Urban Ecosyst
DOI 10.1007/s11252-017-0651-8

Perceptions of rodent-associated problems: an experience in urban and rural areas of Yucatan, Mexico

Jesús Alonso Panti-May[1] · Lorenzo Sodá-Tamayo[2] · Naivy Gamboa-Tec[3] · Rosy Cetina-Franco[3] · Nohemi Cigarroa-Toledo[3] · Carlos Machaín-Williams[3] · María del Rosario Robles[4] · Silvia F. Hernández-Betancourt[2]

© Springer Science+Business Media New York 2017

Abstract Rodents are a threat to agriculture and homes, and are a public health risk. Local perceptions about rodents and the damage they cause are vital, as a first step, to the design and implementation of rodent control or educational programs. A total of 111 interviews were conducted in two urban neighborhoods and two rural villages in Yucatan, Mexico. More than 90% of the interviewed inhabitants perceived rodents as a problem. The fear of rodents (57%), damage to food and stocks (56%), and damage to clothes (34%), were the most cited problems. In the urban neighborhoods, the use of rodent control methods was more frequent (57%) than in the villages (33%) in this study. In addition, the percentage of damage to domestic appliances was lower in villages (10%) than in neighborhoods (33%). Our preliminary results suggest that rodent pests represent a threat to human health and to human food security in the studied sites.

✉ Jesús Alonso Panti-May
panti.alonso@gmail.com

[1] Doctorado en Ciencias Agropecuarias, Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Yucatán (UADY), Km 15.5 carretera Mérida-Xmatkuil, C.P, 97135 Mérida, Mexico

[2] Facultad de Medicina Veterinaria y Zootecnia, UADY, Km 15.5 carretera Mérida-Xmatkuil, C.P, 97135 Mérida, Mexico

[3] Centro de Investigaciones Regionales "Dr. Hideyo Noguchi", UADY, Calle 96, avenida Jacinto Canek y calle 47, Paseo de las fuentes, C.P, 97225 Mérida, Mexico

[4] Centro de Estudios Parasitológicos y de Vectores CEPAVE (CCT-CONICET- La Plata), Universidad Nacional de La Plata (UNLP), Bv 120 e/ 61 y 64, 1900 La Plata, Buenos Aires, Argentina

Keywords Rodent pests · Urban · Rural · Public health · Interviews · Mexico

Introduction

Rodents account for approximately 44% of mammal species and inhabit all continents except Antarctica (Wolff and Sherman 2007). Despite the large number of rodent species, only 5–10% are considered a serious economic problem in both urban and rural areas (Stenseth et al. 2003). Among these, commensal rodents, particularly the Norway rat (*Rattus norvegicus*), the black rat (*Rattus rattus*) and the house mouse (*Mus musculus*) are considered the most important pests in the world (Battersby et al. 2008). These rodents are serious pests to crops, on animal farms, in industries, and in homes (Pimentel et al. 2005). In Asia, every year, the estimated loss of rice due to rodents is approximately 30 million metric tonnes (5% of production); an amount that could feed 180 million people for a year (Capizzi et al. 2014). In 1993–94, in Australia, a house mouse plague caused losses to crops (e.g. maize, rice, soybeans) estimated at US$60 million (Brown et al. 2004). In the USA, Pimentel et al. (2005) estimated that the cost of destruction to crops by rats (Norway and black rats) is more than US$19 billion per year. In addition, rodents are a public health risk due to the zoonotic pathogens they maintain and spread, such as viruses (e.g. Seoul hantavirus), bacteria (e.g. *Leptospira interrogans*), and helminths (e.g. *Hymenolepis nana*) (Meerburg et al. 2009; Himsworth et al. 2013b).

Despite the ubiquity of rodent pests, field studies have shown that the distribution, abundance, and composition of rodent communities can vary over time and habitats depend on environmental factors and the landscape characteristics of each habitat (Davis 1953; Cavia et al. 2009; Garba et al.

Published online: 30 January 2017

2014a; Himsworth et al. 2014). For example, in Sao Paulo, Brazil, de Masi et al. (2009) found that rodent infestation was associated with food availability. In particular, black rats were abundant in dwellings with animal food, whereas Norway rats infested dwellings with fructiferous trees.

