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New host, geographical records, and factors affecting the prevalence of helminths infection from synanthropic rodents in Yucatán, Mexico

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Summary

The aim of this paper was to study the occurrence of helminths in *Mus musculus* and *Rattus rattus* from urban, suburban and rural settlements in Yucatán, Mexico; and to analyse the host factors (e.g. sex) related to helminths' distribution. Helminths in a total of 279 rodents were surveyed by visual examination of the liver for metacestodes and faecal examination for helminth eggs using the formalin-ethyl acetate sedimentation technique. The cestodes *Hydatigera taeniaeformis* (metacestodes detected in the liver) and *Hymenolepis diminuta* , and the nematodes *Aspiculuris* sp., *Nippostrongylus brasiliensis*, *Syphacia muris*, *Syphacia obvelata*, and *Trichuris muris* were identified. In *M. musculus*, the prevalence of infection with *T. muris* and *H. taeniaeformis* was higher in the rural village compared to those in the suburban neighbourhood. For *R. rattus*, a higher prevalence of infection with *H. diminuta* was found in the urban site compared to that in the suburban site. This study reports the occurrence of *H. diminuta* among rodents living in close proximity to humans, representing a potential public health risk. In addition, this survey increases our understanding of dynamic transmission among intestinal helminths recorded in Yucatán, Mexico.
Keywords: *Mus musculus*; *Rattus rattus*; helminths; zoonoses; Mexico

Introduction

Mus musculus Linnaeus 1758 and *Rattus rattus* Linnaeus 1758 are two of the most important synanthropic rodents in the world (Battersby *et al.*, 2008). These species are the cause of extensive economic damage to stored food, farms, industries, and households (Drummond, 2001). Also, they represent an important health risk due to the zoonotic pathogens they harbour and spread, such as viruses, bacteria, protozoa and helminths (Meerburg *et al.*, 2009).

Synanthropic rodents inhabit non-commensal (e.g., islands, forests) and commensal habitats (e.g., households, farms) (Battersby *et al.*, 2008). In urban areas, these rodents are usually abundant in low-income neighbourhoods with precarious households and lack of basic services such as garbage disposal, piped water, and electricity (Langton *et al.*, 2001; de Masi *et al.*, 2009). In rural settlements, the presence of extensive areas of ground, vegetation coverage, and livestock, are factors favouring the abundance of synanthropic rodents (Langton *et al.*, 2001; Promkerd *et al.*, 2008). All these factors favour the close contact with inhabitants which could increase the risk for pathogen transmission (Costa *et al.*, 2014).

The helminth fauna of the synanthropic *M. musculus* and *R. rattus* has been studied in both urban and rural areas from several coun-

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tries of the world (e.g. de León, 1964, Waugh *et al*., 2006, Rafique *et al*., 2009, Mohd Zain *et al*., 2012, Panti-May *et al*., 2015). However, in Mexico, few studies have examined the intestinal parasites of synanthropic rodents (Coronel-Guevara, 1953; García-Prieto, 1986; Falcón-Ordaz *et al*., 2010; García-Prieto *et al*., 2012; Panti-May *et al*., 2015), and only one of them has been carried out in an urban area (Tay Zavala *et al*., 1999). This study reported *Hymenolepis diminuta* Rudolphi 1819 and *Rodentolepis nana* Von Siebold 1852 among *R. rattus* and *R. norvegicus* populations.

On other hand, in Mexico, the majority of scientific publications on the helminths in synanthropic rodents have been reported from less than 50 specimens, and without analysing the rodent population characteristics such as sex, age, sexual activity or related to the type of environment therefore limiting the scope of those studies (Tay Zavala *et al*., 1999; Pulido-Flores *et al*., 2005; Falcón-Ordaz *et al*., 2010).

In south-eastern Mexico, only the species *Nippostrongylus brasiliensis* Travassos 1914, *Hydatigera taeniaeformis* (larvae) Batsch 1786, *Trichuris muris* Schrank 1788, and *Syphacia muris* Yamaguti 1935 have been reported from populations of *M. musculus* and *R. rattus* in a rural community in the state of Yucatán (Panti-May *et al*., 2015).

