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A checklist of the helminth parasites of sympatric rodents from two Mayan villages in Yucatán, México

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Abstract

In this survey, 19 species of helminths including Cestoda (Davaineidae, Hymenolepididae, and Taeniidae), Acanthocephala (Oligacanthorhynchidae), and Nematoda (Trichuridae, Ornithostrongylidae, Heligmonellidae, Oxyuridae, and Gongylonematidae) from *Rattus rattus*, *Mus musculus*, *Sigmodon toltecus*, *Heteromys gaumeri*, and *Peromyscus yucatanicus* in two Mayan villages in Yucatán, México, were recorded. Ten species of helminths were collected in both localities. The highest species richness was recorded in *R. rattus* from Xkalakdzonot (6 taxa). Twelve species are new records for Yucatán and two are registered for the first time in México. This survey constitutes the first checklist of helminth parasites in small rodents in the south-southeast of México.

Key words: Commensal rodents, Distribution, Helminths, México, Wild rodents

Introduction

Rodents account for approximately 44% of mammal species (Wolf & Sherman 2007). In México, Rodentia consists of 233 species, of which 180 are small rodents (Ramírez-Pulido *et al.* 2014). In the state of Yucatán, 14 species of small rodents have been recorded, of which three species are endemic (i.e. *Heteromys gaumeri* Allen & Chapman, *Peromyscus yucatanicus* Allen & Chapman, and *Otonyctomys hatti* Anthony) and two are commensal or synanthropic (i.e. *Rattus rattus* Linnaeus and *Mus musculus* Linnaeus) (Zaragoza-Quintana *et al.* 2016).

Studies on helminths parasitizing small rodents in México are still scarce (Martínez-Salazar *et al.* 2016) and most of them have been carried out in north-central México (e.g. Coronel-Guevara 1953; García-Prieto 1986; Tay Zavala *et al*. 1999; Pulido-Flores *et al*. 2005; Falcón-Ordaz *et al*. 2010; García-Prieto *et al*. 2012; Martínez-Salazar *et al*. 2016). There are only a limited number of surveys in the south-southeastern region that reported helminths from *Ototylomys phyllotis* Merriam, *M. musculus*, *Rattus norvegicus* (Berkenhout), *R. rattus*, and *H. gaumeri* (Chitwood 1938; Cigarroa-Toledo *et al.* 2017; Panti-May *et al.* 2015, 2017).

Although there are taxonomic studies and inventories of helminths parasitizing small rodents, they have been focused on few states such as Hidalgo, México City, Michoacán, Nuevo León, and Zacatecas (see Caballero y Caballero 1958; Gutiérrez-González 1980; Pulido-Flores *et al*. 2005; García-Prieto *et al*. 2010; García-Prieto *et al*. 2012; Falcón-Ordaz *et al*. 2013; García-Prieto *et al*. 2014; Martínez-Salazar *et al*. 2016).

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In rural areas, the presence of factors such as animal food, poor condition of households, poor sanitation, and abundance of vegetation, favor the abundance of commensal rodent populations. Moreover, wild rodents also occur in forest patches surrounding households where they can interact with domestic animals and commensal rodents (Barko *et al.* 2003; Panti-May *et al.* 2012). In this context, the diversity of helminth species could be higher, compared with urban or natural areas. The aim of this study was to analyse the taxonomic and ecological aspects of the helminths found in the assemblage of rodents (Heteromyidae, Cricetidae, and Muridae) from two Mayan villages in Yucatán, México.

Material and methods

This study was carried out in two Mayan villages of Yucatán: Xkalakdzonot (20°26′21.35″N, 88°34′10.25″W), in the municipality of Chankom, and Paraíso (20°40′34.36″N, 90°06′54.23″W), in the municipality of Maxcanú. The state of Yucatán is situated on the Yucatán Peninsula, southeastern México. The regional climate is warm, sub-humid with summer rains. Temperatures average 36 °C in May and 16 °C in January and an average annual rainfall of 1100 mm (Instituto Nacional de Estadística y Geografía 2015). In each village, 25 households were selected for trapping rodents using Sherman traps. The trapping effort was 1950 night-traps in Xkalakdzonot and 1930 night-traps in Paraíso. All animal procedures and methods were carried out following biosafety protocols as previously described (Panti-May *et al.* 2016). Trapped specimens were anesthetized with isoflurane and euthanized by cervical dislocation or with overdose of sodium pentobarbital. Rodents were identified following Reid (2009). When necessary, scientific names of hosts were updated following Ramírez-Pulido *et al*. (2014).

The ethics committee for the use of animals in research from the Campus de Ciencias Biológicas y Agropecuarias (CCBA), Universidad Autónoma de Yucatán (UADY) approved the protocols used in this study (protocol number CB-CCBA D-2016-002). The guidelines of the American Society of Mammalogists for the use of wild mammals in research (Sikes *et al.* 2011) and the guidelines of the American Veterinary Medical Association for the euthanasia of animals (Leary *et al.* 2013) were followed. The rodent trapping was conducted under license from the Mexican Ministry of Environment (SGPA/DGVS/08420/15).

The heart, lungs, stomach, small and large intestines, liver, pancreas, and mesenteries of each specimen were collected and stored in 96% ethanol or frozen at -20°C except the liver which was examined fresh. Helminths were preserved in 70% ethanol. For identification, nematodes were cleared in lactophenol, while cestodes and acanthocephalans were stained with carmine acid, dehydrated through an ethanol series, cleared in eugenol and mounted in Canada balsam. Helminths were identified following keys for Nematoda (Anderson *et al.* 2009), Cestoda (Khalil *et al.* 1994), and Acanthocephala (Amin 1987), among other specific literature. All measurements are in micrometers unless otherwise stated.

