	large stream	riffle
	Rhyncholimnochares	1		
	Hydrodroma	2		
	Neomamersa	1		
	Tubophorella	1		
	Corticacarus	1		
	Hygrobates	1		
	Atractidella	1		
	Atractides	4		
Be 18 - 5b	*Torrenticola*	48	large stream	riffle at the edge of the stream
	Neomamersa	4		
	Hygrobates	1		
	Atractides	2		
	Tubophorella	1		
Be 18 - 5c	*Hydrodroma*	14	large stream	pool
	Atractides	4		
	Hygrobates	3		
	Atractidella	2		
	Limnesia	1		
	Monatractides	1		
	Torrenticola	3		
	Neoatractides	4		
	Neoaxona (Lamellaxona)	1		
	Polyaxonopsella	1		
Be 18 - 5d	*Torrenticola*	16	large stream	aquatic plants
	Atractides	11		
Be 18 - 6	*Torrenticola*	1	rheocrene	
Be 18 - 7	*Stygarrenurus*	5	rheopsammocrene	
	Atractides	1		
Be 18 - 8a	*Limnesia*	3	large stream	pool
	Koenikea	1		
Be 18 - 8b	*Torrenticola*	9	large stream	fast riffle
	Neoatractides	1		
	Sperchon	1		
	Clathrosperchon	1		
	Arrenurus	1		
Be 18 - 8c	*Rhyncholimnochares*	1	large stream	slower riffle at the edge
	Torrenticola	14		
	Neoatractides	1		
	Santiagocarus	4		
	Tubophorella	1		
	Hydrodroma	4		
	Atractides	1		
	Arrenurus	2		
	Stygarrenurus	1		
	Frontipodopsis	2		
Be 18 - 9	*Hydrodroma*	2	small stream	mix
	Neoatractides	2		
	c.f. Monatractides	1		
	Stygarrenurus	1		
	Aturus	1		
Be 18 - 10a	*Torrenticola*	57	river	riffle
	Atractides	12		
	Sperchon	2		
	Clathrosperchon	1		
	Neomamersa	1		
Be 18 - 10b	*Hygrobates*	8	river	pool
	Atractides	2		
	Lebertia	1		
	Paraschizobates	1		
	Limnesia	2		
	Torrenticola	1		