The aim of this study was to identify helminths from *M. musculus* and *R. rattus* trapped in urban, suburban and rural settlements in Yucatán, Mexico; including demographic factors such as sex, age, and maturity in relationship to the distribution of helminths, so that we could determine the potential health risk of zoonotic parasites carried by rodents.

Materials and Methods

Study sites

This study was carried out within the residential neighbourhoods of San Jose Tecoh (20° 53' 16.0'' N, 89° 37' 19.9'' W) and Plan de Ayala Sur (20° 54' 54.0'' N, 89° 37' 22.8'' W) in the city of Mérida, and the village of Opichen (20° 33' 05.26'' N, 89° 51' 21.76'' W), in Yucatán, Mexico. The urban studied site (San Jose Tecoh) is an area of 1,112,984 m^2 and ~ 6001 inhabitants (Instituto Nacional de Estadística y Geografía, 2012). Its infrastructure is characterized by having paved streets, small businesses, several households in poor conditions showing cracks or holes in doors or windows, and a few vegetated areas. In the backyard and premises, it is common to find some weeds, shrubs, and unserviceable domestic appliances. The suburban studied site (Plan de Ayala Sur) is located within the 'Cuxtal' Ecological Reserve, where the vegetation is representative of a low deciduous tropical forest. It is an area of 1,336,707 m^2 and has ~ 3037 inhabitants (Instituto Nacional de Estadística y Geografía, 2012). This neighbourhood is growing and extending the coverage of basic service such as piped water, electricity and paved roads. It is characterized by having many small households in poor conditions, small businesses, vacant lots, farms, and secondary forest patches at the periphery of the neighbourhood. In the majority of the backyards, it is common to find weeds, shrubs, fruit trees, hen houses, unserviceable domestic appliances and construction rubbish. The rural studied site (Opichen) is an area of 1,460,466 m^2 and has ~ 4761 inhabitants (Instituto Nacional de Estadística y Geografía, 2012). It is located at the western part of Yucatán. The majority of inhabitants live in houses constructed with limestone, wooden poles and thatched with palm leaves adjacent to small rooms constructed with concrete blocks, and it is common to find backyard animals such as chickens, pigs, and cattle. Weeds, shrubs, fruit trees, and vegetable patch plots are also commonly present in the yards.

Rodent trapping

In the neighbourhoods, rodents were trapped from May to October 2013, whereas in the rural village, the trapping was conducted in August and September 2013. Weekly, Sherman traps (two sizes were used, 8 x 9 x 23 cm and 8 x 9.5 x 30.5 cm; HB Sherman Traps Inc., Tallahassee, Florida, USA) were set in each household during three consecutive nights (Panti-May *et al*., 2016). Traps were baited with a mixture of oatmeal and vanilla essence and were distributed inside the house and yard, where signs of rodent activity and potential sources of food or shelter were identified. The rodent trapping was conducted under license from the Mexican Ministry of Environment (SGPA/ DGVS/02528/13).

Ethics

Trapped rodents were transported to the laboratory, anesthetized with an intraperitoneal injection of sodium pentobarbital, and euthanized by overdose of the same product. Handling of rodents in the field and laboratory, was following the guidelines of the American Society of Mammalogists for the use of wild mammals in research (Sikes *et al*., 2011), the guidelines of the American Veterinary Medical Association for the euthanasia of animals (Leary *et al*., 2013), and national specifications for the transportation and euthanasia of animals (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, 1999).

