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Ticks collected from humans, domestic animals, and wildlife in Yucatan, Mexico

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ABSTRACT

Domestic animals and wildlife play important roles as reservoirs of zoonotic pathogens that are transmitted to humans by ticks. Besides their role as vectors of several classes of microorganisms of veterinary and public health relevance, ticks also burden human and animal populations through their obligate blood-feeding habit. It is estimated that in Mexico there are around 100 tick species belonging to the Ixodidae and Argasidae families. Information is lacking on tick species that affect humans, domestic animals, and wildlife through their life cycle. This study was conducted to bridge that knowledge gap by inventorying tick species that infest humans, domestic animals and wildlife in the State of Yucatan, Mexico. *Amblyomma* ticks were observed as euryxenous vertebrate parasites because they were found parasitizing 17 animal species and human. *Amblyomma mixtum* was the most eryxenous species found in 11 different animal species and humans. Both *A. mixtum* and *A. parvum* were found parasitizing humans. *Ixodes* near *affinis* was the second most abundant species parasitizing six animal species (dogs, cats, horses, white-nosed coati, white-tail deer and black vulture) and was found widely across the State of Yucatan. Ixodid tick populations may increase in the State of Yucatan with time due to animal production intensification, an increasing wildlife population near rural communities because of natural habitat reduction and fragmentation. The diversity of ticks across host taxa documented here highlights the relevance of ecological information to understand tick–host dynamics. This knowledge is critical to inform public health and veterinary programs for the sustainable control of ticks and tick-borne diseases.

1. Introduction

Wildlife and domestic animals play important roles as reservoirs of zoonotic pathogens that are transmitted to humans by ticks (Morse, 1995). Besides their role as vectors of several classes of microorganisms of veterinary and public health relevance (Morse, 1995; Jongejan and Uilenberg, 2004), ticks also burden human and animal populations through their obligate blood-feeding habit (Ostfeld et al., 2006). Tick feeding causes irritation, skin inflammation, pruritus, self-wounding, stress, and allergic responses (Wall and Shearer, 2001). The world's tick fauna comprises around 900 species, which are grouped under three families, Ixodidae, Argasidae and Nuttalliellidae (Guglielmone et al., 2010) and are distributed worldwide as parasites of terrestrial vertebrates (Nava et al., 2009). It is estimated that in Mexico there are 100 tick species belonging to the Ixodidae and Argasidae families (Pérez et al., 2014).

Several emerging and re-emerging tick-borne diseases have a wildlife species as their reservoir (Daszak et al., 2001; Kate et al., 2008; Pérez de León et al., 2014b). The development of improved strategies to mitigate the burden of zoonotic tick-borne diseases requires a better understanding of the biology and ecology of ticks, including the role of wildlife species as tick hosts and the epidemiology of tick-borne pathogens (Estrada-Peña et al., 2013; Ogden et al., 2013; Esteve-Gassent et al., 2014). Scientific progress is advancing our understanding of tick host specificity. Some tick species are host generalists and can feed on different vertebrate species depending on their availability and abundance (Wilson et al., 1984; Anderson, 2002), whereas other species may be more specific and use

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a narrow host range (Guglielmone et al., 2014). Many ticks parasitize domestic animals but few ticks feed exclusively on them as most tick species may also parasitize wild animals. Wild and domestic cycles are often complementary. Immature tick stages that parasitize wild and peridomestic animals can feed later as adults on domestic animals (Ruiz-Fons and Gilbert, 2010). However, it has been proposed that a more ecological view of tick-host associations at the local scale is required to better understand the implications of tick-host-pathogen interactions for the epidemiology, and control of zoonotic tick-borne diseases (McCoy et al., 2013; Ogden et al., 2013).

Studies examining the diversity of ticks parasitizing human, domestic animals, and wildlife in Mexico are scarce. It is important to describe the tick fauna parasitizing domestic animals and wildlife because several of these tick species can also parasitize humans and are reservoirs of zoonotic pathogens. Enhanced knowledge of tick spatial and temporal distributions can translate into improved local and regional tick control programs. Records of tick species infesting human, domestic animals, and wildlife in Yucatan, Mexico are reported here. The veterinary public health implications of these findings are discussed.

