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Short Report: A Common Caatinga Cactus, *Pilosocereus gounellei*, is an Important Ecotope of Wild *Triatoma brasiliensis* Populations in the Jaguaribe Valley of Northeastern Brazil

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Abstract. *Triatoma brasiliensis* is the most important vector of Chagas disease in the Caatinga eco-region of northeastern Brazil. Wild *T. brasiliensis* populations have been reported only from rocky outcrops. However, this species frequently infests/re-infests houses in rock-free sedimentary lowlands. We therefore hypothesized that it should also occupy other natural ecotopes. We show that a common Caatinga cactus, *Pilosocereus gounellei*, locally known as xiquexique, often harbors *T. brasiliensis* breeding colonies apparently associated with rodents (n = 44 cacti, infestation rate = 47.7%, 157 bugs captured). Our findings suggest that infested cacti might be involved in house re-infestation by *T. brasiliensis* in the Caatinga region.

Triatoma brasiliensis Neiva, 1911, and particularly *T. brasiliensis* s.s., is the main vector of human Chagas disease in the semi-arid Caatinga eco-region of northeastern Brazil.[1–5] One crucial feature of *T. brasiliensis* s.s. is its ability to recurrently infest/re-infest insecticide-treated houses and peridomestic structures, hindering long-term control of Chagas disease transmission across its wide geographic range.[4,6–8] To date, the only known ecotopes of wild *T. brasiliensis* populations are rocky outcrops, a typical landscape trait in some areas within the Caatinga.[2,9–12] However, re-infestation of artificial structures is also commonplace in sedimentary lowlands where no such rocky outcrops exist; in addition, *T. brasiliensis* often occurs in wood piles near houses,[13–15] particularly when these are also occupied by rodents (Valença-Barbosa C, unpublished data). These observations led us to hypothesize that *T. brasiliensis* s.s. should be able to exploit alternative (i.e., non-rocky) ecotopes in the wild, possibly in association with rodents.

To test this hypothesis, we conducted a survey of candidate natural ecotopes, concentrating on shrubby cacti (*Pilosocereus gounellei*, locally known as xiquexique or cardeiro; Figure 1), with traces of occupation by rodents (probably *Galea* sp., locally known as preá) and on large, hollow hardwood trees typical of the Caatinga (Table 1). *Copernicia prunifera* palms are also abundant in the Caatinga and often harbor *Rhodnius nasutus* colonies, but have never been found infested by *T. brasiliensis* in the study region (data from our group, n = 1,766 palms) and were therefore not sampled.

The survey encompassed eight different lowland sites of the Jaguaribe Valley (state of Ceará, northeastern Brazil) in which dwelling infestation/re-infestation by *T. brasiliensis* is commonplace but where no rocky outcrops exist. The study area (approximately 15 × 4 km) lies approximately between 4°52′S, 37°51′W and 4°55′S, 37°56′W, and is about 20–50 meters above sea level. Twenty-eight hardwood trees and 44 xiquexique cacti were sampled by means of live-baited (with chicks as bait) sticky traps.[16,17] Traps (1–12, depending on ecotope size) were set inside tree trunk holes or among the ground-level branches of the cacti, and were operated for approximately 12–14 hours, from late afternoon to the following morning. The total trapping effort was 273 trap-nights; in three cacti, manual collections were also attempted after trap removal. Of these collection efforts, 47 trap-nights (17.2%) and all three manual captures were successful, i.e., at least one bug was caught. In one cactus, six traps were negative but three bugs were caught manually.

Triatoma brasiliensis s.s. specimens were captured in 21 of the 44 cacti investigated (infestation rate = 47.7%); detailed results are shown in Table 1. Regarding hardwood trees, triatomines were found in just one *Licania rigida* (3.6% of all trees sampled): two *T. pseudomaculata*, but no *T. brasiliensis*, were collected (Table 1). The large difference in infestation rates between *P. gounellei* and trees ($P < 0.0001$, by Fisher's two-tailed exact test) suggests that *T. brasiliensis* strongly prefers terrestrial, shrubby cacti to arboreal ecotopes in our study sites. Using a simple logistic regression model, we found that the approximate amount of rodent feces present in each ecotope, measured as a score with values from 0 to 5, significantly increased the likelihood of infestation: the odds ratio for each unit increase in this rodent feces score was 5.05 (95% confidence interval = 2.50–12.90; data on rodent feces were missing for 12 hardwood trees; thus, for this analysis, n = 60 ecotopes).