Parasitological examination

The faeces of 173 *M. musculus* and 106 *R. rattus* were examined from three sites (see Table 1). Out of 173 *M. musculus* examined, 81 (46.8 %) were females and 141 (81.5 %) were adults, while 106 *R. rattus* examined, 59 (55.7 %) were females and 55 adults (51.9 %). Liver was examined for larval cestodes in fresh. The faecal and caecum contents were examined for helminth eggs using the formalin-ethyl acetate sedimentation technique (World Health Organization, 2012). Briefly, ~ 1 g of the content was homogenized in a centrifuge tube containing 10 mL of 10 % formalin. After homogenization 3 mL of ethyl acetate were added to the suspension in the tube. The resulting mix was centrifuged at 450 *g* for 3 min. Subsequently, the fatty pug was removed and the supernatant discarded. Finally, ~ 1 mL of saline solution (0.9 %) was added to the sediment and three drops were transferred to a glass slide for

Table 1. Prevalence (P) of helminth species by rodent host species and environment in Yucatán, Mexico.

	Mus musculus			***Rattus rattus***		
	Urban (n = 66)	**Suburban (n = 55)**	**Rural (n = 52)**	**Urban (n = 29)**	**Suburban (n = 55)**	**Rural (n = 13)**
Helminth species	P (CI)	P (CI)	P (CI)	P (CI)	P (CI)	P (CI)
Aspiculuris sp.	0 (–)	0 (–)	0 (–)	3.4 (0.1 – 17.8)	10.9 (4.1 – 22.2)	0 (–)
Nippostrongylus brasiliensis	21.2 (12.1 – 33.0)	36.4 (23.8 – 50.4)	21.2 (11.1 – 34.7)	3.4 (0.1 – 17.8)	5.5 (1.1 – 15.1)	7.7 (0.2 – 36.0)
Syphacia obvelata	0 (–)	0 (–)	9.6 (3.2 – 21.0)	0 (–)	0 (–)	0 (–)
Syphacia muris	0 (–)	0 (–)	0 (–)	10.3 (2.2 – 27.4)	21.8 (11.8 – 35.0)	15.4 (1.9 – 45.4)
Trichuris muris	16.7 (8.6 – 27.9)	9.1 (3.0 – 19.9)	32.7 (20.3 – 47.1)	0 (–)	0 (–)	0 (–)
Hymenolepis diminuta	0 (–)	0 (–)	1.9 (0.01 – 10.3)	31.0 (15.3 – 50.1)	5.5 (1.1 – 15.1)	23.1 (5.0 – 53.8)
Hydatigera taeniaeformis	6.1 (1.7 – 14.8)	3.6 (0.4 – 12.5)	17.3 (8.2 – 30.3)	20.7 (7.9 – 45.5)	10.9 (4.1 – 22.2)	15.4 (1.9 – 45.4)

CI – 95 % confidence interval

examination. In helminth eggs' positive animals, a subset of adult worms was collected to verify the species of helminths by the use of light microscope.

Data analysis
Prevalence (percentage of infected animals from faecal o liver examination) was analysed with the software Quantitative Parasitology 3.0 according to Rózsa *et al*. (2000). The prevalence of helminth infection was compared between mice and rats using the Chi-square test. The relationship between the prevalence of infection of each helminth species relative to demographic characteristics of rodent population, which comprised the host sex, age (mice: subadults ≤ 8 g, adults > 8 g; rats: subadults ≤ 66 g, adults > 66 g), maturity (mature: if females were pregnant, lactating or with vagina open, and if males had scrotal testicles; immature, if females were non-pregnant, lactating or with vagina closed, and if males had inguinal/abdominal testicles), and type of environment (urban, suburban or rural) was tested by Chi-squared and Fisher's exact test. These analyses were confined to parasite with an overall prevalence greater than 10 %.

