1996. The Journal of Arachnology 24:34–38

THE RELATIVE ABUNDANCE OF *BROTHEAS AMAZONICUS* (CHACTIDAE, SCORPIONES) IN DIFFERENT HABITAT TYPES OF A CENTRAL AMAZON RAINFOREST

Hubert Höfer, Evi Wollscheid[1] and **Thierry Gasnier**[2]: Staatliches Museum für Naturkunde, Erbprinzenstr. 13, D-76133 Karlsruhe, Germany

ABSTRACT. During a nine week period, we studied the surface abundance of the scorpion *Brotheas amazonicus*, using 1200 pitfall traps arranged along eight line transects within each of three habitat types in a neotropical rainforest. We collected 193 scorpions of this species. Capture rates in the primary plateau forest and in the primary forest on white sand soil were higher than in disturbed areas. Structural habitat parameters in the vicinity of the trap lines (such as quantity of soil surface litter, number of stemless palms, dead wood and termite mounds on the ground) significantly differed among habitats. Disturbed areas showed lower structural diversity. In a regression analysis the measured habitat parameters proved to affect the abundance of *B. amazonicus*. We conclude that high structural diversity, ultimately reflecting the availability of hiding places, is important for this scorpion species. This is probably influenced by the predation pressure exerted by the highly diverse predator community in central Amazon terra firme forests.

In 1993 we spent three months in the Amazon studying spider ecology in a rainforest reserve near Manaus. We planned to do a study of the abundance of rainforest scorpions because these are frequently observed in all strata and microhabitats where spiders are studied and potentially interfere with spiders by competition and/or intraguild predation (Polis 1990). By preliminary sampling with pitfall traps and ground-photoeclectors, eight species of scorpions were collected in the study area. *Tityus metuendus* Pocock, *T. raquelae* Lourenço and *T. silvestris* Pocock are considered to live in the lower vegetation and trunk region, and *Ananteris dekeyseri* Lourenço, *A. pydanieli* Lourenço and *Chactopsis amazonicus* Lourenço & Francke apparently inhabit the litter (Lourenço 1988). An undescribed species of *Brotheas* cannot yet be classified ecologically because of its scarcity. The largest species, *Brotheas amazonicus* Lourenço, was commonly found under dead wood on the ground, in burrows on the ground, in termite mounds and embankments, and in litter accumulations in the base of stemless palms. *Brotheas amazonicus* was the only species collected in sufficient numbers by pitfall traps to allow correlations with habitat characteristics.

[1]Current address: Morgenbreede 15, D-33615 Bielefeld, Germany

[2]Current address: Instituto Nacional de Pesquisas da Amazônia (INPA), C. P. 478, CEP 69011-970 Manaus, AM, Brazil

METHODS

Site description.—The study was carried out from August to October 1993 in the "Reserva Florestal Adolfo Ducke" (RD), a reserve of the "Instituto Nacional de Pesquisas da Amazônia" (INPA), 26 km northeast of Manaus (03°08'S 60°02'W). The reserve is 10 km² and is covered by non-inundated terra firme rainforest. In the Reserva Ducke, two main forest habitat types occur (Guillaumet 1987). The main habitat, herein called plateau forest, is a primary rainforest with trees to 45 m in height on a typical terra firme clayey latosol. These forests are relatively poor in epiphytes, and lower vegetation is dominated by stemless palms of the genera *Astrocaryum* and *Attalea* (Prance 1990). A dense but lower "campinarana" forest occurs on white sand soils (tropical podsol), characterized by the trees *Rhabdodendron macrophyllum* (Rhabdodendraceae), *Pagamea macrophylla* (Rubiaceae) and *Humiria balsamifera* (Humiriaceae). Epiphytes (Bromeliaceae) are more abundant. For comparison, we choose several disturbed sites near the station buildings at the border of the

Table 1.—Capture rates of *Brotheas amazonicus* and measured habitat parameters per transect line in three different habitat types (if not otherwise stated numbers are individual counts).

Transect lines	1	2	3	4	5	6	7	8	Total	Mean	s
Plateau											
Specimens	7	8	7	9	12	16	22	17	98	12.25	5.55
Litter [cm]	14.8	8.3	10.0	14.3	12.7	15.0	18.5	19.8	113.4	14.18	3.88
Termitarias	2	3	4	1	4	4	5	2	25	3.1	1.36
Trunks	15	12	20	14	16	16	23	13	129	16.1	3.68
Palms	6	3	1	16	0	30	32	37	125	15.6	15.31
Campinarana											
Specimens	12	8	5	13	15	6	3	9	71	8.9	4.19
Litter [cm]	21.2	22.3	22.3	21.2	27.3	16.5	17.7	18.5	167.0	20.9	3.40
Termitarias	0	0	1	1	0	0	2	2	6	0.75	0.89
Trunks	19	14	17	13	13	11	7	7	101	12.6	4.27
Palms	4	0	3	20	1	0	1	0	29	3.6	6.78
Disturbed areas											
Specimens	2	2	1	4	7	5	1	2	24	3.0	2.14
Litter [cm]	0	7.7	0	11.5	12.2	6.7	0	15.5	53.6	6.7	6.17
Termitarias	0	0	0	0	1	0	0	2	3	0.4	0.74
Trunks	10	1	4	12	34	1	0	0	62	7.8	11.58
Palms	0	0	1	6	3	2	1	13	26	3.3	4.40

