ABUNDANCE OF SCORPIONS *Tityus serrulatus* AND *Tityus bahiensis* ASSOCIATED WITH CLIMATE IN URBAN AREA (SCORPIONES, BUTHIDAE)

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ABSTRACT

Scorpion abundance depends on factors like rainfall, temperature, and food availability. To investigate the relationship of scorpion abundance and climatic variables we interviewed people living in an urban area in southern Brazil where scorpions were known to occur and coupled these data with manual collecting. The collecting site was near small remnant forest fragments. During 10 months, we sampled 106 *Tityus serrulatus* (21.7% juveniles, 78.3% adults) and 59 *Tityus bahiensis* (35.6% juveniles, 64.4% adults). The highest abundance for both species was in cold, dry months. We found a negative correlation between humidity and abundance in *T. serrulatus* and *T. bahiensis* populations and no correlations between abundance and rainfall or temperature. The scorpions are well adapted to the urban environment with available food in the water galleries and lack of natural predators. As a result, they are capable to reproduce more than once a year. This study shows that urban habitats can produce very different population dynamic patterns when compared with natural habitats.

Keywords: population dynamic, reproduction, scorpionism, seasonal pattern, habitats

INTRODUCTION

Morphological and physiological adaptations enable scorpions to survive in harsh desert environments. They avoid extreme climatic conditions by hiding in burrows and being active at night. In addition, their extremely impermeable cuticle assists with retention of water as does low metabolism, efficient excretion, and extreme resistance to desiccation (Hadley, 1974).

Tityus Koch (1836), including the highest number of scorpion species described (Fet, *et al.*2000), shows a broad geographic distribution in South America, It is the most specios genus**,** represented by 35 species (Lourenço, 2002). *Tityus* spp. are commonly considered opportunistic, since they have a short life cycle, high reproductive rate**,** low investment in parental care, low corporal size, and large tolerance of environmental stress (Lourenço, 2000).

It is known that some species like *Urophonius tumbensis* has a winter activity period (Pizarro-Araya, *et al*. 2011) and differently several species of scorpions the adults are most active in the summer whereas the juveniles are more active in the winter (Fox, 1975).

Because of this difference in activity between the life stages, cases of scorpionism are higher in the hot and rainy season according to the study that Chowell *et al*. (2006) carried out in Mexico which corroborates with De Roodt *et al*. (2003), which also recorded a higher incidence of stings by *Tityus trivittatus* during the warmer months in Argentina (October–April). To the contrary, Dehesa-Davila (1989) associated the beginning of the rainy season with a decrease in the number of scorpion stings, while a higher incidence was recorded in the spring.

Scorpionism is a public health problem in Brazil with higher incidence in the hottest climatic regions during hot, rainy months (Neto, *et al*. 1994) and *Tityus serrulatus* LUTZ and MELLO 1922 and *Tityus bahiensis* PERTY 1834 are the main responsibles for sting incidents (Lourenço and Eickstedt, 2003). Severe cases, which can even be lethal, are related solely four species of the genus *Tityus* (Buthidae): *T. bahiensis, T. obscurus, T. serrulatus*,*T. stigmurus* (Brasil, 2009). The yellow scorpion, *T. serrulatus* is considered the most dangerous species in South America (Eickstedt, *et al*. 1994; Freire-Maia, *et al*. 1994). This is an endemic species in Brazil and distributed in the states of Bahia, Espírito Santo, Minas Gerais, Rio de Janeiro, São Paulo, Paraná, Federal District, and Goiás (Fundacentro, 2001).

The present study aims at analyzing the abundance of juvenile and adult individuals of *T. serrulatus* and *T. bahiensis*, in urban areas and determining if reported incidents of stings are related to climatic factors.

MATERIALS AND METHODS

Study area - The study was conducted in a 270.3 hectare middle-high class residential condominium in the city of Campinas. The site was composed of 1.537 plots within which approximately 1,000 already had edifications. Its infra-structure comprises areas of common use with extensive lawns and gardens, plots with no construction covered by mowed grass, and others in which houses have been built. The area includes seven springs of water, three lakes, and a few streams surrounded by riparian forest. All roads have been asphalted and have basic sanitation and pluvial water systems. The site is surrounded by other condominiums and rural areas.