Results

The overall prevalence of intestinal helminths in synanthropic rodents was 42.7 % (119/279). The prevalence of helminth infection was similar between *M. musculus* (42.8 %, 74/173) and *R. rattus* (42.4 %, 45/106) (χ^2 = 0.003, df = 1, *P* = 0.96). Among 74 infected *M. musculus*, 70.3 % harboured one species of helminth, 25.7 % of specimens had two and 4.0 % of individuals had three different species. Among 45 infected *R. rattus*, 80.0 % harboured one species of helminth, 15.6 % of animals had two and 4.4 % of specimens were infected by three different species.
Seven species of helminths were identified in synanthropic rodents: the cestodes *H. diminuta* and *H. taeniaeformis* larvae; and the nematodes *Aspiculuris* sp. Schulz 1927, *N. brasiliensis*, *S. muris*, *Syphacia obvelata* Rudolphi 1802, and *T. muris*. *Hymenolepis diminuta*, *H. taeniaeformis,* and *N. brasiliensis* were found in both *M. musculus* and *R. rattus*, while *S. obvelata* and *T. muris* were found exclusively in *M. musculus* and *Aspiculuris* sp. and *S. muris* only in *R. rattus*. In *M. musculus*, *N. brasiliensis* was the most prevalent helminth (26 %), followed by *T. muris* (19.1 %). In *R. rat-*

Table 2. Relationship between prevalence of infection of *Mus musculus* relative to host sex, age, maturity, and environment from Yucatán, Mexico.

		Prevalence of helminth species		
	No. of mice examined	***Nippostrongylus brasiliensis*** **n (%)**	***Trichuris muris*** **n (%)**	***Hydatigera taeniaeformis*** **n (%)**
Sex				
Male	92	24 (26.1)	17 (18.5)	6 (6.5)
Female	81	21 (25.9)	16 (19.7)	9 (11.1)
		P = 1.000	*P* = 0.985	*P* = 0.284
Age				
Subadult	15	2 (13.3)	2 (13.3)	1 (6.7)
Adult	158	43 (27.2)	31 (19.6)	14 (8.9)
		P = 0.359	*P* = 0.739	*P* = 1.000
Maturity				
No	53	10 (18.9)	23 (19.8)	5 (9.7)
Yes	116	34 (29.3)	10 (18.9)	9 (7.8)
		P = 0.213	*P* = 1.000	*P* = 0.766
Site				
Urban	66	14 (21.2)	11 (16.7)	4 (6.1)
Suburban	55	20 (36.4)	5 (9.1)	2 (3.6)
Rural	52	11 (21.1)	17 (32.7)	9 (17.3)
		P = 0.106	*P* = 0.007	*P* = 0.037

Chi-square exact significance (two-sided test) or Fisher's exact test where >25% of cells have an expected count < 5

Table 3. Relationship between prevalence of infection of *Rattus rattus* relative to host sex, age, maturity, and environment from Yucatán, Mexico.

	No. of rats examined	*Hymenolepis diminuta* n (%)	*Hydatigera taeniaeformis* n (%)	*Syphacia muris* n (%)
Sex				
Male	59	9 (15.2)	6 (10.2)	8 (13.6)
Female	47	6 (12.8)	8 (17.0)	9 (19.1)
		P = 0.932	*P* = 0.455	*P* = 0.608
Age				
Subadult	44	4 (9.1)	5 (11.4)	8 (18.2)
Adult	62	11 (17.7)	9 (14.5)	9 (14.5)
		P = 0.329	*P* = 0.856	*P* = 0.812
Maturity				
No	32	1 (3.1)	4 (12.5)	6 (18.8)
Yes	72	13 (18.1)	10 (13.9)	10 (13.9)
		P = 0.059	*P* = 1.000	*P* = 0.562
Site				
Urban	29	9 (31.0)	6 (20.7)	3 (10.3)
Suburban	64	3 (4.7)	6 (9.4)	17 (26.6)
Rural	13	3 (23.1)	2 (15.4)	2 (15.4)
		P = 0.001	*P* = 0.283	*P* = 0.166

Chi-square exact significance (two-sided test) or Fisher's exact test where >25% of cells have an expected count < 5

tus, *S. muris* was the most prevalent helminth (16.0 %), followed by *H. diminuta* (14.2 %). In relation to the trapping site, *S. obvelata* was found only in the rural site, *Aspiculuris* sp. in both urban and suburban sites while *N. brasiliensis*, *S. muris*, *T. muris*, *H. diminuta* and *H. taeniaeformis* were found in the three sites (Table 1).