2. Materials and methods

2.1. Study area

The study was carried in 17 municipalities in Yucatan State, Mexico between January 2009 to December 2014. Because domestic and wild animals were not sampled during all seasons of the year, some tick species or tick stages may not be represented due to the differences in seasonal activity among tick species and tick stages. The climate of the State is sub-humid tropical with a summer rainy season. The monthly maximum temperature varies from 35 ° to 40 °C (mean 26.6 °C). The relative humidity (RH) varies from 65 to 100% (mean 80%) and the annual rainfall varies from 415 mm to 1290 mm depending on the area (INEGI, 2002).

2.2. Tick collection

Ticks were collected from humans and six domestic animal species: cat (*Felis silvestris catus*), sheep (*Ovis aries*), dog (*Canis lupus familiaris*), goat (*Capra hircus*), cattle (*Bos indicus*/*Bos taurus*), and horse (*Equus caballus*). The 13 wildlife species inhabiting the region under study that were sampled to determine tick infestation included reptiles, birds, and mammals. The reptile species sampled were: crocodile (*Crocodylus acutus*), box turtle (*Terrapene carolina mexicana* and *T. c. yucatana*), snake (*Boa constrictor*), black spiny-tailed iguana (*Ctenosaura similis*). Black vultures (*Coragyps atratus*) were the bird species inspected for ticks. Mammal species surveyed included white-tailed deer (*Odocoileus virginianus*), red deer (*Cervus elaphus*), collared peccari (*Pecari tajacu*), northern tamandua (*Tamandua mexicana*), mouse (*Mus musculus),* eastern cottontail rabbit (*Sylvilagus floridanus*), skunk (*Spilogale angustifrons*), and white-nosed coati (*Nasua narica*).

Animals and humans were sampled as follows:

Dogs and cats: Animals were inspected visually for ticks, which were also detected by running one's hand across the dog or cat body.

Ruminants and horses: We inspected the head, neck, ears, and ventral surface of animals for tick collection. All visible ticks were manually removed from the body of the infested animals.

Red deer: Because the head and neck are the primary sites of tick attachment (Rodriguez-Vivas et al., 2013a,b), deer were inspected from the top of the head, just rostral to the ear, posteriorly to the scapula, and from the ventral midline to the dorsal midline of the neck. Ticks were removed manually from the animals.

Mice: Mice were captured by using Sherman traps (Sherman Traps Inc., Tallahassee, Florida, USA) baited with a mixture of oats and vanilla extract. Traps were located in houses at rural communities. The entire body of each rodent was thoroughly examined for ticks by visual inspection and with the aid of a comb.

Wildlife: Most of the wild animals were sampled after being hunter-harvested, or killed on highways (Haemig et al., 2008). Hunter-harvested animals were preserved in sealed plastic bags and transported to the laboratory. The sealed plastic bags allowed the collection of ticks detaching from the carcass. Animals found dead on roads were also transported to the laboratory in sealed plastic bags. Dead animals and container plastic bags were thoroughly inspected in the laboratory for ticks. Ticks were removed manually from dead animals.

Human: Ticks were obtained manually from people that were incidentally bitten and voluntarily went to our laboratory for consented tick removal.

All collected ticks were transferred to 50 ml vails containing ethanol 70%. Specimens were taken to the Parasitology Laboratory at the Biological Sciences and Husbandry Campus of the Autonomous University of Yucatan (CCBA-UADY) for taxonomic identification. Ticks were identified to species, developmental stage, and sex, in the case of adults, under a dissecting microscope using conventional taxonomic keys (Guglielmone and Nava, 2010; Guzmán-Cornejo et al., 2007; Guzmán-Cornejo and Robbins, 2010), and morphological comparison with available identified specimens in the United States National Tick Collection of Georgia Southern University (USNTC) at The James H. Oliver, Jr. Institute for Coastal Plain Science, Georgia Southern University, Statesboro, GA. Ticks were examined with a stereomicroscope (Olympus SZX16, Olympus Corporation). Identified specimens were deposited at the USNTC, and at the Parasitology Laboratory, CCBA-UADY.

The most abundant and widest distributed ticks were georeferenced at collection localities and this information was displayed on maps of Yucatan State. Guides by Campbell (1998), Reid (2009), and Canseco-Marquez and Gutierrez-Mayen (2010) were used as references for the specific and common names of the domestic animals and wildlife species examined.

3. Results

A total of 956 Ixodidae ticks were collected from six species of domestic animals ($n = 807$), 13 species of wild animals ($n = 110$), and humans ($n = 39$), from Yucatan State, Mexico. There were 15 different hard tick species belonging to the genera *Amblyomma*, *Ixodes*, *Rhipicephalus*, *Dermacentor*, and *Haemaphysalis*.