reserve. These do not represent a distinct habitat, but can be characterized by secondary vegetation, more exposed soil surfaces and more sandy soils.

Mean annual rainfall in the Manaus region is 2542 mm, and July–September are the driest months with generally less than 100 mm per month (Ribeiro & Adis 1984).

Sampling procedures.—Collections were made by pitfall traps, consisting of commercially available plastic cups (11.6 cm deep, opening diameter 10 cm), buried flush with the soil surface. Between 4–25 August traps were filled with picric acid. Later (until 2 October) traps were left without preservatives to avoid killing non-target animals. Small holes were made in the bottom of the cups to prevent them from being filled with rainwater. Traps were then inspected daily, and scorpions were collected alive but later transferred to 70% ethanol. Previous observations indicated that scorpions were unable to escape from the cups, except when branches or leaves had filled them.

Capture rates of pitfall traps are clearly activity-based and therefore do not represent pure density data. However, in this study where capture rates for only one species from nearby sites over a short period are compared, we do not expect major variations or changes in activity and therefore consider the capture rates to be good indicators of relative scorpion abundance.

Pitfall traps were deployed in straight lines of 50 m, each line containing 50 cups at intervals of 1 m. Eight line transects were distributed in each of the two habitat types described above and in disturbed areas (total of 24 transects), thus every habitat type was supplied with 400 traps. Line transects were usually separated by more than 100 m, but some of them were less than 50 m apart.

During the study scorpions were regularly observed in the field, collected alive, and held in captivity to observe behavior.

Habitat parameters.—Within an area 10 m × 50 m along each of the transect lines, structural habitat characteristics were recorded. These included the number of termite mounds of *Cornitermes* sp.(> 10 × 10 cm = termitarias), the number of dead wood fragments on the ground (diameter > 10 cm and length > 50 cm = trunks) and the number of stemless palms (higher than 1 m). To measure litter quantitatively, six samples of 1 m^2 were collected in each of the 24 transect areas and the volume estimated by pressing the litter samples in a bucket of known size and measuring the height of the column.

Statistical tests were made using the program STUDENT SYSTAT (Berk 1994).

Table 2.—Comparison of habitat types by measured habitat characteristics (Kruskal-Wallis test statistic = H; *df* = degrees of freedom; + = significant at 5%, ++ = significant at 1%, +++ = significant at 0.1%; reject/accept = reject or accept the hypothesis of equal population means).

Comparison of habitat types by	H	*df*	Probability *P*	Significance	Conclusion
Litter	15.9	2	0.000	+++	Reject
Palms	4.27	2	0.118	–	Accept
Termitarias	13.6	2	0.001	++	Reject
Trunks	8.2	2	0.016	+	Reject

RESULTS

Capture rates.—From the 1200 pitfall traps 211 scorpions were collected. *Brotheas amazonicus* was by far the most abundant species with 193 specimens collected. There were 98 specimens collected in the plateau area, 71 in the campinarana and 24 in disturbed areas (Table 1). The sex ratio (males : females) in traps was 2.9 : 1. Other species collected were *Chactopsis amazonicus* (8 specimens), *Tityus metuendus* (7), *T. silvestris* (2) and *Ananteris sp.* (1). During the first three weeks, 78 specimens of *B. amazonicus* were sampled in pitfall traps with picric acid; during the following 5.5 weeks, 115 scorpions were sampled in traps without preservative liquid.

Differences in number of *Brotheas* scorpions between habitats were significant (Kruskall Wallis test statistic = 13.3 > chi-square 0.5, *df* 2, *P* = 0.001). The nonparametric multiple comparison (Tukey-type, see Zar 1984) ranked the number of scorpions per habitat as follows: disturbed area < campinarana = plateau.

