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A Review of Ectoparasites (Acari and Hirudinea) Associated with Herpetofauna in the Mexican Yucatan Peninsula

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Abstract.—Ectoparasites are common on herpetofauna and can cause skin lesions, thermoregulatory complications, and hinder growth. Herein we present records from the literature and new data from the Calakmul Biosphere Reserve on ectoparasites of herpetofauna in the subclasses Acari (mites and ticks) and Hirudinea (leeches) from the Mexican Yucatan Peninsula. Our new records fill important gaps in our knowledge of reptiles and amphibians affected by ectoparasites and the geographic distribution of these interactions in Mexico. We also discuss conservation implications of recording ectoparasites particularly for vulnerable reptilian species as well as anthropological health issues that could arise with diminishing natural habitats causing these animals and their parasites to live closer to humans.

Ectoparasites, especially in the subfamilies Acari (mites and ticks) and Hirudinea (leeches) impact reptilian species in various ways, including infliction of skin lesions (Goldberg and Bursey 1991), hindering growth rates (Curtis and Baird 2008), reducing offspring survival rates (Sorci and Clobert 1995), and causing thermoregulatory issues (Johnson et al. 2019). With regard to amphibians, ectoparasites can damage the protective mucus layer on the skin of some species, which can lead to secondary infections by other pathogens such as bacteria and viruses (Watermolen 2019).

Because these ectoparasites can use endangered herpetofaunal species as hosts, understanding the parasite-host associations can be important in the conservation of those species (Fajfer 2012; Watermolen 2019). Gutsche et al. (2012) found that 60% of 125 *Ctenosaura bakeri*, a critically endangered iguana endemic to Utila Island, Honduras, were carrying ectoparasites. Two tick species, *Amblyomma dissimle* and *Ornithodorus talajae* were identified using iguanas as hosts, along with the mite *Hirstiella boneti*. The majority of the iguanas were infested with *O. talajae* (in the nostrils of 43.2% of iguanas) and *H. boneti* (in the ear openings of 40% of iguanas). Effects of these ectoparasites on the fitness of *C. bakeri* is not known and further investigations are necessary. Furthermore, Acari are known to have the potential to transmit herpetofaunal diseases. For example, Bonorris and Ball (1955) described the unicellular pathogen *Schellackia occidentalis* using the Lizard Mite (*Geckobiella texana*) as a vector for entering the bloodstream of Californian lizards. Mites in the genus *Hirstiella* (as on *Ctenosaura bakeri*) are known to transmit similar pathogens and are used as a vector by the blood parasite *Hepatozoon sauromali* infecting iguanids in the genus *Sauromalus* (Lewis and Wagner 1964), potentially including endangered species such as *Sauromalus hispidus* (Montgomery et al. 2019). In New Zealand, other species of Acari, such as the mites *Odontacarus lygosomae* and *O. scincorum* are used as vectors by another blood parasite (*Hepatozoon lygosomarum*) to infect the skink genus *Oligosoma* (Reardon and Norbury 2004). This genus is endemic to New Zealand and includes endangered species, such as *O. otagense* and *O. grande* and high rates of blood infections in these two species require further investigation (Reardon and Norbury 2004). The body condition of another New Zealand endemic, the rhynchocephalian Tuatara (*Sphenodon punctatus*), is negatively affected by infestations of ticks and mites during particular times of year (Godfrey et al. 2009). Understanding the impact of these blood parasites on the fitness of endangered species is important for implementing long-term conservation practices (Godfrey et al. 2009). Furthermore, the tick *Amblyomma dissimile* is known to transmit the blood parasite *Hepatozoon* fusifex to other herpetofauna, such as the *Boa constrictor* (Ball et al. 1969).

Endangered amphibians also can be negatively affected by ectoparasitic infestations. Mendoza-Roldan et al. (2020) found heavy mite loads on the digits of frogs and toads in

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Brazil and suggested that these could lead to avascular necrosis. The impact of this on the fitness of species is not well understood and further research is required to understand if mite loads could negatively impact Brazilian endemic, critically endangered amphibians, such as *Melanophryniscus admirabilis* (IUCN SSC Amphibian Specialist Group and Instituto Boitatá de Etnobiologia e Conservação da Fauna 2023) and *Cycloramphus faustoi* (Brasileiro 2008).

