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Ectoparasite prevalence of the Flathead Knob-scaled Lizard *Xenosaurus platyceps* in tropical and temperate populations

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Chigger mites (Arachnida: Trombidiformes: Trombiculidae, genus *Eutrombicula*) are common and widespread ectoparasites on lizards. Mite prevalence, the proportion of individuals in a population with mites, in American lizard populations can be quite high, with some populations having prevalences exceeding 90% (e.g, *Ameivula ocullifera*: 92.6% after Xavier et al. 2019; *Sceloporus jarrovii*: 93% after Bultéet al. 2009 or 100% after García-de la Peña et al. 2010; *Tropidurus* spp.: > 95%, after Rocha et al. 2008, 2020). Chigger mite loads, the number of mites per individual, and prevalence in lizard populations are affected by several factors, e.g., mite prevalence may vary seasonally (Jackson & Bateman 2018, Pollock & John-Alder 2020, Paterson & Blouin-Demers 2020). Variation in mite load and prevalence within and between lizard populations may be influenced by slope orientation (i.e., north- vs. south-facing slope see Smith 1996), habitat (e.g., Wu et al. 2019, Xavier et al. 2019, Gwiazdowski et al. 2020, Drechsler et al. 2021, but see Smith 1996), and altitude (Conover et al. 2015, Seddon & Hews 2016, Er-Rguibi et al. 2021, Hamilton et al. 2021, but see Comas 2020). Mite prevalence and loads are often higher in habitats and at altitudes with denser vegetation (Curtis & Baird 2008, Bulté et al. 2009, Wu et al. 2019) or greater moisture levels (Zippel et al. 1996, Xavier et al. 2019). Apparently loads and prevalence are also higher in male lizards than in female lizards (e.g., García-de la Peña et al. 2007, 2010, Watkins & Blouin-Demers 2019), although some lizard species exhibit no intersexual differences (de Carvalho et al. 2006). A higher male ectoparasite load and prevalence may be related to testosterone levels (Cox & John-Alder 2007).

We here report on the Trombulicid mite prevalence in the Flathead Knob-scaled Lizard, *Xenosaurus platyceps*, from two populations in contrasting environments in Tamaulipas, Mexico. One population is located in a temperate location, El Madroño (23°36'09" N, 99°13'42" W), and the other in a tropical location, Gómez Farías (23°03'58" N, 99°10'06" W). *Xenosaurus platyceps* are crevice-dwellers (Lemos-Espinal et al. 1997), and *Xenosaurus* spp. appear to be relatively sedentary in general (Lemos-Espinal et al. 2003). In addition, previous work has shown these two populations to vary in demography (Rojas-González et al. 2008a), litter size (Rojas-González et al. 2008b), and individual growth rate (Rojas-González 2009).

We compared *X. platyceps* from two locations that are separated by approximately 60 km in the state of Tamaulipas, Mexico. The temperate site, El Madroño, is located in an oak forest at 1460 m altitude. Annual temperature at this locality averages 18.3°C with annual rainfall averaging 1089 mm (El Balcón de Moctezuma meteorological station, Mexican National Meteorological Service). The tropical locality, Gómez Farías, is located in a sub-deciduous tropical forest at 420 m a.s.l. within the El Cielo Biosphere Reserve, where the average annual temperature is 23.4°C and average annual rainfall is 1834 mm (Gómez Farías meteorological station, Mexican National Meteorological Service).

At each locality we established a plot of approximately 5 ha. We visited the study sites monthly from April 2000 through February 2004. During each visit we checked nearly all the crevices that typically contained *X. platyceps* within a plot and attempted to capture all observed lizards by hand. For each capture, we identified the sex of each individual and whether or not it was infested with chigger

Table 1. Mite prevalence (%; N in parentheses) in *Xenosaurus platyceps* from Gómez Farías and El Madroño for each study year listed for all lizards, males and females separately.