The nomenclature about the family group and terms for the Strongylida (Nematoda) follow Durette-Desset & Chabaud (1993) and Durette-Desset & Digiani (2012). The nomenclature of morphometric characteristics for Trichuridae follows Robles *et al*. (2006). Vouchers of hosts were deposited in the Colección Mastozoológica (CM), CCBA (CM-1057–1061, 1077–1095, 1249–1297), and helminth specimens were deposited in the Helminthological Collection of the Museo de La Plata (MLP-He), Argentina, and in the Colección Nacional de Helmintos (CNHE), of the Instituto de Biología, Universidad Nacional Autónoma de México, México.

Prevalence and mean and range of intensity of infections, were calculated following (Bush *et al.* 1997).

Results

Three hundred and ninety eight rodents (223 in Xkalakdzonot and 175 in Paraíso) belonging to eight species were examined. We analyzed 118 *R. rattus*, 74 *M. musculus*, 19 *Sigmodon toltecus* (de Saussure), 8 *H. gaumeri*, 3 *P. yucatanicus*, and 1 *O. phyllotis* from Xkalakdzonot, and 159 *M. musculus*, 7 *R. rattus*, 5 *P. yucatanicus*, 2 *Peromyscus leucopus* (Rafinesque), and 2 *Reithrodontomys gracilis* Allen & Chapman from Paraíso.

Nineteen helminth species were identified, including Cestoda (Davaineidae, Hymenolepididae, and Taeniidae), Acanthocephala (Oligacanthorhynchidae), and Nematoda (Trichuridae, Ornithostrongylidae, Heligmonellidae, Oxyuridae, and Gongylonematidae) (Table 1). No helminths were collected from *O. phyllotis*, *R. gracilis*, and *P. leucopus*.

The information is presented in the form of a list of helminth species. For each species of helminth, site of infection, host, locality, prevalence, intensity of infection, and comments are provided (Table 1).

TABLE 1. Prevalence (P) and mean intensity (MI) of infection of helminths in sympatric rodents from the Mayan villages Xkalakdzonot (XKA) and Paraíso (PAR), Yucatán, México.

Helminth species	Locality	Host	n	P	MI (range)
Cestoda					
Raillietina sp.[a]	XKA	*Sigmodon toltecus*	19	26.3	2.4 (1–6)
Hymenolepis diminuta	XKA	*Rattus rattus*	118	15.3	3.3 (1–11)
Rodentolepis microstoma[a,b]	PAR	*Mus musculus*	159	4.4	5.1 (1–9)
Hydatigera taeniaeformis	XKA	*Rattus rattus*	118	28.8	1.3 (1–4)
		Mus musculus	74	1.4	1 (1)
		Sigmodon toltecus	19	15.8	19.7 (1–50)
	PAR	*Mus musculus*	159	6.9	1.2 (1–2)
Acanthocephala					
Oligacanthorhynchidae[a]	XKA	*Rattus rattus*	118	0.8	4 (4)
Nematoda					
Trichuris muris	PAR	*Mus musculus*	159	15.1	3 (1–9)
Trichuris silviae	XKA	*Heteromys gaumeri*[d]	8	75	3 (2–59)
Trichuris sp.[a]	PAR	*Peromyscus yucatanicus*[c,d]	5	20	1(1)
Vexillata vexillata[a]	XKA	*Heteromys gaumeri*[c]	8	100	358.4 (27–1689)
Carolinensis peromysci[a,b]	PAR	*Peromyscus yucatanicus*[c]	5	20	1 (1)
Hassalstrongylus aduncus[a]	XKA	*Sigmodon toltecus*	19	94.7	372.8 (13–1037)
		Rattus rattus	118	1.7	3 (2–4)
Hassalstrongylus musculi[a]	PAR	*Mus musculus*	159	17	23.9 (1–150)
Nippostrongylus brasiliensis	PAR	*Rattus rattus*	7	14.3	37 (37)
Stilestrongylus sp.[a]	PAR	*Peromyscus yucatanicus*[c]	5	20	1 (1)
Syphacia obvelata	PAR	*Mus musculus*	159	3.8	31.5 (6–90)
Syphacia muris	XKA	*Rattus rattus*	118	65.3	77.9 (1–816)
Syphacia peromysci[a]	PAR	*Peromyscus yucatanicus*[c]	5	20	465 (465)
Syphacia sp.[a]	XKA	*Heteromys gaumeri*[c]	8	12.5	10 (10)
Gongylonema neoplasticum[a]	XKA	*Rattus rattus*	118	11.9	9.4 (1–20)
		Mus musculus	74	6.7	3.2 (1–7)

[a]New record for Yucatán
[b]New record for México
[c]New host record
[d]Species endemic to the Yucatán Peninsula

List of species of helminths

Phylum Platyhelminthes Gegenbaur

Class Cestoda Rudolphi

Subclass Eucestoda Southwell

Order Cyclophyllidea Van Beneden in Braun

Family Davaineidae Braun

***Raillietina* Fuhrmann**

***Raillietina* sp.**

Site of infection: Small intestine

Host: *Sigmodon toltecus*

Locality: Xkalakdzonot

Prevalence and mean intensity (range): 26.3% (5/19) and 2.4 (1–6)

Specimens deposited: MLP-He 7422 and CNHE 10714

Comments: The morphological characteristics observed in our specimens agreed with those established for the genus *Raillietina* (Khalil *et al.* 1994), i.e. rostellum with double alternative crowns; armed suckers; craspedote proglotids; single reproductive organs; unilateral genital pores; small cirrus-sac, not reaching or just crossing the osmoregulatory canals; numerous testes; ovary median; two to eight eggs per capsule. Collected specimens had rostellum 105–138 in diameter with 64–68 hooks; hooks 25–28 long; suckers 96–128 in diameter with spines of 6–8 long; 26–29 egg capsules in young gravid proglottids; egg capsules 100–108 long by 60–70 wide; and five to eight eggs of 29–33 long by 25–29 wide. In North America, there are two common species of *Raillietina* in *Sigmodon*, *Raillietina bakeri* Chandler and *Raillietina sigmodontis* Smith. However, the specimens collected from *S. toltecus* cannot be identified at species level due to the fact that gravid proglottids were not mature. Also, our specimens had similar numbers of egg capsules and eggs per capsule to that of *R. sigmodontis* (30–35) and *R. bakeri* (6–9), respectively (Chandler 1942; Smith 1954).