Ticks are mostly obligate sanguivorous ectoparasites (Tavasoli et al. 2007) and all three life stages (larvae, nymph and adult) feed on vertebrate hosts (Uslu et al. 2019). Most species are able to parasitize multiple host species, which is thought to be a survival trait when their preferred host is not available (Keesing et al. 2010). About 900 species are currently recognized (de Campos Brites and Rantin 2004), but this figure is likely to increase due to a steady rhythm of new discoveries and taxonomic revisions (e.g., Ernieenor et al. 2020). The vast majority of tick diversity is in the families Ixodidae (~700 species) and Argasidae (~193 species), both of which are cosmopolitan in their distribution and concentrated in tropical regions (Magnarelli 2009).

Chiggers are the parasitic larval form of mites in the families Trombiculidae and Leeuwenhoekiidae (Bakkegard et al. 2019). Over 3,000 species are recognized worldwide, at least 400 of which use reptiles as hosts; with the genus *Eutrombicula* being the most common in North, Central, and South America (Fajfer 2012; Rocha et al. 2008). Many species of chiggers are not host-specific but are habitat-specific and can be found on a wide range of vertebrate hosts inhabiting the same habitats (Walters et al. 2011). They exhibit complex life cycles consisting of both inactive and active periods. Inactive periods when chiggers are not parasitic occur during specific life stages; an inactive larval stage is known as the deutovum and inactive nymphal stages as nymphochrysalis and imagochrysalis (Bakkegard et al. 2019). During other life stages, chiggers are active and parasitic; these include a six-legged larval stage, an eight-legged nymphal stage, and the adult stage (Bakkegard et al. 2019; Hyland 1950; Wharton 1952; Sasa 1961). Some species will spend a few days feeding before dropping off their hosts to continue their life cycles in the soil, leaf litter, or grass (Mullen and O'Connor 2009). Aggregations of chiggers depend on host taxa; for example, they are easily seen between the scales of snakes, the skin of turtles, or the entire bodies of lizards (Benton 1987; Fajfer 2012). While leeuwenhoekiids are often seen in ear canals and axillae of reptiles, trombiculids occur more frequently in mite pockets located on the neck and in the axilla, groin, and postfemoral regions of lizards (Arnold 1986), and mites likely co-evolved with their hosts to target these locations (Benton 1987).

Leeches are cosmopolitan carnivorous annelid worms that inhabit marine, aquatic, and terrestrial habitats where they feed on invertebrates, although some species are known to be parasites of other animals (Oceguera-Figueroa and León-Règagnon 2014; Vera et al. 2005). The latter consist of about 680 species, of which approximately 31 inhabit Mexico. Some leeches are parasites of amphibians and reptiles, such as those in the genus *Placobdella*, which parasitize aquatic reptiles, such as turtles and crocodiles (García-Grajales and Buenrostro-Silva 2011; Oceguera-Figueroa et al. 2014). Information on leeches in the Yucatan Peninsula is sparse.

Despite the significance of ectoparasites of herpetofauna, this topic remains understudied. Studies reporting associations between ticks and wildlife in Mexico are scarce (Rodríguez-Vivas et al. 2016), particularly in regard to reptiles and amphibians. Herein we present new records of Acari and Hirudinea infecting herpetofaunal species and summarize literature reports from the Mexican portion of the Yucatan Peninsula.

Methods

The information compiled in this work was assembled by combining results of our herpetological surveys in 2012–2022 in the Calakmul Biosphere Reserve (CBR), which is located in the south-central portion of the Mexican Yucatan Peninsula, opportunistic sightings from all authors in the CBR and by PENC in other regions of the Yucatan Peninsula, research-grade records of parasites on amphibians and reptiles from the iNaturalist community (iNaturalist 2021), and records of parasitism on herpetofauna gleaned from a literature review of studies conducted on the Yucatan Peninsula (Pearse 1936; Wharton 1938; Hoffmann 1962; Ernst and Ernst 1977; Paredes-Leon et al. 2008; Charruau et al. 2016, 2020b). We based our taxonomy on that of Lee (2000), Wilson et al. (2013a, 2013b), Meza-Lázaro and Nieto-Montes de Oca (2015), and González-Sánchez et al. (2017), and updated scientific names of species through January 2021 based on Frost (2021) for amphibians and Uetz et al. (2024) for reptiles.