Ten hard tick species were collected from domestic animals (*A. mixtum*, *A. ovale*, *A. maculatum*, *A. sabanerae*, *A. auricularium*, *A. parvum*, *I.* near *affinis*, *Rhipicephalus sanguineus* sensu lato, *Rhipicephalus microplus*, and *D. nitens*) (Table 1). An equal number of ixodid tick species were obtained from wild animals (*A. mixtum*, *Amblyomma rotundatum*, *A. nodosum*, *A. sabanerae*, *A. scutatum*, *A. parvum*, *Haemaphysalis juxtakochi*, *Haemaphysalis leporispalustris*, *Rhipicephalus microplus*, and *I.* near *affinis*) (Table 2). Four tick species were found to be infesting humans (*A. parvum*, *A. mixtum*, *Rhipicephalus sanguineus* s.l., and *R. microplus*) (Table 3) (Figs. 1 and 2).

The genus *Amblyomma* was detected in 17 animal species and humans. The most common tick species in animals (dogs, goat, sheep, cattle, horse, crocodile, northern tamandua, peccary, box turtle, red deer, white-tailed deer) and humans was *A. mixtum*, followed by *I.* near *affinis* (dogs, cats, horses, black vulture, white-tailed deer and white-nosed coati), *A. parvum* (dog, cat, black vulture, white-tailed deer, mouse and human), *R. microplus* (cattle,

Table 1
Domestic host, municipality, species, number of examined specimens, developmental stage, and sex of Ixodid ticks collected in Yucatan, Mexico.

Inspected host	Municipality	Ticks species	Number, stage, and sex of ticks
Goat (*Capra hircus*)	Merida	*Amblyomma mixtum*	3M
Sheep (*Ovis aries*)	Tizimin	*Rhipicephalus microplus* (Canestrini, 1888)	7F
		Amblyomma mixtum	3F
Dog (*Canis lupus familiaris*)	Tizimin	*Amblyomma mixtum*	1F
		Rhipicephalus sanguineus s.l. (Latreille, 1806)	2F
	Tizimin	*Ixodes* near *affinis* Neumann, 1899	1F
	Tizimin	*Amblyomma mixtum*	2M, 2F
	Tizimin	*Amblyomma mixtum*	1F
	Tizimin	*Dermacentor nitens* Neumann, 1897	1F
		Rhipicephalus sanguineus s.l.	12M, 8F
	Tizimin	*Rhipicephalus sanguineus* s.l.	1F
	Calotmul	*Ixodes near affinis*	2F
	Calotmul	*Rhipicephalus sanguineus* s.l.	8M, 7F
	Peto	*Amblyomma sabanerae* Stoll, 1894	2M
		Rhipicephalus sanguineus s.l.	1M, 11F; 4N
	Motul	*Rhipicephalus sanguineus* s.l.	2M, 17F; 5N
	Muna	*Amblyomma mixtum*	1F
		Rhipicephalus sanguineus s.l.	2M, 5F, 3N
	Muna	*Ixodes* near *affinis*	1M
	Muna	*Ixodes* near *affinis*	1M
	Muna	*Ixodes* near *affinis*	1M, 1F
		Rhipicephalus sanguineus s.l.	5M, 9F
	Valladolid	*Amblyomma mixtum*	1M, 4F
		Amblyomma parvum Aragão, 1908	1M, 8F
		Rhipicephalus sanguineus s.l.	5F
	Tekax	*Ixodes* near *affinis*	1F
	Ticul	*Ixodes* near *affinis*	1F
	Ticul	*Ixodes* near *affinis*	1F
	Ticul	*Ixodes near affinis*	1M
	Ticul	*Amblyomma ovale* Koch, 1844	1M
		Rhipicephalus sanguineus s.l.	1M, 4F
	Ticul	*Amblyomma auricularium* (Conil, 1878)	1M
	Ticul	*Amblyomma maculatum* Koch, 1844	1M
	Ticul	*Amblyomma mixtum*	1F
	Ticul	*Amblyomma mixtum*	1M
	Ticul	*Amblyomma mixtum*	1M
		Rhipicephalus sanguineus s.l.	5M, 12F
Cat (*Felis silvestris catus*)	Merida	*Ixodes* near *affinis*	1F
	Merida	*Amblyomma parvum*	3M, 2F
Cattle (*Bos indicus*/*Bos taurus*)	Tizimin	*Amblyomma mixtum*	34F, 23M
		Rhipicephalus microplus	7F
	Peto	*Amblyomma mixtum*	1F, 6M
		Rhipicephalus microplus	7F, 14M
	Cenotillo	*Amblyomma mixtum*	22F, 6M
		Rhipicephalus microplus	54F, 3M
	Mérida	*Amblyomma mixtum*	14F, 4M
		Rhipicephalus microplus	134F; 7M
	Ticul	*Amblyomma mixtum*	23F, 7M
		Rhipicephalus microplus	14F; 17M
	Tunkas	*Amblyomma mixtum*	7F, 6M
		Rhipicephalus microplus	27F, 6M
	Panaba	*Amblyomma mixtum*	4F, 63M
		Rhipicephalus microplus	64F; 8M
Horse (*Equus caballus*)	Valladolid	*Amblyomma mixtum*	1M, 2F
	Tizimin	*Amblyomma mixtum*	3F
		Ixodes near *affinis*	1F
	Tizimin	*Dermacentor nitens*	3M
	Tizimin	*Dermacentor* nitens	2M
	Temozón	*Amblyomma mixtum*	2M, 10F
	Mérida	*Amblyomma mixtum*	1M, 4F
	Tzucacab	*Amblyomma mixtum*	4M, 3F