In Mexico, the knowledge of rodent ecology in commensal habitats is scarce. There are few studies on rodent pests in commensal habitats. In Mexico City, Villa et al. (1997) reported that the Norway rat was the major pest species on poultry farms, and that pregnancy rates vary throughout the year. In Merida, Mexico, Panti-May et al. (2012, 2016) reported that the house mouse was the most abundant species, followed by the black rat in urban and rural areas, and that both species had high reproductive rates. Moreover, in urban habitats, public health risks from rodent-associated zoonoses may be lower than those in rural communities, where rodent abundance is generally high (Battersby et al. 2008). Thus, rodent-associated problems could also vary, depending on rodent species and their abundance and distribution.

Popular perception about rodents and rodent-associated damage provide indirectly useful insights into the impact of rodents on the human environment, as well as the degree of knowledge on rodents of inhabitants (Garba et al. 2014b). Also, this information is fundamental to design and improve integrated pest management programs. Studies of the public opinion about rodent-associated problems in households are rare in scientific literature, and these types of studies are generally restricted to the perceptions of farmers (Makundi et al. 2006; Brown et al. 2008; Gadisa and Birhane 2016). Moreover, popular perceptions, especially from children, can help us to design environmental health education campaigns for rodent control in schools (Hancke and Suárez 2014).

In Niamey, Niger, the most mentioned damage to households, associated to rodents, were on food or food stocks, followed by damages on houses, furniture, and clothes (Garba et al. 2014b). In British Columbia, Canada, Himsworth et al. (2013a) reported that in the opinion of pest control professionals, rats abound in sites with exposed garbage, abandoned buildings, and compost, and that poison baiting is the cheapest and easiest method of rodent control, although environmental modification is the most effective way to control rodent infestations in the long term. In Manchester, the United Kingdom, the majority of residents indicated that rodents pose a public health risk, and that poisons are the best way to control mouse and rat populations (Marshall and Murphy 2003).

As part of a series of surveys focusing on the role of rodents in the transmission of zoonotic diseases, we conducted investigations in several communities in Yucatan, Mexico. To our knowledge, no previous study in the Americas has documented the perceptions of rodent-associated problems in households. We present the perceptions regarding rodent pests of inhabitants of urban and rural settlements in Yucatan, Mexico.

Material and methods

This study was carried out in two urban residential neighborhoods and two rural villages of the Yucatan State, Mexico. The Yucatan State has ~1,955,577 inhabitants, of which 16% live in rural areas (Instituto Nacional de Estadística y Geografía 2010). The sampled neighborhoods were San Jose Tecoh (SJT; 20°53′16.0″N, 89°37′19.9″W) and Plan de Ayala Sur (PAS; 20°54′54.0″N, 89°37′22.8″W), located in a low socioeconomic area within the city of Merida, municipality of Merida. The villages were Xkalakdzonot (XKA; 20°26′21.35″N, 88°34′10.25″W), in the municipality of Chankom, and Paraíso (PAR; 20°40′34.36″N, 90°06′54.23″W), in the municipality of Maxcanú. Typically, in the neighborhoods, the houses occupy a larger area than yards and have solid floors and walls, but these are generally in poor conditions with cracks or holes (Fig. 1a, b). In the villages, the majority of inhabitants live in small houses constructed with stones, wooden poles and thatched with palm leaves, that are adjacent to small rooms constructed with blocks of concrete (Fig. 1c, d).

In these sites, rodent trapping was conducted in order to study the presence of zoonotic pathogens among rodent populations. In each site, 23–30 households were selected for trapping rodents. Briefly, in each household, eight Sherman traps were set for three consecutive nights (24 trap-nights per month). Traps were placed inside houses and yards close to signs of rodent activity (fecal droppings, burrows or active runs), potential sources of food (exposed garbage and human or animal food) or harborage (areas with vegetative coverage and unserviceable domestic appliances) (Panti-May et al. 2016). Interviews were performed exclusively in all rodent trapping households between August and September 2016. A paper-based questionnaire was carried out with the head of the family, usually the mother. The questionnaire consisted of 11 questions about the presence of rodents, rodent control methods, and the perceptions of rodent-associated problems following the categories used by Garba et al. (2014b). All questions, with the exception of rodent control methods, were 'closed' (i.e. expected answers were either 'yes' or 'no').