	Gómez Farías			El Madroño		
Year	All	Male	Female	All	Male	Female
2000	40% (45)	46% (24)	37% (19)	92% (203)	93% (86)	90% (102)
2001	23% (128)	30% (59)	15% (59)	73% (259)	75% (102)	71% (139)
2002	9% (74)	11% (27)	10% (40)	48% (111)	49% (49)	48% (56)
2003	23% (94)	14% (35)	33% (49)	49% (131)	51% (47)	46% (61)

mites (Trombiculidae).We marked each individual by toe-clipping. Each animal was then returned to the crevice of its capture.

For analyses, if an individual had > 1 observations in any given year, we randomly selected a single observation for that individual per year. We used chi-square tests to examine the effects of population, sex, month, and year on mite prevalence. We used an a-value of 0.05 to determine statistical significance. We used JMP Pro 15.1 software (SAS institute, Cary, NC, USA).

In every year of the study, mite prevalence was significantly higher in El Madroño than in Gómez Farías (Table 1; 2000: $c^2_1 = 67.3$, $P < 0.001$; 2001: $c^2_1 = 88.2$, $P < 0.001$; 2002: $c^2_1 = 29.7$, $P < 0.001$; 2003: $c^2_1 = 15.0$, $P < 0.001$).

In the tropical Gómez Farías population, mite prevalence varied between years, with 2000 having the highest prevalence and 2002 having the lowest (see Table 1; $c^2_3 = 15.3$, $P < 0.001$). When years were pooled, mite prevalence differed significantly between months, with peak prevalences in April to October (Table 2; $c^2_9 = 30.9$, $P < 0.001$). Differences in mite prevalence between males and females varied between years, with no difference in 2000 ($c^2_1 = 0.35$, n.s.) and 2002 ($c^2_1 = 0.021$, n.s.), males having a higher prevalence in 2001 ($c^2_1 = 3.89$, $P < 0.05$), and females tending to have a higher prevalence in 2003 ($c^2_1 = 3.67$, n.s., see Table 1).

In the temperate El Madroño population, mite prevalence exhibited marked interannual variation, i.e., in 2000, the highest mite prevalence was recorded and 2002, and 2003 had the lowest number of records (Table 1; $c^2_3 = 100.1$, $P < 0.001$). For all years pooled, there was a significant difference in mite prevalence between months, with peak prevalences ranging from April tthrough January (Table 2; $c^2_{11} = 152.2.$, $P < 0.001$).Males and females exhibited similar mite prevalence rates in each study year (2000: $c^2_1 = 0.48$, n.s.; 2001: $c^2_1 = 0.54$, n.s.; 2002: $c^2_1 = 0.003$, n.s.; 2003: $c^2_1 = 0.21$, n.s.) (Table 1).

We detected significant differences in mite prevalence between the two populations of *X. platyceps*. Mite prevalence was more than twice as high at the temperate El Madroño (70%) than at the tropical Gómez Farías locality (22%). To the best to our knowledge, this is only the second study on mite prevalence in *Xenosaurus*. Previously Olvera Arrieta (2017) reported the prevalence of *Eutrombicula alfreddugesi* in *X. fractus* as being 39% and for *X. rectocollaris* as 70%. Interestingly, in our study the temperate population (El Madroño) had a higher mite prevalence than the tropical population (Gómez Farías), but this pattern was found to be reversed by Olvera Arrieta (2017) with a higher prevalence in the subtropical population of *X. rectocollaris* than in the temperate population of *X. fractus*. Previous studies on mite prevalence and infestation in lizards have found that the prevalence of mites is often related to vegetation cover (Schlaepfer 2006, Bulté et al. 2009, Wu et al. 2019) and higher moisture levels (Zippel et al. 1996, García-Ramírez et al. 2005, Xavier et al. 2019). The contrasting results of our study to those of Olvera Arrieta (2017) may suggest that the general patterns observed in other lizards may not be as important in driving differences in mite prevalence between populations of crevice-dwelling lizards such as *Xenosaurus*. Perhaps the microclimate in the crevice, or the potential of sharing crevices (see Godfrey et al. 2009, Leu et al. 2010) may be a more important factor. The temperate population (El Madroño) had significantly higher lizard densities compared to the tropical population (Gómez Farías, R. I. Rojas-González unpubl. data). Such a higher density likely increases the proximity of individuals and increases the transmission of mites among individuals of the temperate population relative to the tropical population (but see Sorci et al. 1997). In addition, in both populations,

Table 2. Monthly variation of mite prevalence (%; N in parentheses) in *Xenosaurus platyceps* from Gómez Farías and El Madroño for all years pooled.