M: male, F: female, N: nymphs, *Rhipicephalus sanguineus* s.l.: *Rhipicephalus sanguineus* sensu lato.

sheep, red deer and human), and *A. rotundatum* (crocodile, snake, and box turtle) (Tables 1–3).

A. mixtum and *I.* near *affinis* were found parasitizing different animal species and humans across the State of Yucatan (Fig. 3).

4. Discussion

Ixodid ticks were found to parasitize humans, domestic animals, and wildlife in the State of Yucatan, Mexico. Some of these tick species are known vectors of zoonotic pathogens that affect human and domestic animal populations. The most abundant ticks were specimens belonging to species in the genus *Amblyomma*. It appears that ixodid ticks in Yucatan tend to be generalists parasitizing locally available hosts.

The genus *Amblyomma* is one of the largest within Ixodidae, it is widely distributed in the world, and includes 130 species globally (Guglielmone et al., 2014). *A. mixtum* (formerly considered identical with *A. cajennense*, according to (Nava et al., 2013), *A. parvum*,

Table 2
Wild host, municipality, species, number of examined specimens, developmental stage, and sex of Ixodid ticks collected in Yucatan, Mexico.

Host	Municipality	Ticks species	Number, stage, and sex of ticks
Crocodile (*Crocodylus acutus*)	Tizimin	*Amblyomma mixtum*	1F
		Amblyomma rotundatum Koch, 1844	1F
Northern Tamandua (*Tamandua mexicana*)	Calotmul	*Amblyomma mixtum*	2M, 2F
		Amblyomma nodosum Neumann, 1899	3M, 1F
Pecari (*Pecari tajacu*)	Merida	*Amblyomma mixtum*	2M, 1F
	Merida	*Amblyomma mixtum*	1F
	Kanasin	*Amblyomma mixtum*	1F
	Kanasin	*Amblyomma mixtum*	1F
	Merida	*Amblyomma mixtum*	2M, 1F
Box turtle (*Terrapene carolina mexicana*)	Tizimin	*Amblyomma sabanerae*	1F
	Maxcanu	*Amblyomma rotundatum*	1M
Box turtle (*Terrapene carolina yucatana*)	Tizimin	*Amblyomma sabanerae*	1M
	Tizimin	*Amblyomma sabanerae*	2M
	Tizimin	*Amblyomma mixtum*	1F
		Amblyomma sabanerae	3M, 1F
	Tizimin	*Amblyomma sabanerae*	1M, 2F
Snake (*Boa constrictor*)	Merida	*Amblyomma rotundatum*	1M, 2F
White–tailed deer (*Odocoileus virginianus*)	Merida	*Amblyomma mixtum*	1M
		Haemaphysalis juxtakochi Cooley, 1946	1F
	Merida	*Ixodes* near *affinis*	1F
		Amblyomma parvum	1M, 1F
Eastern cottontail rabbit (*Sylvilagus floridanus*)	Uman	*Hemaphysalis leporispalustris* (Packard, 1869)	5M, 1F
Red deer (*Cervus elaphus*)	Tzucacab	*Rhipicephalus microplus*	5F
		Amblyomma mixtum	3M, 4F
Black vuture (*Coragyps atratus*)	Merida	*Ixodes* near *affinis*	1F
		Amblyomma parvum	1M, 1F
Black spiny-tailed iguana (*Ctenosaura similis*)	Merida	*Amblyomma scutatum* Neumann, 1899	21M, 11F
Skunk (*Spilogale angustifrons*)	Merida	*Amblyomma* spp	6L
White-nosed coati (*Nasua narica*)	Hunucma	*Ixodes* near *affinis*	1M, 1F
Mouse (*Mus musculus*)	Merida	*Amblyomma parvum*	3N
	Merida	*Amblyomma parvum*	6N