In México, the genus *Raillietina* has been reported for several mammals. Among small rodents, *Raillietina baeri* Meggitt & Subramanian was recorded from *Heteromys irroratus* Gray in Hidalgo (Carmona-Huerta 1994), and *Raillietina celebensis* (Janicki) from *Oryzomys* sp. in Oaxaca (Flores-Barroeta & Hidalgo-Escalante 1960). Also, unidentified species of *Raillietina* have been reported from *Heteromys pictus* Thomas in Durango (García-Prieto *et al.* 2012), *Dipodomys phillipsi* Gray in Puebla and Veracruz (García-Prieto *et al.* 2012), *Oryzomys couesi* (Alston) and *Oryzomys melanotis* Thomas in San Luis Potosí (Underwood *et al.* 1986), *H. irroratus* in Tlaxcala (García-Prieto *et al.* 2012), and *Chaetodipus* sp. in Zacatecas (Martínez-Salazar *et al.* 2016). This is the first record of a species of *Raillietina* in Yucatán and from *S. toltecus* in México.

Family Hymenolepididae Pierrier

***Hymenolepis* Weinland**

***Hymenolepis diminuta* (Rudolphi)**
(= *Taenia diminuta* Rudolphi; = *Taenia flavopunctata* Weinland)

Site of infection: Small intestine

Host species: *Rattus rattus*

Locality: Xkalakdzonot

Prevalence and mean intensity (range): 15.3% (18/118) and 3.3 (1–11)

Specimens deposited: MLP-He 7423 and CNHE 10699

Comments: The characteristics observed in the specimens collected in Yucatán agreed with descriptions given by Miyazaki (1991) and Fitte *et al*. (2017a), i.e. scolex 146 long by 215–217 wide, with unarmed rostellum and four suckers 90–97 long by 78–90 wide; three testicles separated in two groups by female gonads; and eggs 58–73 long by 45–63 wide without polar filaments.

In México, *H. diminuta* has been recorded from *R. rattus* in Michoacán (Tay Zavala *et al.* 1999), *R. norvegicus* in México City (Caballero y Caballero 1939; Zerecero 1943), Michoacán (Hierro-Huerta 1992; Tay Zavala *et al.*

1999), and Tabasco (Cigarroa-Toledo *et al.* 2017), *Hodomys alleni* (Merriam) in Colima (Miyazaki *et al.* 1980), and *Peromyscus difficilis* (Allen) in Hidalgo (Carmona-Huerta 1994).

In Yucatán, this species was previously reported from *M. musculus* in Opichén (134 km to Xkalakdzonot) and also from *R. rattus* in two localities in Mérida (121–124 km to Xkalakdzonot) and Opichén (Panti-May *et al.* 2017).

***Rodentolepis* Spasskii**

***Rodentolepis microstoma* (Dujardin)**
(=*Taenia microstoma* Dujardin; = *Hymenolepis microstoma* (Dujardin) Blanchard)

Site of infection: Bile ducts

Host: *Mus musculus*

Locality: Paraíso

Prevalence and mean intensity (range): 4.4% (7/159) and 5.1 (1–9)

Specimens deposited: MLP-He 7424 and CNHE 10700

Comments: The traits presented by our material were in accordance with descriptions given by Casanova *et al*. (2001) and Cunningham & Olson (2010), i.e. scolex 258 long by 143 wide, with armed rostellum 67 long by 51 wide and four suckers of 72–78 long by 75–82 wide; rostellum with 26 cricetoid hooks 10.6–11.1 long; three testicles separated by a central lobed ovary; and eggs 63–74 long by 55–60 wide with polar filaments.

Rodentolepis nana (von Siebold) is the only one hymenolepidid cestode registered from *M. musculus* in México, with records in México City (García-Prieto 1986) and Hidalgo (Pulido-Flores *et al.* 2005). This is the first report of *R. microstoma* in México.

Family Taeniidae Ludwig

***Hydatigera* Lamarck**

***Hydatigera taeniaeformis* (Batsch) (*Strobilocercus*)**
(= *Taenia taeniaeformis* Batsch; = *Taenia infantis* Bacigalupo)

Site of infection: Liver

Hosts: *Mus musculus*, *Rattus rattus*, and *Sigmodon toltecus*

Localities: Xkalakdzonot and Paraíso

Prevalence and mean intensity (range): *Mus musculus* 1.4% (1/74) and 1 (1), *R. rattus* 28.8% (34/118) and 1.3 (1–4), *S. toltecus* 15.8% (3/19) and 19.7 (1–56) in Xkalakdzonot. *Mus musculus* 6.9% (11/159) and 1.2 (1–2) in Paraíso

Specimens deposited: MLP-He 7425, 7361, 7362 and CNHE 10701, 10702, 10707

Comments: Each cyst contained one metacestode, which measured from 4 mm to 140 mm prior fixation. The specimens collected in this study showed characteristics which agreed with descriptions given by Jones & Pybus (2001) and Fitte *et al*. (2017b), i.e. scolex with four suckers 692–877 in diameter and rostellum with double alternative crowns of 17–19 hooks each, longer hooks 377–410 in length and smaller hooks 221–253 in length.