Data collection - All data was obtained by means of interviews with residents and active search for scorpions. The study was carried out between January to October 2006 biweekly and we focused on two different situations: 1) Occurrences of scorpions in the residences where the residents themselves noticed

Table 1 Correlation among the number of scorpions and temperature, rainfall and humidity; Campinas region, Southeastern Brazil. (*) Significant differences in Spearman correlations test.

	Tityus serrulatus			*Tityus bahiensis*		
Correlations	**N**	**Spearman**	**p**	**N**	**Spearman**	**P**
Adult and Rainfall	10	-035	032	10	-007	085
Adult and Maximum temperature	10	-049	015	10	-017	064
Adult and Medium temperature	10	-047	017	10	-024	051
Adult and Minimum temperature	10	-048	016	10	-026	046
Adult and Maximum humidity	10	-080	001*	10	-055	010
Adult and Medium humidity	10	-078	001*	10	-048	016
Adult and Minimum humidity	10	-072	001*	10	-048	016
Juvenile and Rainfall	10	-032	037	10	-012	073
Juvenile and Maximum temperature	10	-049	015	10	-012	075
Juvenile and Medium temperature	10	-054	011	10	-018	062
Juvenile and Minimum temperature	10	-048	016	10	-015	067
Juvenile and Maximum humidity	10	-060	007	10	-066*	004*
Juvenile and Medium humidity	10	-067	003*	10	-063	005
Juvenile and Minimum humidity	10	-067	003*	10	-060	007
Total and Rainfall	10	-035	033	10	-004	090
Total and Maximum temperature	10	-049	015	10	-011	076
Total and Medium temperature	10	-049	015	10	-015	067
Total and Minimum temperature	10	-050	014	10	-019	060
Total and Maximum humidity	10	-083	000*	10	-066*	004*
Total and Medium humidity	10	-080	001*	10	-057	009
Total and Minimum humidity	10	-075	001*	10	-055	010

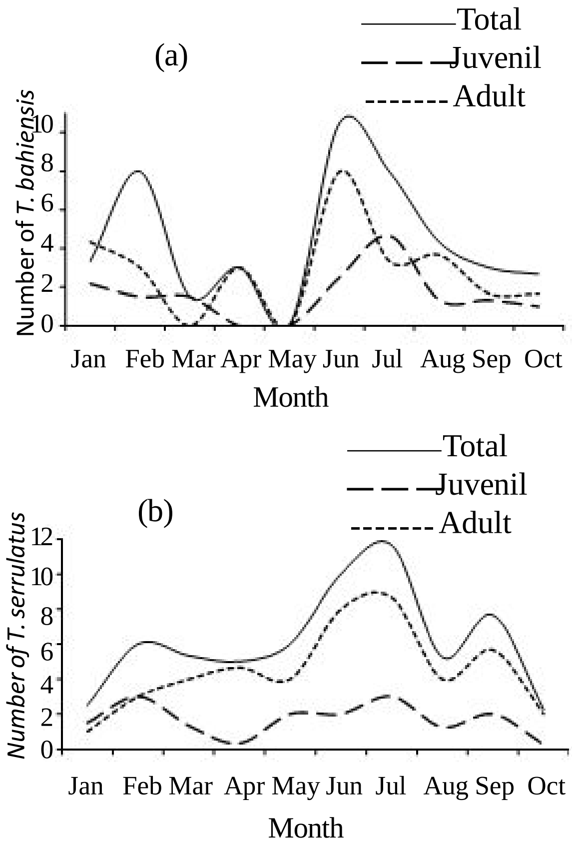

Fig. 1: Monthly distribution of the number of scorpions (a) *Tityus bahiensis* and (b) *Tityus serrulatus* in their developmental stages.

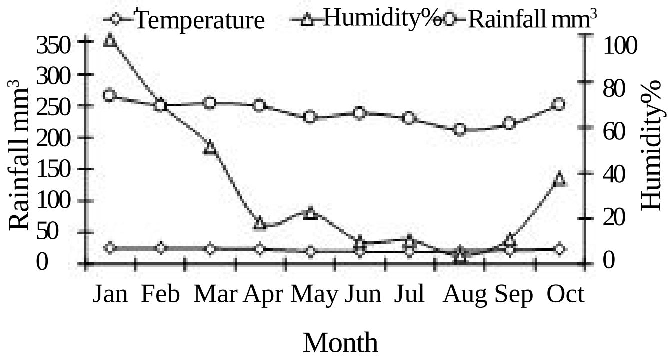

Fig. 2: Climate diagram of the Campinas region, Southeastern Brazil (January 2006-October 2006).

the appearance of the animal. The research team visited the place for interviews and active search around the place. Afterwards, an active search was carried out in the area and in all plots surrounding the residences where the occurrence had taken place. 2) For the common areas with natural vegetation, springs, and playground areas daily active searches were carried out for four hours per visit. We recorded: date (month and year), scorpion species, life cycle stage, average temperature, rainfall, relative humidity. The source for the abiotic variables recorded in the region of Campinas was INPE (National Institute of Spatial Research). All records of occurrence have been geo-referenced in order to help formulate a future control plan.