Fieldwork in the CBR was conducted in compliance with protocols described by Beaupre et al. (2004). Ethics approval was granted annually to Operation Wallacea's long-term monitoring project in collaboration with Pronatura Peninsula Yucatan, by Mexico's Secretariat of Environment and Natural Resources (SEMARNAT; SGPA/DGVS/005403/18). For further detailed information on surveyed locations and methods, see Colston et al. (2015).

Results

Records from our herpetofaunal surveys pooled with data from the literature and opportunistic sightings resulted in 37 ectoparasite-herpetofaunal associations (Tables 1–3), 23 of which originated from our own observations made in the CBR (n = 17) and other localities in the state of Yucatan (n = 7), whereas 14, including one record from the iNaturalist

Table 1. List of ticks (Acari: Ixodidae) recorded on herpetofauna in the Mexican portion of the Yucatan Peninsula. A single askerisk (*) indicates a probable identification. Two asterisks (**) mark new records for this region. Records provided by authors are indicated by initials only.

Tick (attachment)	Host	Location	Source
Amblyomma sp. (between carapacial scutes)	*Rhinoclemmys areolata*	Dos Naciones, Campeche	JO 6 July 2022
Amblyomma sp. (between carapacial scutes)	*Rhinoclemmys areolata*	Calakmul, Campeche	JO 30 June 2022
Unidentified Ixodidae (dorsum)	*Anolis tropidonotus*	Calakmul, Campeche	JO 14 June 2022
Amblyomma sp. (between head and left forelimb)	*Rhinoclemmys areolata* (juvenile)	Dzemul, Yucatán (21.228056, -89.321111)	J. Rizieri Aviles-Novelo 24 June 2020
Amblyomma sp. (above labials behind eye, one on flank)	*Boa imperator* (adult)	Baca, Yucatán (21.170000, -89.362778)	J. Rizieri Aviles-Novelo 8 June 2020
Amblyomma sp. (between carapacial scutes)	*Rhinoclemmys areolata* (juvenile)	Ixil, Yucatán (21.272500, -89.469722)	J. Rizieri Aviles-Novelo 22 February 2020
Unidentified nymph (perimeter of eye socket)	*Basiliscus vittatus* (adult female)	Calakmul, Campeche (18.463333, -90.199444)	JALB-N 28 July 2019
Ambylomma sp. (between carapacial scutes; Fig. 1)	*Rhinoclemmys areolata* (juvenile)	Hormiguero, Calakmul (18.419222, -89.496333)	JP & OS 22 June 2019
Amblyomma sp. (female) (between carapacial scutes)	*Rhinoclemmys areolata* (juvenile)	Calakmul, Campeche	JALB-N June 2019
Amblyomma sp. (female) (lower neck)	*Oxybelis potosiensis***	Yucatán (21.272500, -89.469722)	PEN-C 17 March 2019
Unidentified nymphs (right axilla and limb)	*Mesoscincus schwartzei*** (adult)	Calakmul, Campeche	J. Hutton 17 July 2018
Amblyomma sp. (left hindlimb)	*Rhinoclemmys areolata* (juvenile)	Calakmul, Campeche	R. Smith July 2017
Amblyomma sp. (between anterior carapacial scutes)	*Rhinoclemmys areolata*	Quintana Roo	Gómez (2020)
Unidentified nymph (above anterior labials in front of eye)	*Boa imperator*	Yucatán	PEN-C 26 July 2016
Unidentified nymphs (ventral neck)	*Kinosternon creaseri*	Valladolid, Yucatán (20.648056, -88.280000)	PEN-C 21 July 2016
Amblyomma sp. (gular region, folded dewlap)	*Anolis tropidonotus*	Calakmul, Campeche	JALB-N 2014
Amblyomma dissimile	*Rhinoclemmys areolata* *Kinosternon leucostomum* *Terrapene yucatana*	Chichén Itzá, Yucatán	Pearse (1936)
Amblyomma dissimile	Turtle	Yucatán	Paredes-Leon et al. (2008)
Amblyomma dissimile	Turtle	Kaua, Yucatán	Wharton (1938)
Amblyomma sabanerae (female on shell; 7 immatures on skin)	*Rhinoclemmys areolata*	Campeche	Ernst and Ernst (1977)
Amblyomma sabanerae (6 males, 4 females on shell; 5 immatures on skin)	*Rhinoclemmys areolata*	Cozumel, Quintana Roo Hoffman 1962)	Ernst and Ernst (1977)
Amblyomma rotundatum (right hindlimb)	*Rhinoclemmys areolata*	Yucatán	Ernst and Ernst (1977)
Amblyomma sp.* (posterior head)	*Phrynonax poecilonotus***	Calakmul, Campeche	T.J. Colston 28 July 2012