In México, *H. taeniaeformis* has been reported from *M. musculus* in México City (García-Prieto *et al.* 2012), *R. rattus* in Hidalgo (Pulido-Flores *et al.* 2005), *R. norvegicus* in México City (Caballero y Caballero 1939) and Michoacán (Hierro-Huerta 1992), and *Sigmodon hispidus* Say & Ord in Nuevo León (Gutiérrez-González 1980).

In Yucatán, this cestode has been previously recorded from *M. musculus* and *R. rattus* in three localities in Mérida (116–124 km to Xkalakdzonot and 56–59 km to Paraíso) and in Opichén (30 km to Paraíso) (Rodríguez-Vivas *et al.* 2011; Panti-May *et al.* 2015, 2017). This is the first record of *H. taeniaeformis* from *S. toltecus* in México.

Phylum Acanthocephala Rudolphi

Class Archiacanthocephala Meyer

Order Oligacanthorhynchida Petrochenko

Family Oligacanthorhynchidae Southwell et Macfie

Oligacanthorhynchidae gen. sp.

Site of infection: Small intestine

Host: *Rattus rattus*

Locality: Xkalakdzonot

Prevalence and mean intensity (range): 0.8% (1/118) and 4 (4)

Specimens deposited: MLP-He 7426

Comments: The characteristics presented in the specimens collected in Yucatán belonged to Oligacanthorhynchidae (Yamaguti 1963; Amin 1987), i.e. specimens of 1300–1800 long, with a trunk relatively wide in proportion to length, wider anteriorly than posteriorly; tubular proboscis armed with approximately 72 hooks arranged in spiral rows; trunk without spines; long and tubular lemnisci with several nuclei; and proboscis receptacle with thick muscular wall. Collected specimens were immature.

In México, four families of acanthocephalans have been recorded from wild mammals (i.e. Moniliformidae Van Cleave, Oligacanthorhynchidae, Plagiorhynchidae Golvan, and Polymorphidae Meyer) (García-Prieto *et al.* 2012). In rodents, the family Moniliformidae is the only one recorded from *R. rattus* in México City (Coronel-Guevara 1953) and *R. rattus* and *R. norvegicus* in Michoacán (Hierro-Huerta 1992; Tay Zavala *et al.* 1999). This is the first record of Oligacanthorhynchidae **gen. sp**. from *R. rattus* in México.

Phylum Nematoda Rudolphi

Class Adenophorea Chitwood

Order Enoplida Baird

Superfamily Trichinelloidea Ward

Family Trichuridae Ransom

***Trichuris* Roederer**

***Trichuris muris* (Schrank)**

(= *Trichocephalus muris* Schrank; = *Mastigodes muris* (Schrank) Zeder,; = *Trichocephalus nodosus* Rudolphi)

Site of infection: Caecum

Host: *Mus musculus*

Locality: Paraíso

Prevalence and mean intensity (range): 15.1% (24/159) and 3 (1–9)

Specimens deposited: MLP-He 7427 and CNHE 10703

Comments: The characteristics observed in the specimens of the present material agreed with those described by Hall (1916) and Feliu *et al*. (2000), i.e. males with spicular tube; spicule 721–776 long; proximal cloacal tube (158–221) wider than the distal cloacal tube (75–104); cylindrical spicular sheath or with distal spherical bulge and spiny; females with non-protrusive vulva; and eggs 57–63 long by 30–32 wide.

In México, *T. muris* has been recorded from *M. musculus* in Hidalgo (Pulido-Flores *et al.* 2005) and Tabasco (Cigarroa-Toledo *et al.* 2017), *R. rattus* in México City (García-Prieto *et al.* 2012), *R. norvegicus* in México City (Zerecero 1943) and Tabasco (Cigarroa-Toledo *et al.* 2017), and *H. irroratus* in Morelos (Eslava-Araujo 2005).

In Yucatán, this species has been previously reported from *M. musculus* in three localities in Mérida and Opichén (Panti-May *et al.* 2015, 2017).

***Trichuris silviae* Panti-May & Robles**

Site of infection: Caecum

Host: *Heteromys gaumeri*

Locality: Xkalakdzonot

Prevalence and mean intensity (range): 75.0% (6/8) and 3 (2–59)

Specimens deposited: MLP-He 7428 and CNHE 10704

Comments: The specimens examined in this study had characteristics described by Panti-May & Robles (2016) of trichurids from *H. gaumeri*, i.e. males with spicular tube; spicule 1471–1732 long; proximal cloacal tube 187–236 long, united laterally to a distal cloacal tube 93–121 long; cylindrical and spiny spicular sheath; females with non-protrusive vulva and eggs 57–63 long by 30–32 wide. Notably, specimens from only one host had spicular sheaths with distal spherical bulge. However, the posterior length/spicular length ratio was similar.

Trichuris silviae has only been reported from *H. gaumeri* in Tzucacab, Yucatán (approximately 65 km from this new locality record) (Panti-May & Robles 2016).

***Trichuris* sp.**

Site of infection: Caecum

Host: *Peromyscus yucatanicus*

Locality: Paraíso

Prevalence and mean intensity (range): 20% (1/5) and 1 (1)

Specimens deposited: MLP-He 7429

Comments: The traits observed in the only non-gravid female collected in Yucatán belonged to *Trichuris* (Robles 2011), i.e. anterior part of body being long, narrow, tapered and whip-like; posterior part of body being broad and handlelike with bacillary band located in anterior portion of body. Prominent vulva located just behind the junction of the esophagus and intestine. However, more material, particularly males, should be collected to identify this taxon at species level.