M: male, F: female, N: nymphs, L: larvae.

Table 3
Municipality, species, number of examined specimens, developmental stage, and sex of Ixodid ticks collected from humans in Yucatan, Mexico.

Municipality	Ticks species	Number, stage, and sex of ticks
Tizimin	*Amblyomma parvum*	1F
	Rhipicephalus sanguineu s.l.	4M
	Amblyomma mixtum	2F
Panaba	*Amblyomma mixtum*	1M, 3F
	Rhipicephalus sanguineus s.l.	1M, 2F
Tzucacab	*Amblyomma mixtum*	1M, 3F
	Rhipicephalus sanguineus s.l.	1M, 2F
Tzucacab	*Rhipicephalus microplus*	18L

M: male, F: female, L: larvae, *Rhipicephalus sanguineus s.l.: Rhipicephalus sanguineus* sensu lato.

A. nodosum, *A. sabanerae*, *A. auricularum*, *A. maculatum*, *A. rotundatum*, *A. scutatum*, and *A. ovale* are present in several ecoregions, in tropical and subtropical grassland, mainly in savannas, scrubland and broadleaf forest (dry or humid) (Guglielmone et al., 2014). *A. mixtum* is distributed from southern Texas, throughout Mexico and Central America into parts of South America (Nava et al., 2014). *A. rotundatum* has a biogeographical range from Argentina to Mexico, including the Caribbean Islands (Guglielmone et al., 2003; Nava et al., 2007; Voltzit, 2007; Guzmán-Cornejo et al., 2011) and the southern part of Florida (Corn et al., 2011).

Twenty-four *Amblyomma* species have been recorded in Mexico parasitizing amphibians, reptiles, birds and mammals, distributed mainly in the neotropical region (Guzmán-Cornejo et al., 2011). We confirmed previous reports for the nine *Amblyomma* species identified in this study (Hoffmann and López-Campos, 2000; Vargas-Sandoval et al., 2014). *Amblyomma* ticks were observed as euryxenous vertebrate parasites because they were found parasitizing 17 animal species and humans as described by Guglielmone et al. (2014). *A. mixtum* was the most eryxenous species found in 11 different animal species and humans.

We found *A. mixtum* and *A. parvum* parasitizing humans. This observation is of epidemiological relevance for the zoonotic transmission of tick-borne pathogens by *Amblyomma* ticks in the Mexican tropics. Several of the *Amblyomma* species found in the present study are known to be involved in the transmission cycle of zoonotic pathogens. *A. mixtum* transmits *R. rickettsii*, which causes Rocky Mountain Spotted Fever (RMSF) (Labruna, 2009). *A. ovale* has been incriminated as vector of *Hepatozoon canis* (Rubini et al., 2009). *A. maculatum* transmits *Ehrilichia ruminantium*, *H. americanum*, and *R. parkeri* (Jongejan and Uilenberg, 2004). All the life stages of these *Amblyomma* species can bite humans leaving a painful lesion (Guglielmone et al., 1991), and increasing the risk for zoonotic transmission of public health important pathogens like *R. rickettsii*. This has relevant public health implications because RMSF occurs in the Yucatan peninsula and fatal cases have been reported (Zavala-Velázquez et al., 1999; Zavala-Castro et al., 2006).