Month	Gómez Farías	El Madroño
January	17% (6)	69% (26)
February	11% (65)	41% (123)
March	3% (32)	31% (54)
April	50% (14)	65% (43)
May	–	100% (9)
June	30% (66)	66% (110)
July	29% (14)	96% (55)
August	–	100% (22)
September	39% (44)	85% (91)
October	29% (31)	98% (55)
November	15% (47)	74% (66)
December	14% (22)	82% (50)
Total	22% (341)	70% (704)

females frequently share their crevices with neonates or males. *X. platyceps* are relatively sedentary and show extreme crevice fidelity, with some individuals remaining in the same crevice for > 3 years (R.I. Rojas-González unpubl. data). Additional studies specifically exploring the role of such factors in mite prevalence of *Xenosaurus* lizards would be useful.

For both populations, mite prevalences were highest in 2000 with lower infestation levels in the other years, especially 2002 at the Gómez Farías site. One factor that might drive such annual variations in mite prevalence is annual variation in climatic variables such as temperature and precipitation that have been shown to help explain seasonal variation in mite prevalence and abundance in the environment (e.g., Pollock & John-Alder 2020). To address this possibility, we examined monthly mean temperatures (Fig. 1) and total annual precipitation that the two populations were exposed to (Table 3). Both variables did not substantially differ between years, except that 2000 was drier near El Madroño. It therefore seems unlikely that the annual variation in mite prevalence we observed in *X. platyceps* was a consequence of annual variation in temperature or precipitation. We are aware of only one other study considering annual variation in mite prevalence in lizards: the number of mites on *Anolis apletophallus* increased over the course of a three-year study period (Cox et al. 2020). We encourage others to study the annual variation in mite prevalence and their potential correlates (e.g., temperature, precipitation, vegetative cover) in lizards.

Mite prevalence in both populations tended to be higher from April through either October (Gómez Farías) or January (El Madroño). This pattern is similar to that observed in *X. fractus* (where the prevalence was higher in August than in November), but contrasts with that observed in *X. rectocollaris* (where the prevalence was higher in October than in July, see Olvera Arrieta 2017). Our results are generally consistent with observations on seasonal mite prevalence in other species of lizards (e.g., Huyghe et al. 2010, Lumbad et al. 2011, Jackson & Bateman 2018, Paterson & Blouin-Demers 2020). Seasonal variation in mite prevalence and load in lizards is often positively related to mite abundance in the environment (Klukowski 2004, Pollock & John-Alder 2020), which may be related to temperature (Pollock & John-Alder 2020).

Table 3. Total annual precipitation data (in mm) obtained from weather stations near the two study sites, Gómez Farías (Gómez Farías weather station: 4.68 km from study area) and El Madroño (Balcón de Moctezuma weather station: 1.42 km from study area) during the four study years.

	2000	2001	2002	2003
Gómez Farías	1830	1612	1853	1763
El Madroño	467	1372	1141	1436

Figure 1. A Flathead Knob-scaled Lizard, *Xenosaurus platyceps*, from Tamaulipas, Mexico, with mites on the neck. Photo: Julio Lemos-Espinal.