(Table 1 continued)

(Table 1 continued)

Unidentified (various life stages) (left forelimb, dorsum, one on paratoid gland; Fig. 3)	*Rhinella horribilis* (adult)	Mancolona, Calakmul, Campeche (18.808611, -89.286389)	JO 28 July 2019
Unidentified (dorsum and flanks)	*Incilius valliceps***	Mancolona, Calakmul, Campeche (18.808611, -89.286389)	JO 1 July 2019
Amblyomma sp. (female) (posterior dorsum)	*Rhinella horribilis*	Calakmul, Campeche (18.449444, -89.305833)	JO 9 March 2019
Amblyomma dissimile	*Rhinella horribilis*	Mucuyché, Yucatán (20.625278, -89.604444)	Pearse (1936)
Ambylomma sp.* (one on lower jaw, one in left axilla; 3 dead)	*Crocodylus moreletii* (subadult)	Yucatán	PEN-C 1 March 2021
Amblyomma dissimile (female) (dorsal base of tail)	*Crocodylus moreletii* (adult female)	Quintana Roo (19.841667, -88.750278)	Charruau et al. (2016)
Amblyomma dissimile (female) (between scales on left hindlimb)	*Crocodylus acutus* (adult female)	Quintana Roo (20.273611, -86.989444)	Charruau et al. (2016)
Amblyomma dissimile (male) (between scales of right groin)	*Caiman crocodilus chiapasius* (hatchling)	Chiapas (15.068333, -92.752222)	Charruau et al. (2016)

Table 2. Chigger mite (Acari: Trombiculidae) recorded on two *Anolis* lizard species in the Mexican portion of the Yucatan Peninsula. Both are new records for this region. Records provided by authors are indicated by initials only.

Attachment	Host	Location	Source
Post-femoral area (Figs 4 & 5)	*Anolis tropidonotus* (adult)	Calakmul, Campeche (basking on tree trunk)	AT June 2019
Post-femoral area (Figs 4 & 5)	*Anolis lemurinus* (adult)	Calakmul, Campeche (basking on tree trunk)	AT June 2019

Table 3. Records of leeches (Hirudinea) parasitizing crocodilians in the Mexican portion of the Yucatan Peninsula. The askerisk (*) indicates a probable identification. Records provided by authors are indicated by initials only.

Leech (attachment)	Host	Location	Source
*Haementeria acuecueyetzin** (most in axillary and post-femoral areas; some on palate and feet)	*Crocodylus moreletii*	Calakmul, Campeche	JALB-N 2017–2019
Haementeria acuecueyetzin (frequently on legs, feet, abdomen, back and palate)	*Crocodylus moreletii*	Dziuché, José María Morelos, Quintana Roo	Charruau et al. (2020)

database, were extracted from the literature. Geographically, 17 records were from the CBR, 14 from other sites in Yucatan, five from Quintana Roo, and one from Campeche outside the CBR. Ectoparasitic species records are distributed among two orders and three families.