The proportion of positive answers was first compared between SJT and PAS (urban neighborhoods), and then between XKA and PAR (rural villages), using a Chi-square test of independence (McDonald 2014). When >25% of cells had an expected count of 5, a Fisher's exact test was used (McDonald 2014). In the case of rodent control methods, no associations were tested between control methods and sites due to their low number of positive answers. As SJT and PAR, and XKA and PAR had similar proportions, data were pooled into urban and rural, respectively, and were analyzed in the same manner (see results).

Fig. 1 Photographs of a typical household in San Jose Tecoh (**a**), Plan de Ayala Sur (**b**), Xkalakdzonot (**c**), and Paraíso (**d**), in Yucatan, Mexico, illustrating the conditions of the houses, walls, fences, and yards

Results

Although this study is not a proper investigation on commensal rodent communities in urban and rural areas of Yucatan, the results of trapping are presented. A total of 790 rodents were trapped with an overall trap success (TS) of 7.5%. In the neighborhoods, 386 commensal rodents were trapped: in SJT, *M. musculus* was the dominant species (TS = 4.9%) followed by *R. rattus* (TS = 1.2%), whereas in PAS, *R. rattus* (TS = 3.4%) and *M. musculus* (TS = 2.5%) had similar trap successes. In the villages, 404 rodents were trapped: in XKA, *R. rattus* (5.7) and *M. musculus* (3.6) were the dominant species, followed by the native species *Sigmodon hispidus* (TS = 0.9%), *Heteromys gaumeri* (TS = 0.4%), *Peromyscus yucatanicus* (TS = 0.1%), and *Ototylomys phyllotis* (TS = 0.05%), whereas in PAR, *M. musculus* was the dominant species (TS = 7.7%), followed by *R. rattus* (TS = 0.3%), *P. yucatanicus* (TS = 0.2%), *Peromyscus leucopus* (TS = 0.1%) and *Reithrodontomys gracilis* (TS = 0.1%). Thus, *M. musculus* and *R. rattus,* were the most common rodent species in both urban and rural households.

A total of 111 people were interviewed in Yucatan: 30 in both SJT and PAS, 28 in XKA, and 23 in PAR. Of the four sites, 73.9% (82/111) of the interviewed people saw rodents in their households during the last six months and 45.9% (51/111) of them declared using at least one rodent control method. The most reported methods were glue traps (30.4%, 17/56) and rodenticides (26.8%, 15/56) (see Table 1). Rodents were perceived as a problem by 91% (101/111) of the respondents. Responses from all participants showed that fear, by at least one relative, was the most cited nuisance (56.9%, 62/109), followed by damage to food and stocks (56%, 61/109), and clothes (34.2%, 38/111). Damage to domestic appliances (22.5%, 25/111), furniture (18%, 20/111), and houses (15.3%, 17/111) were the less cited rodent-associated problems. Interestingly, only two cases (1.8%, 2/111) of rodent bites were reported; both cases were mentioned in PAS.

There were significant differences between the urban and rural perceptions and attitudes towards rodents (Table 1). In the villages, the percentage of families that use rodent control methods, 33.3% (17/51) was significantly lower than the 56.7% (34/60) of neighborhoods (χ^2 = 5.14, P = 0.02). Additionally, the percentage of damage to domestic appliances in villages, 9.8% (5/51), was lower than the 33.3% (20/60) of their urban counterparts (χ^2 = 7.45, P = 0.01). In neighborhoods, the main methods of rodent control were glue traps (38.9%) and rodenticides (36.1%), whereas in villages they were live traps (55.0%) and animals (i.e. cats and dogs) (20.0%). There were no differences between the urban and rural perceptions of damage on food and stocks, clothes, furniture, houses, or fear caused by rodents (Table 1).