In México, six species of *Trichuris* have been reported (i.e. *Trichuris citelli* Chandler, *Trichuris dipodomis* Read, *Trichuris elatoris* Pfaffenberger & Best, *Trichuris fossor* Hall, *T. muris*, and *T. silviae*) from several small rodents (Pulido-Flores *et al.* 2005; García-Prieto *et al.* 2012; Panti-May *et al.* 2015; Martínez-Salazar *et al.* 2016; Panti-May & Robles 2016). Unidentified species of *Trichuris* have been reported from small rodents such as *H. pictus* in Chiapas (Caballero y Caballero 1958), *Dipodomys spectabilis* Merriam in Chihuahua (Rendón-Franco *et al.* 2014), and *H. irroratus* in Morelos (Ortíz 1999). This study reports for the first time a species of *Trichuris* from *P. yucatanicus*.

Class Secernentea Von Linstow

Order Strongylida Diesing

Suborder Trichostrongylina Durette-Desest & Chabaud

Superfamily Heligmosomoidea Travassos

Family Ornithostrongylidae (Travassos)

Subfamily Ornithostrongylinae Travassos

***Vexillata* Travassos**

***Vexillata vexillata* (Hall)**
(= *Heligmosomum vexillatum* Hall)

Site of infection: Small intestine
Host: *Heteromys gaumeri*
Locality: Xkalakdzonot
Prevalence and mean intensity (range): 100% (8/8) and 358.4 (27–1689)
Specimens deposited: MLP-He 7430 and CNHE 10705
Comments: The characteristics observed in the specimens examined from Yucatán were in accordance with the original description given by Hall (1916) of parasites from *Thomomys talpoides fossor* (Allen) and the re-descriptions by Sanabria Espinosa *et al*. (1996) and Durette-Desset (1978) from other host species, i.e. synlophe with well-developed careen; 12 cuticular ridges in the synlophe at midbody; subsymmetrical bursa with a pattern of type 2-2-1; dorsal ray with two small and asymmetric accessory branches starting about its mid-length; rays 8 arising from base of dorsal ray and similar in length to it; bifid extremities of dorsal ray; simple genital cone; and simple spicules 301–406 long.

Among the 14 species of *Vexillata* described to date, 9 have been described from Heteromyidae, 4 from Geomyidae, and 1 from Leporidae (Falcón-Ordaz & García-Prieto 2005; Falcón-Ordaz *et al.* 2006; Digiani *et al.* 2007). In México, *V. vexillata* has been reported from *H. pictus* in Chiapas (Caballero y Caballero 1958), *H. irroratus* and *P. difficilis* in Hidalgo (Sanabria Espinosa *et al.* 1996), and *H. irroratus* in Morelos (Ortíz 1999). This is the first record of *V. vexillata* from *H. gaumeri* and for Yucatán.

Family Heligmonellidae Skrjabin & Schikobalova

Subfamily Nippostrongylinae Durette-Desset

***Carolinensis* Travassos**

***Carolinensis peromysci* (Durette-Desset)**
(= *Boreostrongylus peromysci* Durette-Desset)

Site of infection: Small intestine
Host: *Peromyscus yucatanicus*
Locality: Paraíso
Prevalence and mean intensity (range): 20% (1/5) and 1 (1)
Specimens deposited: MLP-He 7440
Comments: The infected mouse harbored only one female specimen. The morphological and metrical characteristics observed in our material agreed with the original description of females given by Durette-Desset (1974) for the parasites found in *Podomys floridanus* (Chapman) and *Peromyscus gossypinus* (Le Conte), i.e. synlophe with 16 ridges at midbody and morphology of the posterior end, including the presence of a wide cuticular fold partially covering the posterior end and leaving free the tail sensu stricto; conical tail, without a mucron, and tail length about half length of the vulva-posterior end distance.

Four species of *Carolinensis* have been reported in México: *Carolinensis carolinensis* (Dikmans) from *Peromyscus maniculatus* (Wagner) in Hidalgo (Pulido-Flores *et al.* 2005), *Carolinensis huehuetlana* Falcón-Ordaz & Sanabria Espinoza, from *P. difficilis* in Hidalgo (Falcon-Ordaz & Sanabria Espinoza 1996) and *Peromyscus mexicanus* (de Saussure) in Hidalgo (Falcón-Ordaz *et al.* 2013), *Carolinensis perezponcedeleoni* Jiménez from *Nyctomys sumichrasti* (de Saussure) in Veracruz (Jiménez 2012), and *Carolinensis petteri* (Denke) from *P. mexicanus* in Veracruz (Denke 1977). This is the first report of *C. peromysci* in México and of *Carolinensis* in *P. yucatanicus*.

***Hassalstrongylus* Durette-Dessete**

***Hassalstrongylus aduncus* (Chandler)**
(= *Longistriata adunca* Chandler; = *Longistriata norvegica* Dikmans)

Site of infection: Small intestine

Hosts: *Rattus rattus* and *Sigmodon toltecus*

Locality: Xkalakdzonot

Prevalence and mean intensity (range): *Rattus rattus* 1.7% (2/118) and 3 (2–4), *S. toltecus* 94.7% (18/19) and 372.8 (13–1037)

Specimens deposited: MLP-He 7431, 7442 and CNHE 10713

Comments: The specimens collected in Yucatán presented morphological characteristics in accordance with the original description given by Chandler (1932) for the parasites of *S. hispidus* and the re-description by Durette-Desset (1972) of parasites from the same host, i.e. 23 cuticular ridges in the synlophe at midbody; subsymmetrical bursa, with two well-developed lateral lobes and small dorsal lobe, bursal pattern type 1-4 with ray 2 well separated and divergent from the ray 3; dorsal ray with a thick trunk at the base and forking in the shape of an inverted U; and spicules 302–639 long with sigmoid tips.