Habitat characteristics.—All habitat characteristics, (i. e., the number of palm bases, dead trunks, termitarias and litter quantity) varied considerably within the habitats (Table 1) but are also significantly different among habitats (except palms; Table 2). From differences in rank sums of the nonparametric Kruskal-Wallis test, we see that the plateau differs from the other two habitats in all measured characteristics. The transects in disturbed areas showed higher variabilities in nearly all measured parameters and differed significantly only in litter quantity and number of dead trunks from the campinarana. In regression analyses all measured habitat characteristics (variables) proved to affect the abundance of *B. amazonicus* (Table 3). However, some of these variables were highly influenced by the habitat (e. g., termitarias and trunks). When habitat was included in the model for each factor, the proportion of variance explained by each factor was lower in the case of litter and palms, but higher in the case of termitarias and trunks. Thus including litter and palms as covariates improved the analysis of variance (Table 3).

Natural history of *Brotheas amazonicus*.—The scorpion species appears strictly nocturnal. Only one specimen was observed during the day – on a wall of the station only a few centimeters from his burrow. Many scorpions were observed, often close to burrows of theraphosid spiders (*Ephebopus uatuman*), in burrows on the embankment of an unpaved road entering the reserve. Burrows typically have oval, nearly elliptical openings and reach 20 cm depth. At night (observed from 2000–0200 h) the scorpions sit in wait for prey directly in the burrow openings, with only the pedipalps reaching forward most of the time. One specimen was observed taking possession of the burrow of a *Tityus metuendus*. Overall 33% of all captured females were gravid (embryos visible): 6 of 20

Table 3.—Regression analysis of number of scorpions (*Brotheas amazonicus*) by habitat characteristics with and without habitat included (+ = significant at 5%, ++ = significant at 1%, +++ = significant at 0.1%).

Variable	*P*	Significant	Variable + covariate	*P*	Significant
Litter	0.002	++	Habitat + litter	0.006	++
Palms	0.000	+++	Habitat + palms	0.001	++
Termitarias	0.006	++	Habitat + termitarias	0.447	–
Trunks	0.007	++	Habitat + trunks	0.101	–
Habitat	0.032	+			

females in the campinarana, 7 of 22 in the plateau forest and 3 of 7 in the disturbed areas. One gravid female was observed waiting for prey during three consecutive nights, then disappeared for three nights and reappeared carrying newborn scorpions. In the following 14 days this female appeared on an average of every second night at the entrance of the burrow, resting in a position where the pedipalps nearly closed the opening and responding to the slightest disturbance by retreating. In contrast to *Tityus* scorpions, *B. amazonicus* was never observed above the forest ground and appeared in arboreal funnel traps (3 m high on trunks) only when army ants (*Eciton burchelli*) had hunted on the ground below the trunks.

DISCUSSION

With eight scorpion species living sympatrically in the study area, Reserva Ducke is among the sites with the most diverse scorpion communities and the site of the greatest diversity outside of desert areas (Polis 1990). The apparent dominance of one species, *Brotheas amazonicus,* is probably biased by the capture method because we know that at least some of the other species live in higher strata. Between 7–22 *B. amazonicus* scorpions were sampled per line transect in the plateau forest (Table 1). The sex ratio in the traps, compared with actual sex ratios in Polis (1990) is certainly reflecting the fact that males are more vagrant (probably looking for females; see Polis 1990 and Polis & Sissom 1990). We considered the low level of surface activity of most scorpions (Polis 1990), our own observations for this species, and the greater activity ranges for males (3 m from burrow, 1 m for females) during the reproduction period to calculate very rough abundances of *B. amazonicus* in the plateau forest: 9.5/300 m^2 (males) and 2.75/100 m^2 (females), leading to an overall density estimate of 0.06/m^2. During our spider study we used five ground-photeclectors, each covering one m^2 of plant-free, litter-covered soil surface, and moved them every four weeks during the 12 months to another place within an area of approximately 10 ha. Thus from 60 m^2 covered by these traps, nine *B. amazonicus* were collected. The resulting density estimate of 0.15/m^2 is certainly still an underestimate because the scorpions apparently prefer to hide in habitat structures, which were not covered by traps. The only abundance value for a neotropical forest scorpion species available for comparison is 0.40/m^2 for *Centruroides margaritatus* (Gervais) in Costa Rica (unpubl. data in Polis 1990).

Despite significant differences in habitat characteristics between campinarana and plateau forest, differences in capture rates of the scorpion species were not significant. Sampling actual abundance might show differences better than activity-based pitfall trapping. Capture rates at the disturbed sites were significantly lower than in forest sites. Although some habitat characteristics of these sites were different from the forest sites, they do not represent a distinct habitat type, which explains the high variability of the measured parameters.