Discussion

In this study, we present the perception of inhabitants towards rodents and their associated problems from urban and rural settlements in Yucatan, Mexico. Our results show that rodents are perceived as a problem by 91% of the interviewed people. Fear of rodents was the problem most mentioned (56.9%) by

Table 1 Summary of answers obtained from our questionnaires presented by urban and rural areas, neighborhood, village, as well as for the Yucatan State. The percentages of positive answers were calculated on the basis of exploitable answers

		Urban			Rural			Yucatan
		SJT	PAS	All	XKA	PAR	All	Total
Presence of rodents:	N exploitable answers	30	30	60	28	23	51	111
	N positive (%) answers	23 (76.7)	22 (73.3)	45 (75.0)	20 (71.4)	17 (73.9)	37 (72.5)	82 (73.9)
Rodent control:	N exploitable answers	30	30	60	28	23	51	111
	N positive (%) answers	17 (56.7)	17 (56.7)	**34 (56.7)**	9 (32.1)	8 (34.8)	**17 (33.3)**	51 (45.9)
Rodent control methods*:		17	19	36	10	10	20	56
Rodenticide	N positive (%) answers	4 (23.5)	9 (47.4)	13 (36.1)	1 (10.0)	1 (10.0)	2 (10.0)	15 (26.8)
Glue trap	N positive (%) answers	9 (52.9)	5 (26.3)	14 (38.9)	0 (−)	3 (30.0)	3 (15.0)	17 (30.4)
Snap trap	N positive (%) answers	2 (11.8)	0 (−)	2 (5.6)	0 (−)	0 (−)	0 (−)	2 (3.6)
Live trap	N positive (%) answers	1 (5.9)	0 (−)	1 (2.8)	6 (60.0)	5 (50.0)	11 (55.0)	12 (21.4)
Animal (cat or dog)	N positive (%) answers	1 (5.9)	5 (26.3)	6 (16.7)	3 (30.0)	1 (10.0)	4 (20.0)	10 (17.9)
Rodent-associated problems	N exploitable answers	30	30	60	28	23	51	111
	N positive (%) answers	27 (90.0)	27 (90.0)	54 (90.0)	25 (89.3)	22 (95.7)	47 (92.2)	101 (91.0)
Damages to food and stocks	N exploitable answers	28	30	58	28	23	51	109
	N positive (%) answers	17 (60.7)	19 (63.3)	36 (62.1)	14 (50)	11 (47.8)	25 (49.0)	61 (56.0)
Damages to domestic appliances	N exploitable answers	30	30	60	28	23	51	111
	N positive (%) answers	11 (36.7)	9 (30.0)	**20 (33.3)**	2 (7.1)	3 (13.0)	**5 (9.8)**	25 (22.5)
Damages to clothes	N exploitable answers	30	30	60	28	23	51	111
	N positive (%) answers	10 (33.3)	13 (43.3)	23 (38.3)	5 (17.9)	10 (43.5)	15 (29.4)	38 (34.2)
Damages to furniture	N exploitable answers	30	30	60	28	23	51	111
	N positive (%) answers	9 (30.0)	6 (20.0)	15 (25.0)	2 (7.1)	3 (13.0)	5 (9.8)	20 (18.0)
Damages to houses	N exploitable answers	30	30	60	28	23	51	111
	N positive (%) answers	5 (16.7)	7 (23.3)	12 (20.0)	3 (10.7)	2 (8.7)	5 (9.8)	17 (15.3)
Fear	N exploitable answers	30	29	59	27	23	50	109
	N positive (%) answers	22 (73.3)	14 (48.3)	36 (61.0)	12 (44.7)	14 (60.9)	26 (52.0)	62 (56.9)
Bites	N exploitable answers	30	30	60	28	23	51	111
	N positive (%) answers	0 (−)	2 (6.7)	2 (3.3)	0 (−)	0 (−)	0 (−)	2 (1.8)

Numbers highlighted in bold show a P value <0.05

*The total of positive answers are higher than the total of positive answers for rodent control because some inhabitants use two methods

inhabitants. Mothers and children were the most frequently cited regarding fear (data no shown). Although fear or phobia can be acquired vicariously (ÖSt and Hugdahl 1981), fear of rodents in the surveyed families could be related to high levels of rodent infestations and the close contact with rodents (Panti-May et al. 2016). In general, people with fear of rodents have a strong dislike or aversion towards them, but in some cases the high level of fear can cause rodent phobia, in which individuals suffer a significant amount of distress or interference in their lives (Hsia 2003). In this survey, some people mentioned high levels of anxiety when they only see rodents. Thus, it would be advisable to conduct psychological and epidemiological studies in order to determine the health impact of fear of rodents on inhabitants.