In México, *H. aduncus* has only been reported from *S. hispidus* in Hidalgo and Jalisco (García-Prieto *et al.* 2012). This is the first record of *H. aduncus* from *S. toltecus* and from *R. rattus* in this country.

***Hassalstrongylus musculi* (Dikmans)**
(= *Longistriata musculi* Dikmans)

Site of infection: Small intestine

Host: *Mus musculus*

Locality: Paraíso

Prevalence and mean intensity (range): 17.0% (27/159) and 23.9 (1–150)

Specimens deposited: MLP-He 7432 and CNHE 10711

Comments: The characteristics observed in our material agreed with those described by Dikmans (1935) of parasites from *M. musculus*, and the re-description by Durette-Desset (1974) of parasites from the same host, i.e. 24 cuticular ridges in the synlophe at midbody; slightly disymmetrical bursa with right lobe larger than left, with pattern of type 1-3-1; rays 8 stout and longer than the dorsal ray; dorsal ray divided in its second third; spicules 400–441 long with typical foot shaped tips; and absent gubernaculum.

In México, *H. musculi* has been recorded from *Oligoryzomys fulvescens* (Saussure) *O. couesi*, and *O. melanotis* in San Luis Potosí (Underwood *et al.* 1986). This is the first record of *H. musculi* from its type host (*M. musculus*) in this country.

***Nippostrongylus* Lane**

***Nippostrongylus brasiliensis* (Travassos)**
(= *Heligmosomum braziliense* Travassos; = *Heligmosomum muris* Yokogawa)

Site of infection: Small intestine

Host: *Rattus rattus*

Locality: Paraíso

Prevalence and mean intensity (range): 14.3% (1/7) and 37 (37)

Specimens deposited: MLP-He 7433 and CNHE 10712

Comments: The specimens collected in this study exhibited characteristics described by Yokogawa (1920) and Haley (1961), i.e. 14 cuticular ridges in the synlophe at midbody; asymmetrical bursa with right lobe longer than left, with pattern of type 1-4; in right lobe, ray 2 long and slender, rays 3 and 6 short and slender, rays 4 and 5

thick contiguous and diverging in distal portion; in left lobe, rays 2 to 5 long and slender, ray 6 thick and curved towards dorsal lobe; both rays 8 short and slender; short dorsal ray; rays 9 arising at same level of division of the dorsal ray; and spicules 565–618 long.

In México, *N. brasiliensis* has been recorded from *M. musculus* in Tabasco (Cigarroa-Toledo *et al.* 2017), *R. rattus* in Hidalgo (Pulido-Flores *et al.* 2005) and Tabasco (Cigarroa-Toledo *et al.* 2017), and *R. norvegicus* in Michoacán (Hierro-Huerta 1992) and Tabasco (Cigarroa-Toledo *et al.* 2017).

In Yucatán, this species has been previously reported from *M. musculus* and *R. rattus* in three localities in Mérida and Opichén (Panti-May *et al.* 2015, 2017).

Stilestrongylus Freitas, Lent & Almeida

Stilestrongylus sp.

Site of infection: Small intestine

Host: *Peromyscus yucatanicus*

Locality: Paraíso

Prevalence and mean intensity (range): 20% (1/5) and 1 (1)

Specimens deposited: MLP-He 7439

Comments: Infected mouse harbored one non-gravid female specimen. The characteristics of the synlophe (24 small and subequal ridges with oblique axis of orientation), and morphology of the posterior end (monodelphic, with invaginated tail) evoke clearly the females of the genus *Stilestrongylus* (Notarnicola *et al.* 2010). However, more material, particularly males, should be collected to identify this taxon at species level.

Two species of *Stilestrongylus* have been reported in México: *Stilestrongylus hidalguensis* Falcón-Ordaz & Sanabria Espinoza from *Peromyscus* sp. and *Stilestrongylus peromysci* Falcón-Ordaz & Sanabria Espinoza from *P. difficilis* in Hidalgo (Falcón-Ordaz & Sanabria Espinoza 1999). Also, an unidentified species of *Stilestrongylus* was reported from *Oryzomys* sp. in Oaxaca (García-Prieto *et al.* 2012). This is the first record of a species of *Stilestrongylus* from *P. yucatanicus* and for Yucatán.

Order Oxyurida Chabaud

Superfamily Oxyuroidea Cobbold

Family Oxyuridae Cobbold

Subfamily Syphaciinae Railliet

Syphacia Seurat

Syphacia obvelata (Rudolphi)

(= *Ascaris obvelata* Rudolphi; = *Fusaria obvelata* Zeder; = *Oxyuris obvelata* Bremser; = *Oxyuris stroma* Linstow)

Site of infection: Caecum and large intestine

Host: *Mus musculus*

Locality: Paraíso

Prevalence and mean intensity (range): 3.8% (6/159) and 31.5 (6–90)

Specimens deposited: MLP-He 7434 and CNHE 10708

Comments: The characteristics observed in the specimens agreed with those described by Khalil *et al*. (2014) and Abdel-Gaber (2016), i.e. rounded cephalic plate; amphids located medial to the submedian papillae; slight lateral alae present only in females; males with three mamelons, spicule 81–82 long, gubernaculum 32–33 long, accessory hook without ornamentation, three pairs of caudal papillae surrounding the cloacal region, and tail 134–135 long; females with slightly prominent vulva, tail 417–600 long, and eggs 120–137 long by 37–41 wide.