With around 243 species, the genus *Ixodes* comprises more than a quarter of the tick species worldwide (Guglielmone and Nava, 2005). Despite the dominance of this genus in the Northern hemisphere, relatively few *Ixodes* species have been recorded in

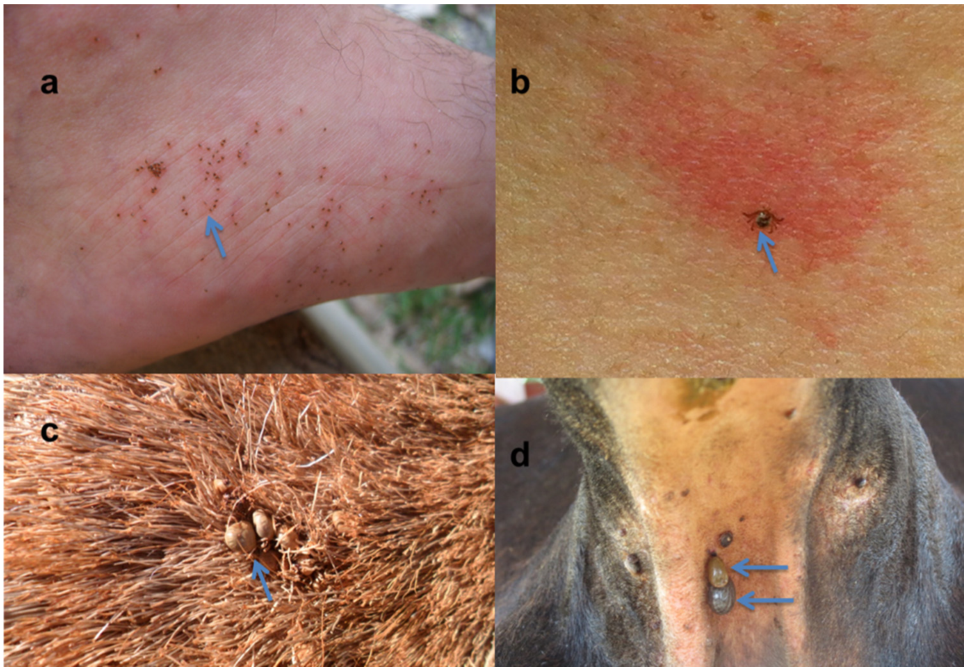

Fig. 1. Ixodid ticks collected from humans and animals in the Mexican tropics. (a) *A. mixtum* larvae attached to the lower leg of a human; (b) nymph of *A. mixtum* on the chest of a human; (c) *R. microplus* on red deer (*Cervus elaphus*); (d) *R. microplus* (upper arrow) and *A. mixtum* (lower arrow) attached in the coccygeal fold of cattle (*Bos taurus*).

Fig. 2. Ixodid ticks collected from domestic animals and wildlife in the Mexican tropics. (a) *Amblyomma sabanerae* on a box turtle (*Terrapene carolina mexicana*); (b) *A. mixtum* in the ear of a horse; (c) *A. scutatum* in the tail of a black spiny-tailed iguana (*C. similis*); and (d) *R. sanguineus* in the ear of a dog.

Mexico. The most common Ixodes species are *I. boliviensis*, *I. luciae*, *I. rubidus*, *I. scapularis*, *I. spinipalpis*, *I. tancitarius*, *I. woodi* and *I. affinis* (Guzmán-Cornejo et al., 2007). The latter has been only reported in the Mexican States of Chiapas and Yucatan; specimens were collected from a coati, a mazama deer, and cattle (Hoffmann, 1962; Guzmán-Cornejo et al., 2007).

We found *I.* near *affinis* to be the second most abundant species across Yucatan parasitizing six animal species (dogs, cats, horses, white-nosed coati, white-tailed deer and black vulture). Previously, *I. affinis* was found infesting dogs in a rural community of Yucatan (Solís-Hernández et al., 2015). However, the specimens observed in this study were inconsistent with the original descriptions of *I. affinis*. All key morphological features (pattern of punctations, dentition and shape of hypostome, size of coxal spurs) used for identification of this species throughout its geographic distribution were present in the Yucatan specimens. But, the number of large punctations along the posterior margin of the female's scutum and in the center of the male's conscutum was lower than in specimens