Statistical analysis - We used the Spearman correlation test to test relationships between the number of individuals (adults and juveniles of both species) and abiotic factors.

RESULTS

In a ten-month period, we collected 23 juveniles (21.7%) and 83 adults (78.3%) of *T. serrulatus* and 59 individuals of *T. bahiensis* including 21 juveniles (35.6%) and 38 adults (64.4%). *Tityus serrulatus* is more abundant in the cold and dry months from June to August than in the hot and rainy months from February to April (Fig.1 a); *T. bahiensis* follows the same pattern of incidence, occurring more abundantly in June, July followed by February (Fig. 1 b).

For *T. bahiensis* juveniles, a negative correlation with maximum humidity (rs = -0.66, P = 0.04) was found. Strong negative correlations among *T. serrulatus* adult abundance and maximum (Spearman rs = -0.80, P = 0.00), medium (rs = -0.78, P = 0.01) and minimum (rs = -0.72, P = 0.02) humidity were found, and a negative correlation for juveniles with medium and minimum humidity (rs = -0.67, P = 0.03) (Fig. 2).

No significant correlations have been found between rainfall and maximum, medium, and minimum temperatures for either species in any phase of the life cycle, even when both phases were considered together (juveniles and adults) and even when considering the total number of individuals of the both species together (Table 1).

DISCUSSION

In both species, fewer juveniles than adults were found. Such data corroborates with Kaltsas, *et al*. (2006) in his study in the Greek Islands where the proportion of adults always seem to be higher than that of juveniles; in Creete and Volos, respectively, he found 80.7% of adults and 19.3% of juveniles; 75.5% of adults and 24.5% of juveniles. In both sites the population density was low in winter, intermediate in autumn, starting to grow in the spring, and has its peak in the summer. This standard is common for various species of scorpions (Polis and Farley, 1979), and he points out that these standards refer to natural environments rather than urban areas.

It has been pointed out in this study that *T. serrulatus* and *T. bahiensis* appear in higher abundance in cold and dry months (June to August). The same higher appearance was observed for *Microtityus jaumei* in Sierra de Canasta, Cuba in dry months (Cala-Riquelme and Colombo, 2011). But no significant correlation has been found between the distribution of scorpions during the months and rainfall; however, it is possible to observe that in the summer rainy months (January to March) there was a record peak which is very clear for *T. bahiensis* (Fig.1). Corroborating with this pattern of *T. bahiensiss* Chowell *et al*. (2006) confirmed in his study that the peaks of scorpions' occurrence correlate well with rainfall and Araújo *et al*. (2010) found the same in an area of Caatinga vegetation in northeastern Brazil.

This increase probably occurs because precipitation inundates the burrows where scorpions live, forcing them to look for new refuges. At the same time, these incidence peaks in both dry and rainy months could not be attributed to the scorpions' sit-and-wait foraging strategy (Polis, 1990a), leading us to conclude, like Yamaguti and Pinto-da-Rocha (2006), that most scorpions collected in this study were in search of partners and not prey because the reproductive periods are very seasonal, occurring during the hot and wet season. Nevertheless Matthiesen (1968) explains that the reproductive period in scorpions varies according to species, and *T. bahiensis* does not exhibit a well-defined reproductive period, instead remaining active throughout the year.

Considering some reproductive characteristics as the possibility of more than one brood being produced without a new insemination taking place between broods (Huber *et al*. 2002). Koovor, *et al*. (1987) demonstrates the existence of a novel process for the storage of spermatozoa embedded in glandular tissue in the genital tract of the female. In *Tityus* spp, females require only a single insemination to produce multiple broods (one to four) during the favorable wet season. As soon as the dry season begins, inseminated females develop reproductive diapause and gestation is blocked until the return of the following wet season, six months later (Lourenço, 1995b). A diapause is hormonally triggered and manifests itself depending on the abiotic pressure caused by the environment. The occurrence of diapauses is mainly related to humidity, and, thus, also related to rainfall. This reproductive strategy is characteristic of the non opportunist species (Lourenço, 1995). However, Polis (1990a) considers these strategies as being characteristic of opportunistic species.