Mus musculus had higher prevalence (26.0 %) of infection with *N. brasiliensis* than *R. rattus* (4.7 %; χ^2 = 18.4, df = 1, *P* < 0.001), whereas *R. rattus* had higher infection with *H. diminuta* (14.1 %) than *M. musculus* (0.6 %; χ^2 = 22.4, df = 1, *P* < 0.001). On the other hand, both rodent species had similar prevalence of *H. taeniaeformis* (*M. musculus* 8.7 %, *R. rattus* 13.2 %; χ^2 = 1.0, df = 1, *P* = 0.316).

The associations of the prevalence of *N. brasiliensis*, *T. muris*, and *H. taeniaeformis* in *M. musculus* with demographic and environmental variables are shown in the Table 2. The prevalence of *T. muris* was higher in rural rodents (32.7 %) compared to that from the suburban neighbourhood (9.1 %; χ^2 = 7.7, df = 1, *P* = 0.005), but there was no association with the urban site or with demographic variables (sex, age and maturity). The prevalence of infection with *H. taeniaeformis* was higher in the rural site (17.3 %) compared to the suburban neighbourhood (3.6 %), but no statistical difference was found with that in the urban site or demographic variables. No significant associations were found between *N. brasiliensis* and any of the explanatory variables. For *R. rattus*, the association of prevalence of *H. diminuta*, *S. muris* and *H. taeniaeformis* with demographic and environmental variables are shown in the Table 3. A higher prevalence of infection with *H. diminuta* was found in the urban site (31.0 %) compared to the suburban site (4.7 %; Fisher exact test, *P* = 0.001), but there was no association with the rural site or with the demographic variables (sex, age and maturity). No statistical differences were found between *S. muris* and *H. taeniaeformis* and any of the explanatory variables.

Discussion

In Mexico, most of the parasitological studies on synanthropic rodents have been conducted in rural environments such as farms or villages (Gutierrez-González, 1980; Pulido-Flores *et al.*, 2005; Falcón-Ordaz *et al.*, 2010; Panti-May *et al.*, 2015). These studies have reported a total of nine species of helminths in both *M. musculus* and *R. rattus*, whereas the only study conducted in an urban settlement reported *H. diminuta* and *R. nana* among *R. rat-*

Table 4. List of intestinal helminth species recorded in *Mus musculus* and *Rattus rattus* from Mexico.

Helminth species	Host (s)	TE	State	Reference
CESTODA				
Monoecocestus sigmodontis	*M. musculus* and *R. rattus*	R	Nuevo León	Gutierrez-González 1980
Hymenolepis diminuta	*R. rattus*	U	Michoacán	Tay Zavala et al. 1999
	M. musculus and *R. rattus*	USR	Yucatán	Present study
Rodentolepis nana	*M. musculus*	–	Distrito Federal	García-Prieto 1986
	M. musculus	R	Hidalgo	Pulido-Flores et al. 2005
	R. rattus	U	Michoacán	Tay Zavala et al. 1999
Hydatigera taeniaeformis larva	*M. musculus*	–	Distrito Federal	García-Prieto et al. 2012
	R. rattus	R	Hidalgo	Pulido-Flores et al. 2005
	M. musculus and *R. rattus*	R	Yucatán	Panti-May et al. 2015
	M. musculus and *R. rattus*	USR	Yucatán	Present study
ACANTHOCEPHALA				
Moniliformis monoliformis	*R. rattus*	–	Distrito Federal	Coronel-Guevara 1953
NEMATODA				
Gongylonema sp.	*R. rattus*	R	Hidalgo	Pulido-Flores et al. 2005
Longistriata sp.	*M. musculus* and *R. rattus*	–	Nuevo León	Gutierrez-González 1980
Aspiculuris huascaensis	*M. musculus*	R	Hidalgo	Falcón-Ordaz et al. 2010
Aspiculuris cf. *lahorica*	*M. musculus*	R	Hidalgo	Pulido-Flores et al. 2005
Aspiculuris sp.	*R. rattus*	U	Yucatán	Present study
Nippostrongylus brasiliensis	*R. rattus*	–	Michoacán	Hierro-Huerta 1992
	M. musculus and *R. rattus*	R	Yucatán	Panti-May et al. 2015
	M. musculus and *R. rattus*	USR	Yucatán	Present study
Syphacia muris	*R. rattus*	R	Hidalgo	Pulido-Flores et al. 2005
	R. rattus	R	Yucatán	Panti-May et al. 2015
	R. rattus	USR	Yucatán	Present study
Syphacia obvelata	*M. musculus*	R	Hidalgo	Pulido-Flores et al. 2005
	M. musculus	R	Yucatán	Present study
Trichuris muris	*M. musculus*	R	Hidalgo	Pulido-Flores et al. 2005
	M. musculus	R	Yucatán	Panti-May et al. 2015
	M. musculus	USR	Yucatán	Present study