Ticks were the most frequently recorded ectoparasites, with 23 records on reptiles (excluding crocodilians), six on crocodilians, and four on amphibians (Table 1). Two chigger-squamate associations involved two species of *Anolis* lizards (Table 2) and two leech-crocodile associations involved *Crocodylus moreletii* (Table 3). The observed leech-crocodilian interactions from CBR (n = 14) included seven crocodiles with only one leech and seven with four or more to a maximum of twelve in a sample of 109 *C. moreletii*. The vast majority of leeches were in the axillary and postfemoral regions, but some leeches were on the palate and feet.

Discussion

That 17 of 29 hosts of ticks were turtles does not appear to reflect host preferences as many ticks infect snakes and lizards (Vitt and Caldwell 2013), which also applies to Mexican ticks in the genus *Amblyomma*, although some species, such as *A. sabaranae,* seem to associate most frequently with turtles (Guzman-Cornejo et al. 2011). Although accounts of ticks in the genus *Amblyomma* parasitizing turtles exist, much of the literature on turtle-tick associations originated in North America and comparable reports from Central and South America are sparse (Garcés-Restrepo et al. 2013). In Mexico, five species of *Amblyomma* (*A. dissimile*, *A elaphense*, *A. rotundatum*, *A. sabanerae*, and *A. scutatum*) have been associated with turtles (Guzman-Cornejo et al. 2011), and *A. sabanerae* was the most frequently observed tick on six species of *Rhinoclemmys* (formerly *Callopsis*) in Mexico, Guatemala, Belize, Costa Rica, and Panama (Ernst and Ernst 1977), and the distribution of that species has recently been extended from western and southern Mexico to as far south as the Valle de Cauca on the Pacific Coast in trans-Andean Colombia (Garcés-Restrepo et al. 2013; Rodkey and Tellez 2019).

Due to limitations imposed by collecting permits, much of our data was based on photographic records, which precluded identification of ticks to species, although we were able in many cases to identify ticks to genus based on descriptions in the literature and help from experts. Twelve of the 17 tick-turtle associations we report here involve species of *Amblyomma* and *Rhinoclemmys areolata* (Fig. 1; Table 1), which is not surprising as these turtles are abundant, mostly terrestrial, and often conspicuous by day during the rainy season (Lee 2000). The relatively greater frequency of tick-turtle records in comparison with those involving other reptiles is likely attributable to the more elusive nature of snakes (Parker et al. 1987) and the relatively greater difficulty in capturing species of squamates for close inspections. Nevertheless, we recorded ticks parasitizing *Anolis tropidonotus* (Fig. 2), *Boa imperator*, *Oxybelis potosiensis*, and *Phrynonax poecilonotus.* Except for our record of chiggers parasitizing *A. tropidonotus* (see below), we found no other ectoparasitic associations for these species or similar hosts, which we attribute to a lack of records from Mexico and especially from the Yucatan Peninsula. However, reports of ticks attached to species of *Boa* are not unusual. In the lower Amazon region of Brazil, *Boa constrictor* is parasitized by the tick *Amblyomma dissimile* (Torres et al. 2018), and in the Pernambuco region of Brazil, *B. constrictor* appears to be an important host for the rarely seen tick *Amblyomma fuscum* (Dantas-Torres et al. 2008). On Roatán, one of the Honduran Bay Islands, the snake *Oxybelis wilsoni* is a documented host of ticks, which often attach to the snake's head (Villa and McCranie 1995), which is similar to our observation of an *O. potosiensis*, on which ticks were attached on the lower neck. *Oxybelis fulgidus* also has been

Figure 2. A Greater Scaly Anole (*Anolis tropidonotus*) in the Calakmul Biosphere Reserve (Campeche, Mexico) with a tick (*Amblyomma* sp.) attached to its dorsum. Photograph by Joseph Oakley.

Figure 1. A juvenile Furrowed Wood Turtle (*Rhinoclemmys areolata*) in the Calakmul Biosphere Reserve (Campeche, Mexico) with a tick (*Amblyomma* sp.) attached between carapacial scutes. Two holes bored into the carapace were visible after the tick was removed. Photographs by Josh Phangurha.

