

## SHORT COMMUNICATION

### Soil type preference and the coexistence of two species of wandering spiders (*Ctenus amphora* and *C. crulsi*: Ctenidae) in a rainforest in Central Amazonia

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**Abstract.** The wandering spiders *Ctenus amphora* Mello-Leitão 1930 and *Ctenus crulsi* Mello-Leitão 1930 are sympatric in central Amazonian rainforests; however, the former is more abundant in sandy soils and the latter in clay soils. In previous studies authors suggested that *C. crulsi* is competitively superior on clay soils and avoids sandy soils. Thus, we hypothesized that these species differ in their responses to the soil type. To test this, we placed 37 *C. amphora* and 30 *C. crulsi* in chambers providing two choices (sand or clay) and compared the proportion of observations in each to evaluate both species' preferences. *Ctenus crulsi* significantly preferred clay to sand ( $P < 0.01$ ), while *C. amphora* showed no evidence of preference between two types of soil. We discuss the possible ecological consequences of this difference in behavior. This is the first study that experimentally shows a difference between the responses of spider species to soil type as an explanation of their coexistence.

**Keywords:** Araneae, behavior, habitat selection, microhabitat

A variety of cues can be used by organisms as proximal stimuli for selecting a habitat (Krebs 1985). Soil type (e.g., sandy, clayey, hydromorphic) may affect many characteristics of the microhabitat, such as litter amount and its associated fauna (De Castillo et al. 2006; Luizão et al. 2007), important resources for ground wandering spiders. However, as far as we know, there are no studies showing that spiders can rely on soil type as a cue to select habitat.

The sympatric spiders *Ctenus amphora* Mello-Leitão 1930 and *C. crulsi* Mello-Leitão 1930 (Araneae: Ctenidae) are among the most abundant medium-sized spiders (mean prosoma length of adults ~7.5–8.9 mm) wandering on the ground in Central Amazonian rainforests (Höfer et al. 1994; Gasnier et al. 2002). However, they differ in patterns of abundance. *Ctenus amphora* is more abundant on relatively dry sandy soils in heath forests or “campinarana”, but is also relatively common in clay soil areas with yellow latossol in dense forest vegetation, while *C. crulsi* is predominant in areas of dense forests and is nearly absent in heath forests (Gasnier & Höfer 2001). The diet of both species consists mostly of arthropods, including cockroaches, crickets and other spiders (including other *Ctenus* species: T.R. Gasnier unpublished data) found on the leaf litter. But the diets differ in the high consumption of termites (*Syntermes*: Termitidae) by *C. crulsi* (about 50% of the prey), while termites make up less than 10% of the prey of *C. amphora*. Based on distribution data of *Ctenus* spiders and termites and on the differences in diets, Gasnier et al. (2009) suggested that *C. crulsi*, being more efficient at capturing termites, is competitively superior to *C. amphora* on the clay soil. Furthermore, they suggested that this species avoids sandy soils, where the termites are rare, releasing this habitat to *C. amphora*. Based on the previous studies, we hypothesized that in captivity *C. crulsi* would avoid sandy soil, and *C. amphora* would show no difference in response or would respond positively to sandy soils.

Juvenile *C. amphora* ( $n = 37$ ) and *C. crulsi* ( $n = 30$ ) and samples of sandy and clay soils were collected in August and November 2011 at the “Fazenda Experimental da Universidade Federal do Amazonas” - UFAM (02° 39'41.4" S, 60° 07'57.5" W) an area of 3,000 ha of primary rainforest in Central Amazon, Brazil. We used only juvenile *Ctenus* to avoid the influence of difference in activity observed in adult males and females (Salvestrini & Gasnier 2001). We selected spiders with a carapace length greater than 5 mm for inclusion in the

experiment, since this is the minimum size sufficient to ensure proper identification to species based on color and design patterns on their bodies (Höfer et al. 1994).