In México, *S. obvelata* has been reported from *M. musculus* in Hidalgo (Pulido-Flores *et al.* 2005) and Tabasco (Cigarroa-Toledo *et al.* 2017), and *R. norvegicus* in Tabasco (Cigarroa-Toledo *et al.* 2017).

In Yucatán, *S. obvelata* has been previously recorded from *O. phyllotis* in Chichen Itzá (aproximately 162 km from this new locality record, Chitwood 1938) and *M. musculus* in Opichén (Panti-May *et al.* 2017).

***Syphacia muris* (Yamaguti)**
(= *Enterobius muris* Yamaguti)

Site of infection: Caecum and large intestine

Host: *Rattus rattus*

Locality: Xkalakdzonot

Prevalence and mean intensity (range): 65.3% (77/118) and 77.9 (1–816)

Specimens deposited: MLP-He 7435 and CNHE 10706

Comments: The traits presented in our specimens were in accordance with those described by Hugot & Quentin (1985), Robles *et al*. (2008), and Khalil *et al*. (2014), i.e. quadrangular cephalic plate; amphids located close to the ventral submedian papillae; slight swellings of the cuticle instate of lateral alae; males with three mamelons, spicule 50–56 long, gubernaculum 25–30 long, accessory hook without ornamentation, three pairs of caudal papillae surrounding the cloacal region, and tail 174–250 long; and females with no prominent vulva, tail 334–650 long, and eggs 73–80 long by 27–37 wide.

In México, *S. muris* has been reported from *R. rattus* in Hidalgo (Pulido-Flores *et al.* 2005) and Tabasco (Cigarroa-Toledo *et al.* 2017).

In Yucatán, this species has been previously reported from *R. rattus* in three localities in Mérida and in Opichén (Panti-May *et al.* 2015, 2017).

***Syphacia peromysci* Harkema**

Site of infection: Caecum and large intestine

Host: *Peromyscus yucatanicus*

Locality: Paraíso

Prevalence and mean intensity (range): 20% (1/5) and 465 (465)

Specimens deposited: MLP-He 7436 and CNHE 10709

Comments: The specimens examined from Yucatán had traits described by Kruidenier *et al*. (1961), Quentin & Kinsella (1972), and Falcón-Ordaz *et al*. (2016), i.e. cephalic plate rounded (males) or elongated (females); amphids located medial to the ventral submedian papillae; lateral alae present; males with three mamelons, spicule 62–71 long, gubernaculum 31–33 long, accessory hook with ornamentation, three pairs of caudal papillae surrounding the cloacal region, and tail 67–79 long; and females with no prominent vulva and tail 276–321 long. All females were non-gravid.

In México, *S. peromysci* has been recorded from *P. maniculatus* in Hidalgo (Pulido-Flores *et al.* 2005) and *P. difficilis* in Veracruz (Falcón-Ordaz *et al.* 2016). This is the first record of *S. peromysci* from *P. yucatanicus* and for Yucatán.

***Syphacia* sp.**

Site of infection: Caecum

Host: *Heteromys gaumeri*

Locality: Xkalakdzonot

Prevalence and mean intensity (range): 12.5% (1/8) and 10 (10)

Specimens deposited: MLP-He 7437 and CNHE 10715

Comments: The morphological characteristics observed in the collected specimens belonged to *Syphacia*

genus (Anderson *et al.* 2009), i.e. short and stout body; cephalic papillae near amphids; well defined esophagus bulb; and females with long tail, and elliptical eggs flattened at one side. Collected specimens were 10 females with transversal striations in the cuticule that begin in the cuticular collar; rounded cephalic plate; deirids present; lateral alae absent; body 3196–4010 long; tail 663–896 long; and eggs 90–96 long by 30.2–30.7 wide. However, new material, mainly males, should be collected to identify this taxon at a species level.

In México, three species of *Syphacia* have been reported (*S. muris*, *S. obvelata*, and *S. peromysci*) from several small rodents (García-Prieto *et al.* 2012). Also, unidentified species of *Syphacia* have been reported from *P. mexicanus* and *Reithrodontomys* sp. in Hidalgo (Falcón-Ordaz *et al.* 2013; Iturbe-Morgado *et al.* 2017), *R. rattus* in México City (García-Prieto *et al.* 2012), *H. irroratus* in Morelos (Eslava-Araujo 2005), *Oryzomys* sp. and *Peromyscus aztecus* (de Saussure) in Oaxaca (García-Prieto *et al.* 2012), *O. fulvescens* and *O. melanotis* in San Luis Potosí (Underwood *et al.* 1986), and *P. difficilis* in Veracruz (García-Prieto *et al.* 2012). This is the first record of a species of *Syphacia* from *H. gaumeri*.

Order Spirurida Chitwood

Superfamily Spiruroidea Oerley

Family Gongylonematidae (Hall)

***Gongylonema* Molin**

***Gongylonema neoplasticum* (Fibiger & Ditlevsen)**
(= *Spirometra neoplastica* Fibiger & Ditlevsen; = *Gongylonema problematicum* Schulz; = *Gongylonema orientale* Yokogawa)

Site of infection: Stomach

Hosts: *Mus musculus* and *R. rattus*

Locality: Xkalakdzonot

Prevalence and mean intensity (range): *Mus musculus* 6.7% (5/75) and 3.2 (1–7), *R. rattus* 11.9% (14/118) and 9.4 (1–20)

Specimens deposited: MLP-He 7438, 7441 and CNHE 10710

Comments: The characteristics presented by our material agreed with descriptions given by Hall (1916) and Kruidenier & Peebles (1958), i.e. anterior portion of the body with longitudinal cuticular bosses; two prominent lateral alae beginning at level of base of pharynx (95–136 from the anterior tip); the tail of males curved ventrally with two subsymmetrical caudal alae; left spicule longer (519–671) than right (97–110); and 8–9 pairs of caudal papillae (4–5 precloacal and 4 postcloacal).