When analyzing *P. gounellei* data separately from tree data, we found that infestation by *T. brasiliensis* was extremely frequent in cacti located in relatively well-preserved sites (20 infested/22 sampled, 90.9%), albeit, it was also detected in cacti growing in heavily disturbed landscapes (1 infested of 22 sampled, 4.6%; $P < 0.0001$, by Fisher's two-tailed exact test). Infested cacti were found at distances ranging from 50–100 meters to 1–2 km from the nearest dwelling. Immature *T. brasiliensis* specimens were collected in 20 of the 21 infested *P. gounellei* (colonization rate = 95.2%).

We also explored the possibility that cactus architecture may affect infestation odds.[18] For this analysis, we classified cacti into three coarse categories: open (cactus base and lower branches leaving bare ground visible), closed (cactus base and lower branches covering most of the ground immediately below), and intermediate. Although we believed that closed cacti might offer better micro-environmental conditions for the bugs[19,20] and their vertebrate hosts, our limited data provided little evidence of any such effect: infestation rates were 33.3% (5 of 15) for open, 53.3% (8 of 15) for intermediate, and 57.1% (8 of 14) for closed cacti (likelihood-ratio test: $\chi^2 = 1.96$, degrees of freedom = 2, $P = 0.38$).

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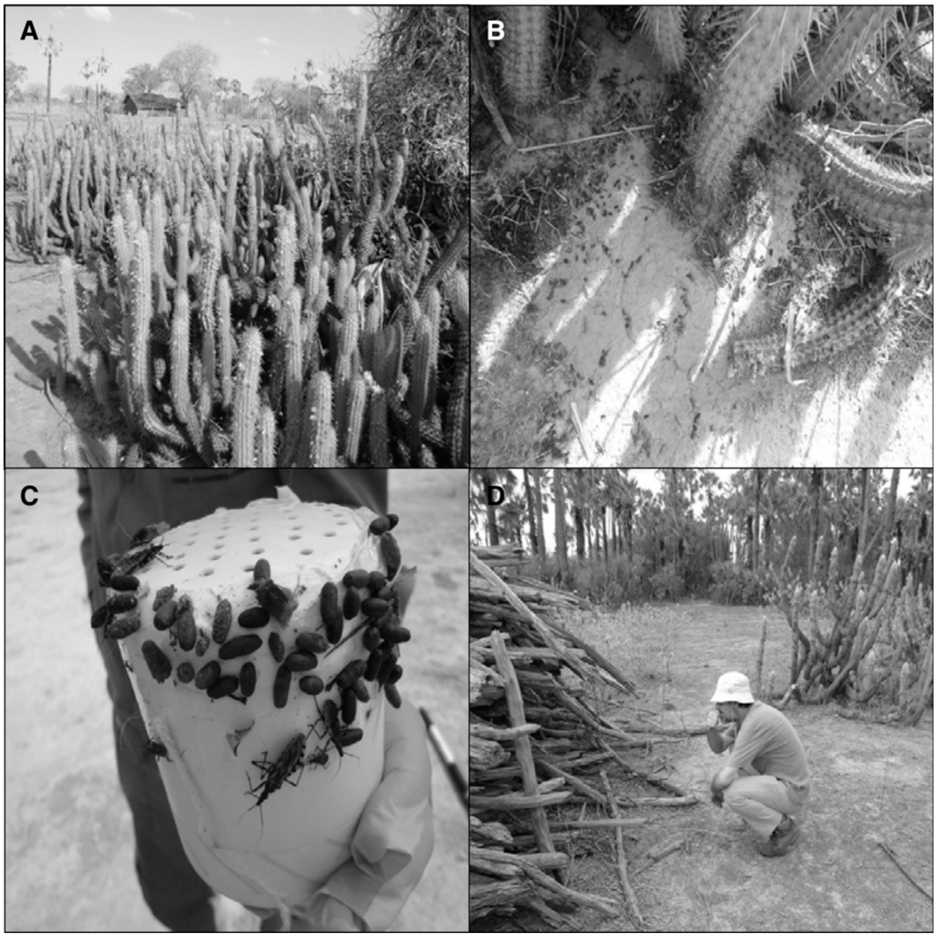

Figure 1. **A**, *Pilosocereus gounellei* (xiquexique) cacti, a common natural ecotope of both rodents and *Triatoma brasiliensis* in the Caatinga, northeastern Brazil. **B**, Rodent feces under a xiquexique cactus. **C**, Live-bait traps with rodent feces and *T. brasiliensis*. **D**, A researcher observes a timber pile occupied by *T. brasiliensis* and *Galea* sp. located near xiquexique cacti in a preserved lowland site of the Jaguaribe valley, Ceará, Brazil.