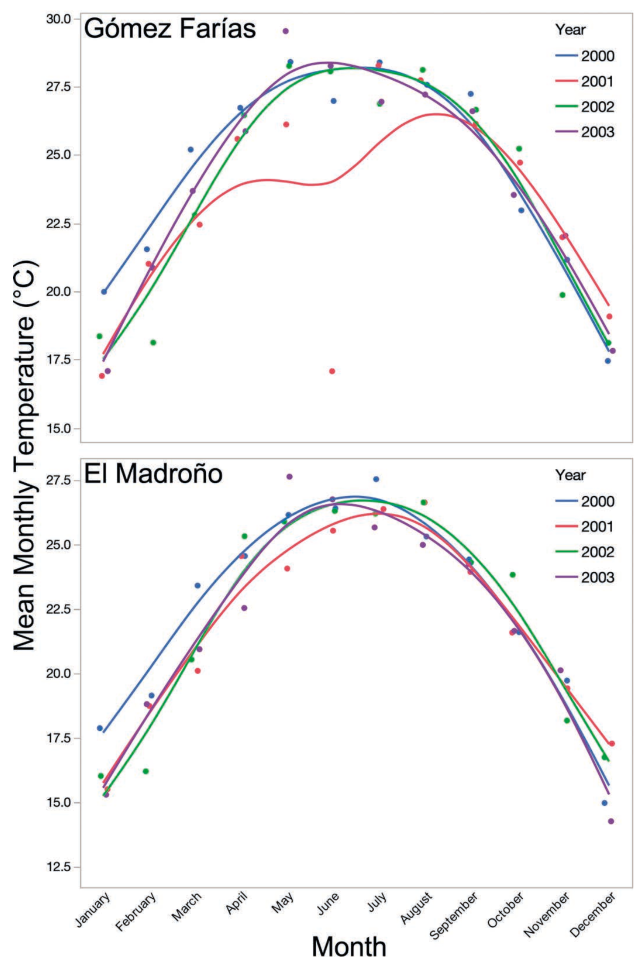

Figure 2. Monthly mean air temperatures from weather stations near the two study sites Gómez Farías (Gómez Farías weather station: 4.68 km from study area) and El Madroño (Balcón de Moctezuma weather station: 1.42 km from study area) during four study years.

Males and females at our two study sites exhibited a similar prevalence. In a previous study, Olvera Arrieta (2017) also found that the sexes of both *X. rectocollaris* and *X. fractus* did not differ in their mite prevalence. The results for Knob-scaled Lizards contrast to most other studies on lizard ectoparasite infestations in that the latter reported a higher mite prevalence in males than in females (e.g., Smith 1996, Schall et al. 2000, Klukowski & Nelson 2001, García-de la Peña et al. 2007, 2010, Watkins & Blouin-Demers 2019). However, three species of *Tropidurus* lizards did not exhibit sexual differences in mite prevalence (de Carvalho et al. 2006). It is unclear why there should be intersexual difference in the prevalence of mites in *Xenosaurus* or *Tropidurus* lizards compared to the other lizards that have been studied. At least for *Xenosaurus*, it is tempting to speculate that their crevice-dwelling habits potentially contribute to ectoparasite infestations. Previous studies reporting higher prevalences in males compared to females have been carried out primarily on more active lizard species with larger home ranges and territorial males such as phrynosomatid lizards (Bulté et al. 2009, Cox & John-Alder 2007, García de la Peña et al. 2007, 2010), sphaerodactylids (Comas 2020), Dactyloidae (Zippel et al. 1996) and lacertids (Salvador et al. 1996, Gwiazdowicz et al. 2020). Xenosaurid lizards, on the other hand, have comparably small home ranges (e.g., the mean distance moved by individual *X. newmanorum* was 5.47 m, including returns to previously occupied crevices; Lemos-Espinal et al. 2003); which may explain the lack of intersexual differences in ectoparasite infestation. Clearly, additional and more detailed studies are needed to better understand the factors driving variation in mite prevalence for xenosaurid lizards.

In conclusion, our results suggest that mite prevalence in *X. platyceps* is higher in a temperate than in a tropical population, that it is seasonal, and that it may vary between years. However it is as yet unclear what the drivers of mite prevalence patterns are. Our and the previous results of Olvera Arrieta (2017) demonstrate that Knob-scaled Lizards, *Xenosaurus* ssp., might provide a good system to explore the factors influencing ectoparasite abundance in lizards in general.

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