In México, *G. neoplasticum* has been reported previously for *R. norvegicus* in Michoacán (Hierro-Huerta 1992). Also, unidentified species of *Gongylonema* were reported for *M. musculus* in Hidalgo (Pulido-Flores *et al.* 2005) and *Dipodomys merriami atronasus* Merriam in Zacatecas (Martínez-Salazar *et al.* 2016). This is the first record of *G. neoplasticum* for *R. rattus* and *M. musculus* in México.

Discussion

Prior to our study, eight species of helminths had been reported from small rodents in Yucatán (i.e. *Aspiculuris* sp., *H. diminuta*, *N. brasiliensis*, *S. muris*, *S. obvelata*, *T. taeniaeformis*, *T. muris*, and *T. silviae*) (Chitwood 1938; Panti-May *et al.* 2015, 2017; Panti-May & Robles 2016). In this context, we report 19 helminths from two Mayan villages, 12 of which are new records for Yucatán, 6 represent new host records, and 2 are reported for the first time in México (see Table 1).

We recorded helminths with direct (species within the genera *Carolinensis*, *Hassalstrongylus*, *Nippostrongylus*, *Stilestrongylus*, *Syphacia*, *Trichuris*, and *Vexillata*) and indirect (*H. taeniaeformis*,

Oligacanthorhynchidae **gen. sp**., *H. diminuta*, *R. microstoma*, *Raillietina* sp., and *G. neoplasticum*) life cycles. Notably, *H. taeniaeformis* was the only species found in both localities and in more than one host (see Table 1). The contrasting species richness between localities, could be associated with factors such as the diets of hosts, host specificity of helminth parasites, and micro-environmental conditions and hosts abundance (final and intermediate hosts) in each locality (Krasnov *et al.* 2006).

In this survey, parasites with direct life cycles had higher prevalence and mean intensity of infection compared with those needing an intermediate host. In commensal rodents, *S. muris* had the highest prevalence (65.3%) and intensity (77.9) among *R. rattus* specimens, while *H. musculi* (17.0%) and *S. obvelata* (31.5) had the highest values in *M. musculus*. For wild rodents, the species with highest prevalence and intensity were *H. aduncus* in *S. toltecus* (94.7% and 372.8) and *V. vexillata* in *H. gaumeri* (100% and 358.4) (Table 1). In parasites with direct life cycles, the distribution and worm burdens depend on favorable environmental conditions (e.g. temperature, humidity) for the survival of infective stages, and on the host density to ensure contact between infective stages and hosts (Arneberg 2001; Wilson *et al.* 2002), among other factors.

Domestic animals and commensal rodents can introduce new pathogens to native fauna, and can also act as new hosts for native pathogens (Kelly *et al.* 2009), from which infection may spill back to native fauna and humans. We found two helminth species present in both commensal and wild rodents (*H. taeniaeformis* and *H. aduncus*). In anthropic habitats, domestic cats are the main final hosts for *H. taeniaeformis* and commensal rodents serve as intermediate hosts (Jones & Pybus 2001). Previous studies reported *H. taeniaeformis* as a common parasite of *M. musculus* and *R. rattus* in urban and rural areas in Yucatán (Rodríguez-Vivas *et al.* 2011; Panti-May *et al.* 2015, 2017). In hosts that are not usually prey for cats, cysts may occur in large number and lead to liver failure and possibly death (Dvotakova & Prokopic 1984). On the other hand, we found *H. aduncus*, a common parasite of *Sigmodon* species, in *R. rattus*, suggesting that this rat can act as a new host for this nematode. This parasite has been identified from *Rattus* sp. in the USA (Durette-Desset & Digiani 2005). Our results highlight the importance of parasitological surveys at the wildlife/domestic interface in tropical rural areas where the interaction between domestic, commensal and wild mammals occurs.

Rattus rattus and *M. musculus* have an important role in the life cycle of some helminth species that can cause diseases in humans (Meerburg *et al.* 2009). Among these, we found three cestodes: *H. diminuta*, *R. microstoma*, and *H. taeniaeformis*. Commensal rodents act as the main definitive hosts for *H. diminuta* (*R. rattus* and *R. norvegicus*) and *R. microstoma* (*M. musculus*) and beetles and fleas serve as intermediate hosts. *Hymenolepis diminuta* has been reported in cases of human enteritis, mainly in children, throughout the world (Tena *et al.* 1998; Marangi *et al.* 2003), while *R. microstoma* has only been identified in an Australian community. Similarly, infections in humans with *H. taeniaeformis* have been reported in Argentina, Japan, Sri Lanka, and the Czech Republic (Sterba *et al.* 1977; Ekanayake *et al.* 1999). Although there are few clinical cases of these infections, they have been associated with low levels of hygiene, which favors the abundance of definitive and intermediate hosts, and a close physical proximity with inhabitants (Sterba *et al.* 1977; Macnish *et al.* 2003; Marangi *et al.* 2003), conditions that are prevalent in many tropical rural areas. These results suggest that *R. rattus* and *M. musculus* could be important reservoirs for *H. diminuta* and *R. microstoma* in the study sites, as well as the potential value of commensal rodents as indicators for *H. taeniaeformis*.

This survey constitutes the first checklist of helminth parasites in small rodents in the south-southeast of México. Our list of parasites includes morphological data which are elementary to studying the richness of parasites in assemblages of small rodents in Yucatán. In this context, the checklist helps us to increase our understanding of the ecology and richness of parasites in the region. Moreover, this survey provides preliminary information that can form the basis for future studies examining the effect of intrinsic and extrinsic host factors on the prevalence, burden, host specificity and distribution of parasites.

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