Damage to food and/or stocks (56%) was the second most important rodent-associated problem mentioned by inhabitants. Similarly, in Niamey, Niger, Garba et al. (2014b) reported damage to food and stocks in 63.1% of urban households. In the neighborhoods, inhabitants mentioned that rodents damage mainly human foodstuffs, whereas in villages, rodents consume human foodstuffs and crops (e.g. corn, pumpkin). In general, the foodstuffs and crops in the studied households are stored in open spaces where they are freely accessible to rodents. Hence rodents could be a threat to human food security in the studied sites.

Another frequently cited problem was damage to clothes (34.2%). In Russian educational institutions, Sidorov and Putin (2010) reported that the percentage of damage to items made of natural fibers (e.g. clothes) caused by house mice was 12.6%. Similarly, Nigerien families mentioned that the percentage of destruction of clothes by rodents in their homes was 16.8% (Garba et al. 2014b). This difference could be explained by the abundance of house mice in both urban and rural households. Indeed, some inhabitants mentioned that

when house mice are abundant, they often build nests inside closets or beds.

In one site, PAS, two cases of rodent bites (1.8% in Yucatan) were mentioned. In Niamey, Niger, Garba et al. (2014b) reported a low percentage of bites (5.4%) in inhabitants of urban households. In New York City, USA, Childs et al. (1998) evaluated 514 cases of rodent bites from 1984 to 1994, and they found that rats were the most frequent rodent involved in bites (81%) and that people who had been bitten lived on blocks with low incomes and poor structural conditions. In the two cases mentioned in PAS, bites were caused by rats, and the respondents mentioned no health problems after the event. Apparently, rodent bites are infrequent and rarely involve pathogen transmissions (Elliott 2007). However, bites can result in a rare but potentially fatal illness caused mainly by the bacterium *Streptobacillus monoliformis*, the agent of the rat-bite fever (Graves and Janda 2001; Centers for Disease Control and Prevention 2005). In addition, rodents can transmit numerous zoonotic pathogens through contact with their ectoparasites, urine or feces. In Yucatan, several studies on rodent populations have reported zoonotic agents, such as flavivirus (Cigarroa-Toledo et al. 2016), *Leptospira interrogans* (Torres-Castro et al. 2014), *Rickettsia felis* (Panti-May et al. 2015b), and helminths (Panti-May et al. 2015a).

This study found differences between urban and rural perceptions. In neighborhoods, the use of some method of rodent control was more frequent (57%) than in villages (33%). This suggests that inhabitants from urban areas are less tolerant to the presence of rodents than people from rural areas, or that the education or knowledge about the control of rodents is better in the city. In neighborhoods, the most popular methods of rodent control were rodenticides (38%) and glue traps (35%), whereas in villages, live traps (53%) and animals (20%) were the main methods. In urban areas, the popularity of rodenticides and glue traps could be related to their low price and the ease of buying them in supermarkets or agricultural supply stores. In contrast, live traps are popular in villages because they are cheap and easily repairable, allowing their use for several months. Also, rural inhabitants frequently adopt a cat or a dog because they perceive that predation by cats or dogs significantly affect the size of rodent populations. On the other hand, damage to domestic appliances were infrequent in villages (10%) when compared to neighborhoods (33%). The reason for this difference is unknown, but could be related to the higher number of domestic appliances in urban houses than rural houses.

The perception of residents towards rodents is an important and often neglected area of rodent control programs (Marshall and Murphy 2003). If the perceptions and beliefs of residents are not incorporated into control programs, then residents may believe that rodent control is the responsibility of government agencies or that they have little to contribute to control programs (Marshall and Murphy 2003). Successful rodent control programs need the active participation of residents. The incorporation of the perceptions of residents in control programs may increase their motivation and participation in community groups and control activities such as clean-up campaigns (Nolte et al. 2003). Moreover, the understanding of the beliefs is also important to select the most appropriate approaches to control strategies (Marshall and Murphy 2003). If residents from villages believe that the presence of predators, such as cats, eradicates rodent populations in the houses or that rodenticides are the best way to control rodents, then they may put little effort into environmental management and rodents will continue colonizing houses.