We kept the spiders individually in plastic containers (15 cm diameter × 11 cm height) and subjected them to a constant 12:12 light:dark cycle at ~27°C in the laboratory. We provided water ad libitum and fed the spiders one peanut beetle larva [*Palembus dermestoides* (Fairmaire): Tenebrionidae] once every three days. We deprived the spiders of food for five days prior to the experiment to control their hunger levels. We transported and stored the soil samples for a week after collection in plastic bags until the day of the experiment. We checked the soil samples before the trials to ensure no animals were found within them.

We placed samples of dry clay soil and sandy soil in the plastic containers, 19 cm in diameter × 7 cm height, which had a styrofoam base. The base had a partition 1 cm high and 1 cm wide placed in its center to prevent contact between the two soil types (Fig. 1).

We placed each spider under a plastic vial in the center circle of an arena and left it there to acclimate for 3 min. After this acclimatization period we recorded on which type of soil each spider was found every 10 min between 2010 and 0500 h, making a total of 54 observations for each spider. We used individual samples of soil only once, disposing of them at the end of each set of observations. We tested each spider once. We registered the behavior of 27 spiders during two nights in August 2010 ( $n = 17$  *C. amphora*,  $n = 10$  *C. crulsi*). Five *C. crulsi* and eight *C. amphora* were observed the first night, and five *C. crulsi* and nine *C. amphora* were observed the second night. We observed 40 other spiders ( $n = 20$  *C. amphora*,  $n = 20$  *C. crulsi*) during two nights in November 2012, 10 *C. crulsi* and 10 *C. amphora* per night.

For each spider, we recorded the proportion of observations on clay soil ( $P_{\text{CLAY}}$ ) from the total observations on clay and sandy soil. An observation was considered valid when the spider was observed with at least four legs touching one of the soil types and none touching the other soil type.

We used the bootstrap technique to generate confidence intervals of means of  $P_{\text{CLAY}}$  for each species. Bootstrapping allows the calculation of confidence intervals even when the distribution departs from the normal distribution (Efron 1982). In each test, 1000 pseudo-samples

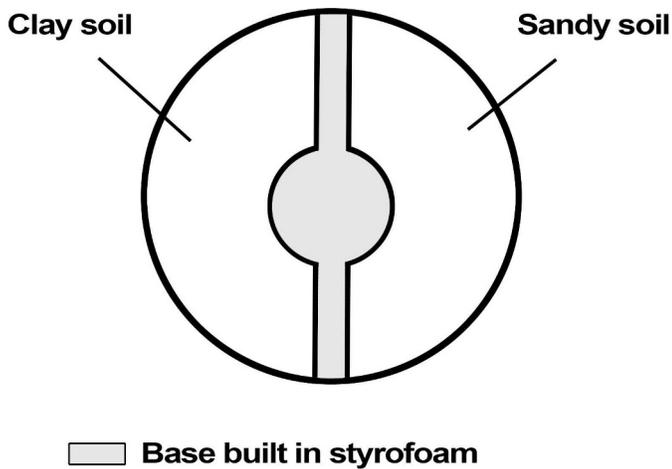


Figure 1.—Testing arena as viewed from above. The bottom was built of styrofoam that had a partition 1 cm high and 1 cm wide (dotted area) to prevent contact between the two soil types. The spider was released in a circular area 5 cm in diameter at the center of the partition.

were generated. The 2.5% inferior and 2.5% superior mean values of the 1000 pseudo-samples were excluded to obtain the 95% confidence interval of mean (CI 95%). The 0.5% inferior and 0.5% superior mean values were excluded to obtain the 99% confidence interval of mean (CI 99%). A confidence interval of  $P_{\text{CLAY}}$  that does not include 0.5 (the mean expected in the absence of preference) is considered evidence of soil selection. Statistical analyses were done with the software R.12.1 (R Development Core Team 2012).

We deposited voucher specimens in the invertebrate collection of the Instituto Nacional de Pesquisas na Amazônia, Manaus-AM under the numbers INPA-AR 8000-AR-INPA 8005.