U, urban; R, rural; USR, urban, suburban, and rural

A dash (–) indicates unavailability of data *tus* populations (Tay Zavala *et al.*, 1999) (Table 4). In this study, seven species of helminths were found in rodents from urban, suburban, and rural environments, *H. diminuta*, *H. taeniaeformis*, *Aspiculuris* sp., *N. brasiliensis*, *S. muris*, *S. obvelata*, and *T. muris*. Urban and suburban *M. musculus* harboured three species of helminths whereas rural *M. musculus* harboured five species. For *R. rattus*, urban and suburban populations harboured five species of helminths whereas rural rats were infected by four species.

Hymenolepis diminuta, a cestode capable to parasitize rodents, can also infect humans, mainly children living in areas of low socioeconomic status and without adequate sanitation (Tena *et al.*, 1998; Marangi *et al.*, 2003; Martínez-Barbabosa *et al.*, 2012). In this study, *H. diminuta* showed to be more prevalent in *R. rattus* (14.1 %) than in *M. musculus* (0.6 %), and has been reported previously as example in Iran (Pakdel *et al.*, 2013), Italy (Milazzo *et al.*, 2010) and Pakistan (Ahmad *et al.*, 2014). Although, this cestode has an indirect life cycle, its presence in trapped rodents inside households indicates its circulation in the studied sites, which could represent a limited health risk by accidental ingestion of insects.

Rodents serve as intermediate hosts for *H. taeniaeformis* and cats act as final hosts (Lavikainen *et al.*, 2016). This study showed a prevalence of infection in *M. musculus* of 8.7 % and 13.2 % in *R. rattus*. Similar data has been previously reported by Panti-May *et al*. (2015) in a rural community of Mérida, Yucatán (*M. musculus* 9.7 %, *R. rattus* 4.3 %). In the sampled sites for this study, and, in general in Yucatán, the uncontrolled reproduction of stray cats is a serious problem; they forage for food between households laying *H. taeniaeformis* proglottids to the environment. Its occurrence in rodents indicates that it could be enzootic in cat populations in the studied sites, and may thus represent a veterinary interest.

Nippostrongylus brasiliensis and *T. muris* were the most prevalent nematodes in *M. musculus*, demonstrating the high adaptation to this parasite to its host. Infection with *N. brasiliensis* occurs mainly through larval penetration of the host' skin by the infective larvae, therefore tolerating high temperatures and humidity, making this parasite very common in synanthropic rodents of the tropical and Caribbean region (de Leon, 1964; Waugh *et al.*, 2006; Panti-May *et al.*, 2015). It has been reported previously in Yucatán, but with higher prevalences in rodents (*M. musculus* 81.2 %, *R. rattus* 43.5 %) (Panti-May *et al.*, 2015). On the other hand, infection with *T. muris* occurs through ingestion of embryonated eggs laid in the environment, and therefore the low survival in extreme weather conditions could explain the low prevalence (< 20 %) found in this study and in other surveys (see Milazzo *et al.*, 2003; Rafique *et al.*, 2009; Pakdel *et al.*, 2013; Panti-May *et al.*, 2015).