Figure 3. A Mesoamerican Cane Toad (*Rhinella horribilis*) in the Calakmul Biosphere Reserve (Campeche, Mexico) with multiple ticks (Ixodidae), including one attached to the paratoid gland (red arrow). Photograph by Joseph Oakley.

reported to be parasitized by the larval ticks in the genus *Ambylomma* (Torres et al. 2018).

In addition to our single record of tick parasitism in *C. moreletii*, Charruau et al. (2016) found a single *Amblyomma dissimile* parasitizing this crocodilian in Quintana Roo. In that study, just one of 50 captured *C. moreletii* was found with an adult female tick, and the authors also recorded low tick parasitism rates in two other Mexican crocodilians. Only one of 197 captured *Crocodylus acutus* (also in Quintana Roo) had a single adult female *A. dissimile* and only one of 57 *Caiman crocodylus chiapasius* (in Chiapas) had an adult male *A. dissimile*, suggesting that tick parasitism in crocodilians in Mexico is relatively uncommon.

In Central and South America, many records document tick parasitism on amphibians, particularly toads in the family Bufonidae (Guglielmone and Nava 2010; Guzman-Cornejo et al. 2011; Bermúdez et al. 2013; Torres et al. 2018). *Amblyomma dissimile* was recorded on four species, whereas *A. rotundatum* was detected on seven species of Bufonidae, one leptodactylid, and one pipid (Guglielmone and Nava 2010). In Mexico, two species of ticks, *A. dissimile* and *A. rotundatum,* are known to parasitize the bufonid *Rhinella horribilis* (Pearse 1936; Paredes-Leon et al. 2008; Guzman-Cornejo et al. 2011). We observed attachment of ticks on the paratoid gland of *R. horribilis* (Fig. 3), which was unusual. Mailho-Fontana et al. (2016) reported larval *Amblyomma* sp. in paratoid pores of *R. horribilis*. The vascular network in these glands is highly developed, potentially providing an abundant blood source. However, the effects of the toxins produced by the paratoid glands on ectoparasites are not known. We did not observe the toad secreting toxins and the tick appeared to be healthy. Although tick parasitism of *R. horribilis* in the Yucatan region is relatively well recorded, we are unaware of any previous records of ticks on other toads, such as *Incilius valliceps*, indicating that our observation of tick parasitism of *I. valliceps* in the CBR is the first record for this species in the Yucatan region of Mexico and perhaps throughout the entire range of the species.

Anoles are known hosts of chiggers (Zippel et al. 1996; Schlaepfer 2006), and we herein present the presence of chiggers in the post-femoral mite pockets of two new host species, *Anolis tropidonotus* and *A. lemurinus* (Fig. 4). The exploitation of mite pockets appears to increase egg safety and renders removal by the host difficult, supporting the co-evolutionary theory of target locations on some lizard hosts (Arnold 1986; Benton 1987). Mite loads vary greatly, and Halliday et al. (2014) reported that larger individuals harbor higher loads. Although our sample size was too small to draw any conclusions, we noticed that *A. tropidonotus* had deeper mite pockets than *A. lemurinus*, which could affect mite loads. We also noted no evidence of skin irritation on the *A. lemurinus*, with a single chigger, whereas the *A. tropidonotus*, with numerous mites, showed signs of inflammation at the chigger attachment site (Fig. 4). This might be attributable to the higher number of parasites, but levels of inflammation can