The proportion of observations on the clay soil for *C. amphora* ( $P_{\text{CLAY}} = 0.497$ , CI 95% = 0.435–0.558, CI 99% = 0.420–0.576; Fig. 2) was almost coincident with the expected value in the absence of preference for one of the soil types. The proportion for *C. crulsi* ( $P_{\text{CLAY}} = 0.607$ , CI 95% = 0.531–0.689, CI 99% = 0.507–0.702) was significantly higher than the expected value in the absence of preference for soil type, indicating a preference for clay by this species.

This result corroborates the hypothesis that *C. crulsi* is able to select areas of clay over sandy soil, which seems to be a proximal cause for their greater abundance on this type of soil. We believe that the choice made by *C. crulsi* is not related to a direct advantage of the soil type, such as a better material for the construction of burrows. A relationship between the distribution of spiders and the soil type has often been found in studies with burrowing spiders (e.g., Hallohan et al. 2000; M'Rabet et al. 2007; Řezáč et al. 2007). However, the two species in this study have never been seen in burrows in the ground in several years of study; apparently, they are using only the leaf litter or tree trunks as shelter (Höfer et al. 1994). Our interpretation is that the type of soil might be a cue for prey occurrence. Whatever the reason, the ability to select the type of soil can be important in this ecosystem where great differences in soil type can be found in nearby places (Chauvel et al. 1987).

The avoidance of sandy soils by *C. crulsi* may also give rise to higher abundance of *C. amphora* in areas with this type of soil. Intraguild predation is probably an important interaction between these species because they prey upon each other, and both species are very abundant on the ground during most months of the year (Gasnier & Höfer 2001). The lack of selection of either of the soils by *C. amphora* observed in this study suggests that its greater abundance in sandy soils is not a result of preference for this soil type as a cue for some important resource used by *C. amphora* in sandy soils. Therefore,

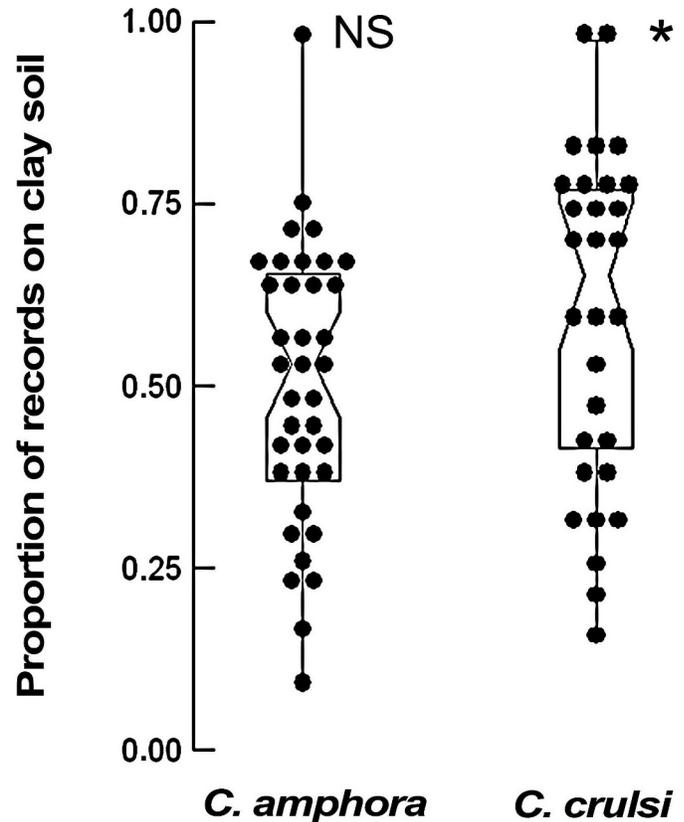


Figure 2.—Proportion of records of the spiders *Ctenus amphora* and *C. crulsi* observed on clay soil among 54 observations at 10-min intervals. The box plot of the data is notched at the median, and widest at the superior and inferior confidence intervals of the median (95%). The overlaying dots represent each spider observed. \* indicates  $P < 0.01$ ; NS indicates non-significance.

considering a spatial scale that includes areas of sandy and clay soils, the preference for clay soils by *C. crulsi* may be an important factor contributing to their coexistence. This is the first study to show experimentally a different response to exposure to two soil types by two spider species, which could help to explain their coexistence.