Three oxyuroids were identified, *S. muris* and *Aspiculuris* sp. in *R. rattus* and *S. obvelata* in *M. musculus*. Infection with *S. muris* occurs through the ingestion of infective eggs or retrofection (Stahl, 1963), suggesting that the grooming behaviour of rodents could favour its maintenance among rodent populations (Anderson, 2000). The prevalence of *S. muris* in *R. rattus* was similar to that previously reported in Yucatán (17.4%). By other means, retrofection appears an unlikely mode of transmission for *S. obvelata* (Chan, 1952), which could explain its occurrence only in the rural village(Opichen) with low prevalence. Parasites of the genus *Aspiculuris* are common in *M. musculus*, although *R. rattus* is also susceptible to infection. Field studies have shown that these parasites are uncommon in rat populations (de Leon, 1964; Waugh *et al.*, 2006; Rafique *et al.*, 2009; Mohd Zain *et al.*, 2012; Pakdel *et al.*, 2013; Panti-May *et al.*, 2015) but our data indicates that infection may be feasible.

In this study, the prevalence of infection with *N. brasiliensis* was higher in *M. musculus* (26 %) than in *R. rattus* (4.7 %), whereas *R. rattus* had a higher infection with *H. diminuta* (14.1 %) than *M. musculus* (0.6 %). The higher prevalence with *N. brasiliensis* in *M. musculus* than in *R. rattus* could be related with the terrestrial habits of *M. musculus*, which can favour a prolonged exposure to larval infective stages of *N. brasiliensis* in the ground, whereas the arboreal habits of *R. rattus* can reduce the contact with larvae (Wells *et al.*, 2007). As intermediate host for *H. diminuta* are arthropods (e.g. beetles), the difference on the prevalence with *H. diminuta* between mice and rats could be related to the feeding behaviour of rodents. *Rattus rattus* is a selective consumer and prefers to eat more arthropods than *M. musculus* (Clark, 1982; Riofrío-Lazo & Páez-Rosas, 2015).

The prevalence of infection and the occurrence of some helminths varied between environments. The prevalence of *T. muris* and *H. taeniaeformis* was higher in rural *M. musculus* compared with the suburban population, and *S. obvelata* occurred only in the rural site. In addition, urban *R. rattus* had a higher prevalence of infection with *H. diminuta* compared with suburban rats. This shows that climatic and micro-environmental conditions prevalent in the rural site (e.g. ground, vegetation) could favour the viability of infective eggs. In addition, in the case of parasite with direct life cycle, host density can affect the contact rate with infective stages (Arneberg, 2001). For parasites with indirect life cycle (i.e. *H. taeniaeformis* and *H. diminuta*), the dispersion increases with the probability of intermediate host being captured by a suitable predator which reduce the time of exposure of larval stages to the adversity of the external environment (Choisy *et al.*, 2003). This suggests that, the suitability and availability of intermediate hosts also varied between environments.

The results indicate that micro-environmental factors prevalent in each site could alter the dynamic of transmission of helminths present in rodents from the diverse studied sites. To our knowledge, this study is the first to report the presence of *H. diminuta* in *M. musculus* and the infection with *Aspiculuris* sp. in *R. rattus* from Mexico. Although this study increases the total number of helminth species known in synanthropic rodents from Yucatán to seven, the number of species is still lower than that reported in other regions in Mexico and Latin America (de Leon, 1964; Pulido-Flores *et al.*, 2005; Waugh *et al.*, 2006). In addition, we report the occurrence of *H. diminuta* among rodent populations foraging in close proximity to humans, indicating a limited public health risk, especially to the most vulnerable such as children, the elderly and the immunocompromised. The results present here increase our understanding of the dynamic transmission of intestinal helminths observed in Yucatán, Mexico.

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