The maximum number of *T. brasiliensis* specimens captured in an individual *P. gounellei* cactus was 74 (total = 157); on average, 3.6 bugs were caught per sampled cactus and 7.5 bugs per infested cactus (Table 1). We used a simple Poisson abundance model to estimate bug density/abundance based on the number of bugs caught in each trap (or manual capture) in each cactus (i.e., based on repeated counts).[21,22] This model estimated mean bug density at approximately 4.3 (SE = 0.78) for an overall total abundance of about 187.9 *T. brasiliensis* in the 44 cacti we sampled, with an upper limit of the 95% confidence interval of 255.2. Previous surveys [12–15] have detected *Trypanosoma cruzi* infection in 17.4% (95% exact confidence interval 16.1–18.8%) of 2,982 *T. brasiliensis* specimens collected in the study region. Based on model estimates of bug-detection sensitivity (which, for the methods we used was low: mean = 0.15, SE = 0.02), on catch effort, and on the observed patterns of bug presence, our analyses suggest that most of the *P. gounellei* we sampled might have been infested: model-estimated infestation probability was 98.6% (95% confidence interval = 96.5–100%).

Table 1

Triatomine infestation in 72 natural ecotopes sampled in eight Caatinga lowland sites of the Jaguaribe Valley, Ceará, Brazil, 2012.

				No. bugs collected*							
Ecotope	Local name	No, sampled	No. infested (%)	NI	NII	NIII	NIV	NV	Male	Female	Total
Cacti											
Pilosocereus gounellei	Xiquexique	44	21 (47.73)	34	41	45	17	9	7	4	157
Hardwood trees											
Licania rigida	Oiticica	18	1 (5.56)	1	0	0	0	0	1	0	2†
Auxemma oncocalyx	Pau branco	6	0 (0)	0	0	0	0	0	0	0	0
Aspidosperma pyrifolium	Pereiro	2	0 (0)	0	0	0	0	0	0	0	0
Erythrina velutina	Mulungu	1	0 (0)	0	0	0	0	0	0	0	0
Ziziphus joazeiro	Juazeiro	1	0 (0)	0	0	0	0	0	0	0	0
Total trees		28	1 (3.57)	1	0	0	0	0	1	0	2
Total		72	22 (30.56)	35	41	45	17	9	8	4	159

*NI–NV are the five immature stages (nymph I–V) of the Triatominae.

† All specimens were identified as *Triatoma brasiliensis* s.s. except for these two *T. pseudomaculata* bugs collected in one *Licania rigida* tree.

Albeit still preliminary, our novel findings suggest that *P. gounellei* is an important ecotope of wild *T. brasiliensis* s.s. populations in the Caatinga, and that bugs from cacti might be involved in house infestation/re-infestation in lowland areas where no rocky outcrops occur. Based on the data we have presented and on our field observations, we hypothesize that the mechanism linking *T. brasiliensis* populations found in cacti and in dwellings could be as follows. In the rural Caatinga, many persons make use of timber gathered from preserved habitat patches, where *P. gounellei* are common and, as we have shown, are often infested by *T. brasiliensis*. However, timber is not immediately transported to houses. Instead, it is usually piled up in an open area at the site of collection (Figure 1) and remains there for weeks or months until the gatherer has resources to take the timber home. While they remain in the wild, these wood piles often become colonized by rodents such as *Galea* sp. and by *T. brasiliensis* (Figure 1); we hypothesize that the bugs are passively transported to dwellings with timber from those piles. The common observation that rodents and *T. brasiliensis* also co-occur in timber/wood piles in peridomestic environments suggests that bugs and rodents are well adapted to this key ecotope.[15] Our hypothesis might also help explain why the risk of infestation with *T. brasiliensis* was shown to be higher in dwellings whose owners have more frequent contact with preserved Caatinga environments (odds ratio = 2.43, 95% confidence interval = 1.18–5.04; n = 131 dwellings).[23] Active dispersal of adult *T. brasiliensis* from either cacti or rocky outcrops can also directly contribute to dwelling infestation and re-infestation in some areas.[12,13,24]

In conclusion, the observations we report open the way to solving one long-standing question about *T. brasiliensis* s.s. ecology, namely, the origin of re-infesting vectors in areas without rocky outcrops. Future work will aim at confirming our present data with further sampling, at studying vector-host-parasite interactions, and at assessing the genetic relationships of wild (from cacti, rocks, and timber piles), peridomestic and domestic populations of *T. brasiliensis* by using high-resolution molecular markers.[25,26] We expect that this combination of sound ecological modeling[21,27] and molecular genetics[28] will provide crucial insight on the process of dwelling re-infestation by *T. brasiliensis* s.s. in northeastern Brazil.

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