All studied habitat characteristics showed significant correlations with the abundance of the scorpion species under study. Hiding places such as soil surface litter, litter accumulations in palm bases, dead trunks and termitarias seem very important resources for scorpions. We presume predation to be mainly responsible for this. Juveniles of *B. amazonicus* (and of other scorpion species) were several times observed as prey of the army ant *Eciton burchelli*. Adults were found in arboreal funnel traps apparently driven away from the ground by hunting swarms of army ants. In a study of the prey spectrum of two swarm raiding army ant species (*E. burchelli* and *Labidus praedator*) in the Manaus region, scorpions made up about 3% of all prey fragments (Vieira & Höfer 1994). Fragments of scorpions were found in stomach contents of several frogs and lizards (*Leptodactylus pentadactylus* - Galatti 1992; *Uranoscodon superciliosa* - Gasnier et al. 1994) living in our study area. The predator community of Reserva Ducke is highly diverse: three species of arthropod hunting army ants (Vieira & Höfer 1994), 14 species of large cursorial spiders (Höfer et al. 1994), more than 40 species of frogs (Zimmermann & Rodrigues 1990), about 20 species of lizards (Zimmermann & Rodrigues 1990), more than 80 understory insectivorous bird species (Bierregard 1990) and more than 60 non-flying mammals (Malcolm 1990) live in central Amazonian terra firme forests. Most of these predators are generalized insectivores and are potential predators of scorpions.

In general view of the measured habitat parameters, the plateau forest seems to contain more structural diversity than the campinarana sites and certainly more than the disturbed sites. Other habitat characteristics (e. g., climatic factors,

soil humidity, soil hardness, and sandy condition of the soils) might also be important, but their importance remained undetected under "habitat" in the regression analyses.

ACKNOWLEDGMENTS

This ecological study is funded by the German Science Foundation (project Prof. Dr. L. Beck). We are grateful to the National Institute for Amazon Research - INPA in Manaus for the research permit and for providing infrastructure. We thank Ingo Curdt for his participation in field work and Nelson Fé for help in identification of scorpions. Manfred Verhaagh kindly commented on an earlier version of the manuscript. Dr. David Sissom and Dr. Gary Polis reviewed and greatly improved the manuscript.

LITERATURE CITED

Berk, K. N. 1994. Data analysis with Student SYSTAT. Course Technology, Cambridge.

Bierregard, R. O., Jr. 1990. Species composition and trophic organization of the understory bird community in a central Amazonian terra firme forest. Pp. 217–236, *In* Four Neotropical Rainforests (A. H. Gentry, ed.). Yale Univ. Press, New Haven and London.

Bradley, R. A. 1986. The relationship between population density of *Paruroctonus utahensis* (Scorpionida: Vaejovidae) and characteristics of its habitat. J. Arid Environ., 11:165–172.

Galatti, U. 1992. Population biology of the frog *Leptodactylus pentadactylus* in a central Amazonian rainforest. J. Herpetol., 26:23–31.

Gasnier, T. R., W. E. Magnusson & A. P. Lima. 1994. Foraging activity and diet of four sympatric lizard species in a tropical rainforest. J. Herpetol., 28:187–192.

Guillaumet, J.-L. 1987. Some structural and floristic aspects of the forest. Experientia, 43:241–251.

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.

Lourenço, W. R. 1988. Synopsis of the scorpion fauna of the Manaus region, Amazonas state, Brazil, with the description of two new species. Amazoniana, 3:327–337.

Malcolm, J. R. 1990. Estimation of mammalian densities in continuous forest north of Manaus. Pp. 339–357, *In* Four Neotropical rainforests. (A. H. Gentry ed.). Yale Univ. Press, New Haven and London.

Polis, G. A. 1990. Ecology. Pp. 247–293, *In* The Biology of Scorpions. (G. A. Polis, ed.). Stanford Univ. Press, Stanford, California.

Polis, G. A. & W. D. Sissom. 1990. Life history. Pp. 161–223, *In* The Biology of Scorpions. (G. A. Polis, ed.). Stanford Univ. Press, Stanford, California.

Prance, G. T. 1990. The floristic composition of the forests of central Amazonian Brazil. Pp. 112–140, *In* Four Neotropical rainforests. (A. H. Gentry, ed.). Yale Univ. Press, New Haven and London.

Ribeiro, M. N. G. & J. Adis. 1984. Local rainfall variability – a potential bias for ecological studies in the central Amazon. Acta Amazonica, 14:159–174.

Vieira, R. S. & H. Höfer. 1994. Prey spectrum of two army ant species in central Amazonia, with special attention on their effect on spider populations. Andrias, 13:189–198.

Zar, J. H. 1984. Biostatistical Analysis. 2nd ed. Prentice-Hall Intern. Ed., London.

Zimmermann, B. L. & M. T. Rodrigues. 1990. Frogs, snakes, and lizards of the INPA-WWF reserves near Manaus, Brazil. Pp. 426–454, *In* Four Neotropical rainforests. (A. H. Gentry, ed.). Yale Univ. Press, New Haven and London.

Manuscript received 21 March 1995, revised 1 October 1995.