In the present study temperature is not associated with both scorpions species abundances. *T. serrulatus* is highly adaptable to different thermal zones as it has no specific preference for temperature between 14°C and 38°C and is able to tolerate temperatures as low as 8°C in torpor (Hoshino, *et al*. 2006); whereas Cloudsley-Thompson (1975), says that scorpions react positively to humidity and negatively to light and temperatures higher than 39°C. In contrast, Gefen and Ar (2006), describe temperature as the most limiting factor for geographical distribution for a scorpion species *Buthotus judaicus* from Israel, affecting the capacity of osmoregulation, cuticular permeability and loss of water by breathing. Chowell (2005) verified a strong positive association between minimal temperature and scorpions activity.

The urban environments such as those explored in this study offer a great number of micro-climates that favor the proliferation of scorpions, such as waste water galleries and gardens. These habitats, in turn, are constantly watered and have plenty of food (insects). Thus, it is possible that scorpions living in these urban areas and their associated micro-habitats have adapted and now reproduce during more than one yearly cycle. In case, the dry period becomes relevant if the food is offered inside the waste water galleries.

For the partenogenetic *T. serrulatus* it becomes more difficult to find patterns in this environment without gradients. For *T. bahiensis*, on the other hand, two well defined peaks of abundance are demonstrated, which can be considered as one more reproductive cycle in the dry season and not only what literature cites as being in the rainy season. This pattern shows that in the dry season it would be even safer, as risks of lack of food are low in what concerns urban environment and there are no strong showers to flood shelters or cause juveniles mortality.

In conclusion, the scorpions are well adapted to the urban environment with available food in the water galleries and lack of natural predators. As a result, they are capable to reproduce more than once a year. This study shows that urban habitats can produce very different population dynamic patterns when compared with natural habitats.

ACKNOWLEDGEMENTS

We are most grateful to André Luís S. Zecchin from Fundação José Pedro de Oliveira, Dra. Luiza Ishikawa teacher from Pontifícia Universidade Católica de Campinas (PUC) and Maria Eliana Navega teacher from Universidade Metodista Piracicabana (UNIMEP) for their help in proofreading the manuscript, as well as to the whole operational team of Tecnologia e Controle de Pragas Company (TECPRAG) who has helped with data collection in the field. A final thanks to Dr. Wilson Lourenço from Museum from History Naturals of French, department of Systematic and Evolution for helpful about literature.

REFERENCES

Araújo, C.S.; D.M. Candido; H. Araújo F.P.; S.C. Dias and A. Vasconcellos. 2010. Seasonal variations in scorpion activities (Arachnida: Scorpiones) in an area of Caatinga vegetation in northeastern Brazil. *Zoologia*, 27: 372–376.

Cala-Riquelme, F. and M. Colombo. 2011: Ecology of the Scorpion, Microtityus jaumei in Sierra de Canasta, Cuba. *J Insect Sci.*,11: 1-10.

Chowell, G.; J.M. Hyman; P. Díaz-Dueñas and N. W. Hengartner. 2005. Predicting scorpion sting incidence in a endemic region using climatological variables. *Int. J. Environ. Health Res.*, 15: 425-435.

Chowell, G.; J.M. Hyman; P. Díaz-Dueñas and N.W. Hengartner. 2006. Epidemiological and clinical characteristics of scorpionism in Colima, Mexico (2000-2001). *Toxicon,* 20: 1-6.

Cloudsley-Thompson, J.L. 1975. Adaptations of artropoda to arid environments. *Annu. Rev.,* 20: 261-283.

De Roodt, A.R.; S.I. Garcia; O.D. Salomon; L. Segre; J.A. Dolab; R.F. Funes and E.H.Titto. 2003: Epidemiological and clinical aspects of scorpionism by *Tityus trivittatus* in Argentina. *Toxicon,* 41: 971–977.

Dehesa-Davila, M. 1989. Epidemiological characteristics of scorpion sting in Leon, Guanajuato, Mexico. Toxicon, 27: 281–286.