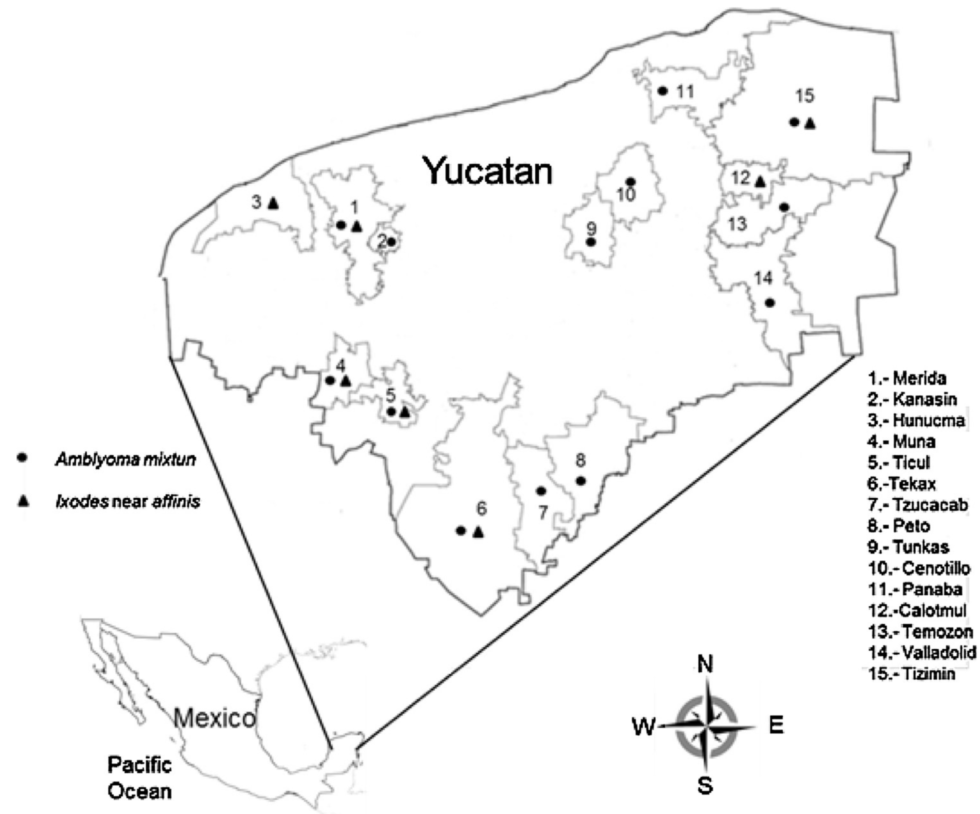

Fig. 3. Localities in the state of Yucatan where domestic animals, wildlife, and humans were found infested with *A. mixtum* and *I.* near *affinis*.

of this species from other parts of its range. For this reason *I. affinis* is reported in this paper as *I.* near *affinis.*

Several *Ixodes* species are of medical and veterinary relevance because they transmit zoonotic pathogens (Goodman et al., 2005). In the United States, *I. affinis* has been incriminated as a cryptic vector of pathogens including *Borrelia burgdorferi* sensu lato (Harrison et al., 2010). In northern Mexico antibodies against *B. burgdorferi* were reported in serological studies of white-tailed deer (*O. virginianus*) and dogs (Salinas-Melendez et al., 1999). Thus, future studies need to investigate the role of *I.* near *affinis* as a potential vector of *B. burgdorferi* s.l. in animals and human residing in Yucatan State.

Our findings in Yucatan further confirm the cosmopolitan distribution of the brown dog tick, *R. sanguineus* s.l. Domestic dogs are the main host of *R. sanguineus* s.l. in both urban and rural areas (Dantas-Torres, 2010). *R. sanguineus* can infest a number of domestic and wild hosts, including cats, rodents, birds, and humans (Lori et al., 1996; Dantas-Torres et al., 2006). Parasitism by *R. sanguineus* s.l. of hosts other than dogs is unusual in certain areas; this situation can be associated with the presence of heavily infested dogs and in highly infested environments. The likelihood of a host other than the dog being attacked by *R. sanguineus* s.l. may vary according to tick population. Human infestation with *R. sanguineus* s.l. is observed in Europe, particularly during the summer (Parola et al., 2008). In contrast, human parasitism is less common, or maybe less reported, in the Americas (Guglielmone et al., 2006). In Brazil, people dealing daily with dogs (e.g., veterinarians, pet shop workers, and dog owners) appear to be at high risk of exposure to *R. sanguineus* s.l. bites (Dantas-Torres, 2010).

R. sanguineus s.l. is a vector of many disease agents, including *Coxiella burnetii, Ehrlichia canis, R. conorii,* and *R. rickettsii*, which are of zoonotic concern (Dantas-Torres, 2008). Pat-Nah et al. (2015) found in Yucatan, Mexico that *R. sanguineus* s.l. ticks are the vector of *E. canis* infections in dogs. The observed high infestations and the wide distribution of *R. sanguineus* s.l. in Yucatan highlight the risk for ehrlichia transmission.