Despite the low number of interviewed persons, the preliminary information generated in this study is relevant to the understanding of the economic and medical impact associated with rodent pests, as well as to the design of rodent control programs. To our knowledge, this study is the first to document contemporary views of inhabitants of urban and rural settlements towards rodents and their associated problems in the Americas. Further studies evaluating the level of destruction by rodents to crops, on animal farms, in industries, and in homes could increase the knowledge on the economic impact of rodent pests in Mexico. Our results suggest that the presence of rodent pests represent a threat to human health and to human food security in the studied sites.

Acknowledgements We thank the families who participated in this research. We are also grateful to Yessica Gurubel, Emir Palomo and Kenia Canché, for their support in the field work, to Lourdes Talavera for her assistance in the Laboratorio de Arbovirología, Universidad Autónoma de Yucatán, and to Thomas Eldridge for his valuable comments and for the revision into English.

Compliance with ethical standards

Funding The fieldwork was partially funded by the Consejo Nacional de Ciencia y Tecnología, Project 'Aplicación de metagenómica en la vigilancia y detección de arbovirosis con potencial emergente y re-emergente en comunidades vulnerables de alto riesgo' (number 2014–247005). J.A. Panti-May was supported by a doctoral grant from Consejo Nacional de Ciencia y Tecnología (number 259164).

Conflict of interest The authors declare that they have no conflict of interest.

References

Battersby S, Hirschhorn RB, Amman BR (2008) Commensal rodents. In: Bonnefoy X, Kampen H, Sweeney K (eds) Public health significance of urban pests. World Health Organization, Copenhagen, pp 387–419

Brown PR, Davies MJ, Singleton GR, Croft JD (2004) Can farm-management practices reduce the impact of house mouse

populations on crops in an irrigated farming system? Wildl Res 31: 597–604

Brown PR, Yee N, Singleton GR et al (2008) Farmers' knowledge, attitudes, and practices for rodent management in Myanmar. Int J Pest Manag 54:69–76

Capizzi D, Bertolino S, Mortelliti A (2014) Rating the rat: global patterns and research priorities in impacts and management of rodent pests. Mamm Rev 44:148–162

Cavia R, Cueto GR, Suárez OV (2009) Changes in rodent communities according to the landscape structure in an urban ecosystem. Landsc Urban Plan 90:11–19

Centers for Disease Control and Prevention (2005) Fatal rat-bite fever: Florida and Washington, 2003. Morbility Mortal Wkly Rep 53: 1198–1202

Childs JE, McLafferty SL, Sadek R et al (1998) Epidemiology of rodent bites and prediction of rat infestation in New York City. Am J Epidemiol 148:78–87

Cigarroa-Toledo N, Talavera-Aguilar LG, Baak-Baak CM et al (2016) Serologic evidence of flavivirus infections in peridomestic rodents in Merida, Mexico. J Wildl Dis 52:168–172

Davis DE (1953) The characteristics of rat populations. Q Rev Biol 28: 373–401

de Masi E, Vilaça P, Razzolini MTP (2009) Environmental conditions and rodent infestation in campo Limpo district, Sao Paulo municipality, Brazil. Int J Environ Health Res 19:1–16

Elliott SP (2007) Rat bite fever and *Streptobacillus moniliformis*. Clin Microbiol Rev 20:13–22

Gadisa T, Birhane A (2016) Farmers' perceptions of rodents as crop pests: knowledge, attitude and practices of farmers about rodent pest management in Southwest Ethiopia. J Agric Ext Rural Dev 8:39–46

Garba M, Dalecky A, Kadaoure I et al (2014a) Spatial segregation between invasive and native commensal rodents in an urban environment: a case study in Niamey, Niger. PLoS One 9:e110666

Garba M, Kane M, Gagare S et al (2014b) Local perception of rodent-associated problems in Sahelian urban areas: a survey in Niamey, Niger. Urban Ecosyst 17:573–584

Graves MH, Janda JM (2001) Rat-bite fever (*Streptobacillus moniliformis*): a potential emerging disease. Int J Infect Dis 5:151–154

Hancke D, Suárez OV (2014) Environmental health education in schools as strategy for rodent control: an experience in a shantytown of Buenos Aires, Argentina. EcoHealth 11:133–140

Himsworth CG, Feng AYT, Parsons K et al (2013a) Using experiential knowledge to understand urban rat ecology: a survey of Canadian pest control professionals. Urban Ecosyst 16:341–350

Himsworth CG, Parsons KL, Jardine C, Patrick DM (2013b) Rats, cities, people, and pathogens: a systematic review and narrative synthesis of literature regarding the ecology of rat-associated zoonoses in urban centers. Vector Borne Zoonotic Dis 13:349–359

Himsworth CG, Jardine CM, Parsons KL, et al. (2014) The characteristics of wild rat (*Rattus* spp.) populations from an inner-city neighborhood with a focus on factors critical to the understanding of rat-associated zoonoses. PLoS One 9:e91654.