Fet, V.; W.D. Sissom; G. Lowe and M.E. Braunwalder. 2000. Catalog of the Scorpions of the World (1758-1998). New York: *New York Entomological Society.* 1-690.

Freire-Maia, L.; J.A. Campos and C.F. Amaral. 1994. Approaches to the treatment of scorpion envenoming. *Toxicon,* 32: 1009-1014.

Fox, W.K. 1975. Bionomics of two sympatric scorpion populations (Scorpionida: Vaejovidae). *PhD thesis, Arizona States University, Tempe* pp 85.

Fundacentro. 2001. Fundação Jorge Duprat Figueredo de Segurança e Medicina do Trabalho. Prevenção de Acidente com Animais Peçonhentos. *São Paulo: Ministério do Trabalho e emprego,* 1-49.

Gefen, E. and A. Ar. 2006. Temperature dependence of water loss rates in scorpions and its effect on the distribuition of *Buthotus judaicus* (Buthidae) in Israel. CBP Comp. *Biochem.Physiol.,* 144: 58-62.

Hadley, N.F. 1974. Adapattion biology of desert scorpions. *J. Arachnol.,* 2: 11-23.

Hoshino, K.; A.T.V. Moura and H.M.G. De Paula. 2006. Selection of enviromental temperature by the yellow scorpion *Tityus serrulatus* Lutz and Mello, 1992 (Scorpiones, Buthidae). *J. Venom. Toxins Incl. Trop. Dis.,* 12: 59-66.

Huber, D.; V. Andrzejewski; L. Albenga and W.R. Lourenço. 2002. Notes on the postembryonic development of two species of *Isometrus* Ehrenberg (Scorpiones, Buthidae) from Sri Lanka. *Entomol. Mitteilungen.,* 166: 53-61.

Kaltsas, D.; I. Stathi and M. Mylonas. 2006. The effect to insularity on the seasonal population structure of *Mesobuthus gibbosus* (Scorpiones: Buthidae). *Euscorpius,* 44: 1-8.

Koovor, J.; W.R. Lourenço and A Muñoz-Cuevas. 1987. Conservación des spermatozoides dans les voies genitales des females et biologie de la reprodution des Scorpions (Chélicérates). *C. R. Acad. Sci.,* 3: 259-264.

Lourenço, W.R. 1995. Scorpions, scorpionism, life history strategies and parthenogenesis. *J. Venom. Anim. Toxins,* 1: 51-62.

Lourenço, W.R. 1995b. *Tityus fasciolatus* Pessôa, Scorpions Buthidae à traits caractéristiques d'une espèce non opportuniste. *Biogeographica,* 71: 69-74.

Lourenço, W.R. 2000. Reproduction in scorpions, with special reference to parthenogenesis. *Eur. Arachnol.,* 71-85.

Lourenço, W.R. 2002. Scorpions of Brazil. *Paris: Les Éditions l' If.* 1-308.

Lourenço, W.R. and V.R.D. Eickstedt Von. 2003. Escorpiões de importância médica. Cited from Animais peçonhentos no Brasil. *Biologia, clínica e terapêutica dos acidentes.* 198-208.

Matthiesen, F.A. 1968. On the sexual behavior of some Brazilians scorpions in captivity. Braz. *J. Méd. Biol. Re.*,1: 93-96.

Neto, C.C.; P.G. Filho and C.R.W. Yassuda. 1994. Ensaio de campo no controle de escorpiões (*T. serrulatus*) empregando Diazinon microencapsulado, na cidade de Aparecida, SP. *Rev. Soc. Bras. Med. Trop.*, 27: 123.

Polis, G.A. and R.D. Farley. 1979. Behavior and ecology of mating in the cannibalistics scorpion, *Paruroctonus mesaensis* Stahnke (Scorpionida: Vaejovidae). *J. Arachnol.,* 7: 33-46.

Polis, G.A. 1990a. Introduction. Cited from The Biology of Scorpions. 1-8.

Stutz, W.H. 1990. Ocorrência de escorpionídeos em Uberlândia Minas Gerais. Monografia, Universidade Federal de Uberlândia. 32pp

Yamaguti, H.Y. and R. Pinto-Da-Rocha. 2006. Ecology of *Thestylus aurantiurus* of the Parque Estadual da Serra da Cantareira, São Paulo, Brazil (Scorpiones, Bothriuridae). *J. Arachnol.* 34: 214-220.