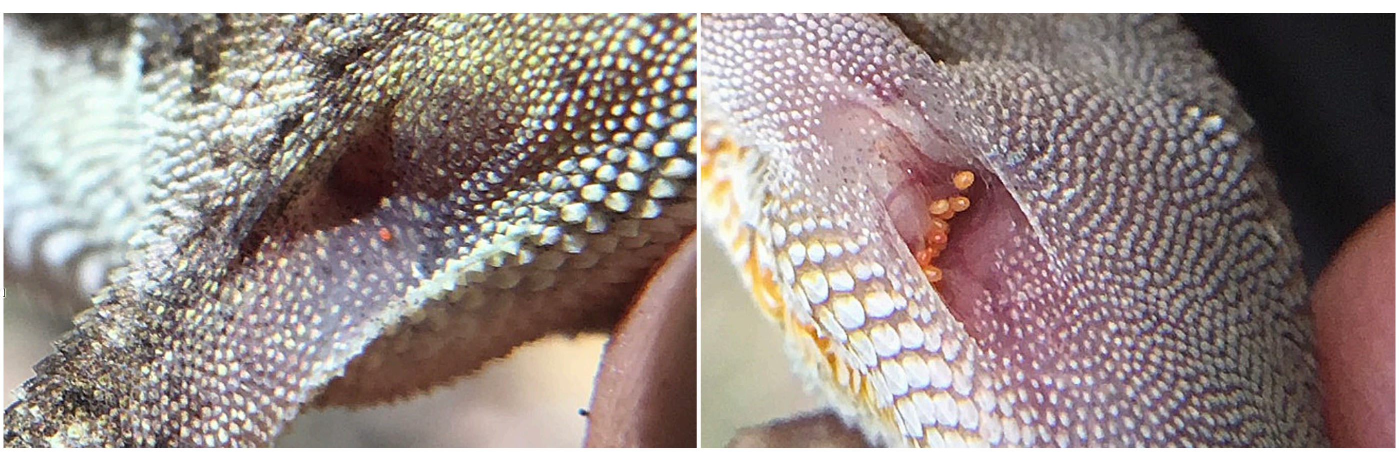

Figure 4. A Ghost Anole (*Anolis lemurinus*) (left) with a chigger (larval trombiculid mite) in the postfemoral mite pocket and a Greater Scaly Anole (*Anolis tropidonotus*) (right) with an inflammation of the skin presumably caused by chiggers. Photographs by Alexandros Theodorou.

vary between species and individuals. Further negative effects have been observed in a different anole; *A. sagrei* exhibited a negative growth rate and poor body condition associated with heavy mite loads, a factor more prevalent in areas with a high lizard density (Schoener and Schoener 1978). In contrast, in *Anolis polylepis*, a species commonly parasitized by chiggers, Schlaepfer (2006) found that growth rates and body condition were not affected.

Throughout the Mayan jungle (Belize, northern Guatemala, and Mexico's Yucatan Peninsula), leech parasitism of reptiles is rare, with Belize reporting the highest number of observations: *Placobdella ringueleti* as a parasite of *Kinosternon acutum* (Tellez et al. 2017b); *Haementeria acuecueyetzin* and a species in the family Glossiphoniidae on *C. moreletii* and *C. acutus*, respectively (Corry-Roberts et al. 2017; Tellez et al. 2017a). In the Mexican portion of the Yucatan Peninsula, only one published record documents parasitism by *H. acuecueyetzin* in 21 *C. moreletii* in the José María Morelos lagoons of Quintana Roo (Charruau et al. 2020a), who noted that 18 crocodiles had only one leech, three individuals had two or more, and leeches were seen on legs (similar to our observations), feet, abdomen, and palate. In the CBR, leech parasitism on *C. moreletii* was observed by JALBN in 2017–2019 in 14 of 109 captured individuals. Although unable to collect leeches for species identification due to permit limitations, comparisons of photographs and CBR's proximity (< 50 km) to the records reported by Charruau et al. (2020b) suggest that the leeches involved appear to be *H. acuecueyetzin*.

Parasites and Conservation

Monitoring ectoparasites of wildlife is important due to their potential as vectors capable of transmitting pathogens to both domestic animals and humans. Rocky Mountain Spotted Fever (*Rickettsia rickettsii*) exists in the Yucatan Peninsula and some human fatalities have been reported; *Amblyomma mixtum,* which is known to parasitize multiple hosts, is a confirmed vector of this disease (Zavala-Castro et al. 2006). Detailed information is lacking regarding other potential vectors of this disease in this part of Mexico (Reyes-Novelo et al. 2011), so identifying and monitoring wildlife ectoparasites could contribute to both medical studies and wildlife conservation. *Rickettsia* has been reported in *A. dissimile* attached to *B. imperator*, *Iguana iguana*, and *R. horribilis* and in *A. mixtum* attached to *I. iguana* in parts of southern Mexico (Lampo and Bayliss 1996; Mendoza-Roldan et al. 2020). However, further research is needed on the presence of *Rickettsia* in ticks associated with amphibians and reptiles on the Yucatan Peninsula to monitor its distribution and host versatility (Sánchez-Montes et al. 2019). Furthermore, ticks could play an important role in regulating host population sizes (Lampo and Bayliss 1996). Further studies involving ticks are needed, as the significance of ticks in both natural and human-modified ecosystems is likely greater than what is currently known.