Hsia CC (2003) Four day cognitive behavioral treatment of a rat phobic. Cuad Hispanoam Psicol 3:17–22

Instituto Nacional de Estadística y Geografía (2010) Población total: Yucatán. México en cifras, In http://www3.inegi.org.mx/sistemas/componentes/mapa/default.aspx. Accessed 2 Feb 2016

Makundi RH, Bekele A, Leirs H et al (2006) Farmer's perceptions of rodents as crop pests: knowledge, attitudes and practices in rodent pest management in Tanzania and Ethiopia. Belgian J Zool 135: 153–157

Marshall PA, Murphy RG (2003) Investigating residents' perceptions of urban rodents in Manchester, UK. In: Singleton GR, Hinds LA, Krebs CJ, Spratt DM (eds) Rats, mice and people: rodent biology and management. Australian Centre for International Agricultural Research, Canberra, pp 473–476

McDonald JH (2014) Handbook of biological statistics, 3rd edn. Sparky House Publishing, Baltimore

Meerburg BG, Singleton GR, Kijlstra A (2009) Rodent-borne diseases and their risks for public health. Crit Rev Microbiol 35:221–270

Nolte D, Bergman D, Townsend J (2003) Roof rat invasion of an urban desert island. In: Singleton GR, Hinds LA, Krebs CJ, Spratt DM (eds) Rats, mice and people: rodent biology and management. Australian Centre for International Agricultural Research, Canberra, pp 481–484

ÖSt L, Hugdahl K (1981) Acquisition of phobias and anxiety response patterns in clinical patients. Behav Res Ther 19:439–447

Panti-May JA, Hernández-Betancourt S, Ruíz-Piña H, Medina-Peralta S (2012) Abundance and population parameters of commensal rodents present in rural households in Yucatan, Mexico. Int Biodeterior Biodegrad 66:77–81

Panti-May JA, Hernández-Betancourt SF, Rodríguez-Vivas RI, Robles MR (2015a) Infection levels of intestinal helminths in two commensal rodent species from rural households in Yucatan, Mexico. J Helminthol 89:42–48

Panti-May JA, Torres-Castro M, Hernández-Betancourt S et al (2015b) Detection of *Rickettsia felis* in wild mammals from three municipalities in Yucatan, Mexico. EcoHealth 12:523–527

Panti-May JA, Hernández-Betancourt SF, Torres-Castro MA et al (2016) Population characteristics of human-commensal rodents present in households from Mérida, Yucatán, México. Manter J Parasit Biodivers Occas pap 5:1–6

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecol Econ 52:273–288

Sidorov GN, Putin AV (2010) The house mouse (*Mus musculus* L.) in Omsk educational institutions: seasonal migration, abundance, reproduction, distribution, foraging, and associated damage. Contemp Probl Ecol 3:601–605

Stenseth NC, Leirs H, Skonhoft A et al (2003) Mice and rats: the dynamics and bio-economics of agricultural rodents pests. Front Ecol Environ 1:367–375

Torres-Castro MA, Gutiérrez-Ruiz E, Hernández-Betancourt SF et al (2014) First molecular evidence of *Leptospira* spp. in synanthropic rodents captured in Yucatan, Mexico. Rev Med Vet 7–8:213–218

Villa BC, Whisson DA, Sánchez-Cordero V (1997) Capture rate and reproductive patterns of Norway rats (*Rattus norvegicus*) (Muridae: Rodentia) in a poultry farm in Mexico City. An Inst Biol Ser Zool 68:165–172

Wolff JO, Sherman PW (2007) Rodent societies as model systems. In: Sherman PW, Wolff JO (eds) Rodent societies: an ecological & evolutionary perspective. The University of Chicago Press, Chicago, pp 3–7