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#### LITERATURE CITED

- Chauvel, A., Y. Lucas & R. Boulet. 1987. On the genesis of the soil mantle of the region of Manaus, Central Amazonia, Brazil. *Experientia* 43:234–241.
- De Castilho, C.V., W.E. Magnusson, R.N.O. de Araújo, R.C.C. Luizão, F.J. Luizão, A.P. Lima & N. Higuchi. 2006. Variation in above-ground tree live biomass in a central Amazonian Forest: Effects of soil and topography. *Forest Ecology and Management* 234:85–96.
- Efron, B. 1982. *The jackknife, the bootstrap and other resampling plans*. Society for Industrial and Applied Mathematics, Philadelphia, Pennsylvania, USA.

- Gasnier, T.R. & H. Höfer. 2001. Patterns of abundance of four species of wandering spiders (Ctenidae, *Ctenus*) in a forest in Central Amazonia. *Journal of Arachnology* 29:95–103.
- Gasnier, T.R., C.S. Azevedo, M.P. Torres-Sanchez & H. Höfer. 2002. Adult size of eight hunting spider species in Central Amazonia: temporal variations and sexual dimorphism. *Journal of Arachnology* 30:146–154.
- Gasnier, T.R., H. Höfer, M.P. Torres-Sanchez & C.S. Azevedo. 2009. História natural de algumas espécies de aranhas das famílias Ctenidae e Lycosidae na Reserva Ducke: Bases para um modelo integrado de coexistência. Pp. 223–229. *In* A Fauna de Artrópodes da Reserva Florestal Ducke. Estado Atual do Conhecimento Taxonômico e Biológico. (C.R.V. Fonseca, C. Magalhães, J.A. Rafael & E.A. Franklin, eds.). Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, Brazil.
- Halloran, M.M., M.A. Carrel & J.E. Carrel. 2000. Instability of sandy soil on the Lake Wales Ridge affects burrowing by wolf spiders (Araneae: Lycosidae) and antlions (Neuroptera: Myrmeleontidae). *Florida Entomologist* 83:48–55.
- Höfer, H., A.D. Brescovit & T. Gasnier. 1994. The wandering spiders of the genus *Ctenus* (Ctenidae, Araneae) of Reserva Ducke, a rainforest reserve in Central Amazonia. *Andrias* 13:81–98.
- Krebs, C.J. 1985. *Ecology - The Experimental Analysis of Distribution and Abundance*. Harper & Row, New York, USA.
- Luizão, F.J., R.C.C. Luizão & J. Proctor. 2007. Soil acidity and nutrient deficiency in central Amazonian heath forest soils. *Plant Ecology* 192:209–224.
- M'Rabet, S.M., Y. Hénaut, A. Sepúlveda, R. Rojo, S. Calmé & V. Geissen. 2007. Soil preference and burrow structure of an endangered tarantula, *Brachypelma vagans* (Mygalomorphae: Theraphosidae). *Journal of Natural History* 41:1025–1033.
- R Development Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Online at <http://www.R-project.org/>
- Řezáč, M., V. Řezáčová & S. Pekár. 2007. The distribution of purse-web *Atypus* spiders (Araneae: Mygalomorphae) in central Europe is constrained by microclimatic continentality and soil compactness. *Journal of Biogeography* 34:1016–1027.
- Salvestrini, F.M.D. & T.R. Gasnier. 2001. Differences in the activity of juveniles, females and males of two hunting spiders of the genus *Ctenus* (Araneae, Ctenidae): active males or inactive females? *Journal of Arachnology* 29:76–278.

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