R. microplus ticks commonly parasitize bovines in tropical regions of the world. However, other wild ungulates, such as white-tailed deer, red deer, and nilgai can also serve as hosts of this tick species (Pérez de León et al., 2012). Red deer is a host for *R. microplus* in Yucatan, Mexico; engorged female ticks on red deer were 11 times higher than those on cattle (Rodriguez-Vivas et al., 2013a). *R. microplus* is also a vector of many disease agents to cattle and other ungulates, including *Babesia bovis, B. bigemina* and *Anaplasma marginale* (Rodriguez-Vivas et al., 2004; Pérez de León et al., 2014a). As observed in the present study, this tick species has been reported infesting humans in Cuba (de la Cruz et al., 1991), and Argentina (Guglielmone et al., 1991). To date, there are no diseases known to be transmitted by *R. microplus* to humans, nevertheless its impact on livestock production is of significant relevance (Guerrero et al., 2014; Rodriguez-Vivas et al., 2013a,b).

We found *H. juxtakochi* on white-tailed deer and *H. leporispalustris* on eastern cottontail rabbit. Both tick species were recorded in Mexico parasitizing *Crotophaga sulcirostris*, *S. floridanus* and *Lepus callotis* (Vargas-Sandoval et al., 2014). *H. juxtakochi* is an ectoparasite found from south Mexico through Central and South America, while *H. leporispalustris* is widely distributed in the Americas ranging from Alaska to Argentina (Hoffmann, 1962). In Brazil, *Rickettsia bellii* and *R. rhipicephali* have been detected in *H. juxtakochi* (Labruna et al., 2007); however, the precise role of both *Haemaphysalis* species in the transmission of pathogenic microorganisms to both humans and animals remains unknown (Debárbora et al., 2012).

D. nitens is reported to occur in the Southern US, Mexico, Central America, several Caribbean Islands and in tropical and subtropical South America. This tick species affects mainly horses but can also feed on cattle and other animals. Here, we found *D. nitens* on horses and dogs. This tick is associated with clinical cases of *Babesia caballi* in horses from Yucatan (Rodríguez-Vivas et al., 1996a,b).

As it has been noted in other parts of the world, it is possible that the density of ticks may increase in Yucatan as a function of global change. Potential drivers for an increase in tick populations include animal production intensification, and increasing wildlife populations around rural communities due to the reduction and fragmentation of natural habitat. Yucatan has one of the highest rates of forest cover loss in Mexico (Pennington et al., 2006), which increases the frequency of contact between wildlife, domestic animals, and humans in, and at the edge of the remaining forested areas.

Several tick-borne diseases are among the emerging, re-emerging, and neglected zoonotic diseases in Yucatan State (Reyes-Novelo et al., 2011). Knowledge gaps in the eco-epidemiology of tick-borne diseases in Yucatan impede the development of strategies to mitigate the burden of ticks, and the diseases caused by the pathogens they transmit on human and animal populations in that part of the Mexican tropics. Rickettsioses, for example, are considered an emerging problem in Mexico, but there are parts of the country like Yucatan where the principal tick vectors and wildlife reservoirs remain unknown (Reyes Novelo et al., 2011; Mexican, 2014). Results from our study document that known tick vectors of zoonotic pathogens infest wildlife, domestic animals, and human across the State of Yucatan. Molecular testing of *Amblyomma* ticks like the ones collected in this study is an approach that can help understand the eco-epidemiology of RMSF and other zoonotic rickettsioses in Yucatan (Eremeeva and Dasch, 2015). Further research emphasizing the description of attributes in an ecosystem that influence spatial variations in disease risk or incidence, also known as the pathogenic landscape (Esteve-Gassent et al., 2013), will help quantify the risk of exposure by humans and domestic animals to ticks infected with zoonotic pathogens. Tick-borne disease control tends to focus on interventions targeting tick vector populations that rely on the use of acaricides. The diversity of tick species identified in this study infesting humans, wildlife, and domestic animals in Yucatan stresses the need for the integration of different technologies to manage tick populations that can help mitigate the risk of exposure to tick-borne zoonotic pathogens (Pérez de León et al., 2014b; Rodríguez-Vivas et al., 2013a,b).

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