Turtles are among the most endangered vertebrate groups in the world (Rhodin et al. 2011) and a contributing cause of their decline could be parasitism and associated diseases (Gibbons et al. 2000). For example, the bacterium *Mycoplasma agassizii*, which infects desert tortoises in the southwestern United States and Gopher Tortoises in the southeastern United States, is a potential cause of population declines (Jacobson 1994; Smith et al. 1998). Shell diseases also have been implicated as causes of declines of turtle populations (Jacobson 1994; Lovich et al. 1996). Reptilian hosts that are heavily infested with sanguivorous parasites may be vulnerable to anemia, as well as impairments of aerobic capacity and behavior (Ernst and Ernst 1977; Burridge 2005). Furthermore, ticks can be vectors of blood-associated infections that reduce hemoglobin concentrations in various reptiles (Burridge and Simmons 2003; Ryan and Lambert 2005; McCoy et al. 2007; Readel et al. 2008), which can affect survival rates in populations (Jacobson 1994). With rapid changes in the environment due to habitat encroachment, human overpopulation, and climate change, the density of ticks in some suburban and rural settlements are likely to increase as wildlife, humans, and livestock live closer together than ever before (Rodríguez-Vivas et al. 2016). In Mexico, this is particularly relevant on the Yucatan Peninsula as this region has one of the highest deforestation rates in the country, especially within the state of Yucatan (Pennington and Ratter 2006). This could potentially expose herpetofaunal species, such as *Rhinoclemmys areolata,* to unusually heavy parasitism by ticks and associated diseases. Further research is required as data on ectoparasitism of species of *Rhinoclemmys* and other turtles in the Yucatan are sparse (Garcés-Restrepo et al. 2013). Although ticks have been relatively well studied, the damage they cause to their hosts is poorly understood (Fajfer 2012).

Chigger mites are known to cause skin infections that can cause lesions, inflammation, and short-term blood loss; however, the long-term effects are unknown (Goldberg and Holshuh 1992; Bulté et al. 2009). In contrast, both Goldberg and Bursey (1991) and Conover et al. (2015) did not observe substantial damage to hosts or a negative correlation between body condition and chigger infestations. However, chiggers appeared to reduce body condition, body temperature and thermoregulatory behaviors, dulled dewlap coloration, and limited mating displays in fence lizards and anoles (Cook et al. 2013; Johnson et al. 2019).

Leeches can also exert negative effects on herpetofaunal hosts by causing health problems and reduced fitness by, for example, anemia, bacterial and fungal diseases, and as vectors of *Trypanosoma* (which was observed in some *C. moreletii* in the CBR; A.L. Barão-Nóbrega, unpublished data) and

Hemogregarina in amphibians and turtles, respectively (Maslov et al. 1996; Siddall and Desser 2001; de Campos Brites and Rantin 2004). Species of *Hemogregarina* are intraerythrocytic and are generally considered to have low pathogenicity, but the rates of affected erythrocytes in hosts likely influence prognosis (Wright 2001; Campbell and Ellis 2007).

Conclusion

This work adds to the limited knowledge of herpetofaunal ectoparasites found in the Mexican portion of the Yucatan Peninsula and provides an overview of parasite-host relationships on the peninsula. Not only is recording ectoparasites of herpetofauna important for a better understanding of the ecology and conservation of amphibians and reptiles, it could provide useful baseline information for medical studies involving disease transmission between these parasites and humans, which likely will become more common as human population growth and urban expansion bring wildlife and humans into ever closer proximity.

We strongly suggest further research on this topic in the Mexican portion of the Yucatan Peninsula with collected ectoparasites more accurately identified. This likely would provide important information on the complex interactions of ectoparasites and their herpetofaunal hosts.

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