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ON THE ABUNDANCE AND PHENOLOGY OF PALPIGRADI (ARACHNIDA) FROM CENTRAL AMAZONIAN UPLAND FORESTS

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ABSTRACT. The 745 palpigrads (micro-whip scorpions) collected in a 12 month period in the soil (0–7 cm depth) of a secondary upland forest (120.1 ± 50.8 ind./m²/month) and of a primary upland forest (29.4 ± 20.2 ind./m²/month) near Manaus all belong to the species *Eukoenenia janetscheki* Condé 1993. About 75% of all specimens inhabited the mineral subsoil (3.5–7 cm depth) where monthly catches were negatively correlated with temperature and moisture content of the soil. Females were almost twice as abundant as males. The lack of a distinct reproductive period and the presence of juveniles and adults (both sexes) throughout the year indicate a plurivoltine mode of life. No specimens were caught on or above the soil surface. Abundances of *E. janetscheki* are compared with those of the Schizomida (tartarids) and Thelyphonida (vinegaroons) from the same study sites. *E. janetscheki* also represented the palpigrads obtained from the soil of three other upland forest types in Central Amazonia (0–14 cm depth) and accounted for 0.1–0.3% of the total arthropod fauna.

Terrestrial arthropods of Central Amazonian forests have been investigated for several years (Adis & Schubart 1984; Adis 1997; Adis et al. 1997b,c) cooperatively between the National Institute for Amazonian Research (INPA) at Manaus/Brazil and the Tropical Ecology Working Group at the Max-Planck-Institute for Limnology in Plön/Germany (Projeto INPA/Max-Planck). Data on abundance and phenology of Palpigradi sampled during a 12 month period in 1982/83 in both a primary and a secondary upland forest are now available, as their time-consuming taxonomical evaluation has been completed (Condé 1993, 1997). Our data represent the very first contribution on the phenology of a tropical palpigrad species: *E. janetscheki* Condé 1993. Voucher specimens have been deposited at the Systematic Entomology Collections of the Instituto Nacional de Pesquisas da Amazônia (INPA) in Manaus, Brazil, at the Muséum d'histoire naturelle in Genève, Switzerland and at The Field Museum, Chicago, USA.

Results presented are compared with abundance data of *E. janetscheki* from three other upland forest types near Manaus, and which were sampled between 1985 and 1991.

STUDY AREA AND METHODS

Palpigrads were collected between 1981 and 1983 in the course of ecological studies on Central Amazonian arthropods from two previously investigated and fully described forest types, all within 30 km of Manaus: (1) primary upland forest at Reserva Florestal A. Ducke (= Reserva Ducke; 2°55'S, 59°59'W) on the Manaus-Itacoatiara highway (AM-010 at km 26; *cf.* Penny & Arias 1982), (2) secondary upland forest at Rio Tarumã Mirím (3°2'S, 60°17'W), a tributary of the Rio Negro, where the vegetation was previously cut but unburned (Adis 1992). Both forests are subject to a rainy season (December-May: average precipitation 1550 mm) and a "dry" season (June-November: average precipitation 550 mm, but each month has some rain events; *cf.* Ribeiro & Adis 1984). The yellow

latosoil of the primary and secondary upland forests supported a 2–3 cm thick humus layer, interspersed with fine roots, and a thin surface covering of leaf-litter. One ground photo-eclector (emergence trap) and one arboreal photo-eclector for trunk ascents (funnel trap) were installed in both forests from December 1981 to December 1982 (Adis & Schubart 1984). Distribution of palpigrads in the soil was studied between September 1982 and August 1983 (Morais 1985; Rodrigues 1986). Twelve soil samples were taken once a month from each forest type at random along a transect with a split corer (= steel cylinder with lateral hinges; diameter 21 cm, length 33 cm) which was driven into the soil by a mallet. The combined area of 12 samples represented 0.42 m^2. Each sample of 7 cm depth was then divided into two subsamples of 3.5 cm each. Animals were extracted from subsamples following a modified method of Kempson (Adis 1987). The monthly collection data of palpigrads from the two soil layers in relation to changing conditions of precipitation, temperature and humidity of the air near the forest floor as well as moisture content, temperature and pH of the soil were statistically evaluated with a linear correlation test (Cavalli-Sforza 1972) using the original field data (*cf.* Morais 1985; Rodrigues 1986) of the previous month. In addition, the presence of palpigrads in tree crowns of the primary upland forest was tested by fogging canopies with pyrethrum (with and without synergist) during the dry and rainy seasons (July 1977, August 1991, February & August 1992, July 1994; Adis et al. 1984, 1997a). Palpigradi sampled were classified as juveniles, subadults and adults (males and females) according to Condé (1984a,b, 1993, 1997).

RESULTS

Palpigradi obtained from different upland forest types in the vicinity of Manaus were represented by only one species: *Eukoenenia janetscheki* Condé 1993. The body length of adult males (without flagellum) reached 1 mm.

A total of 146 specimens was collected in the primary upland forest at Reserva Ducke and 599 specimens in the secondary upland forest at Rio Tarumã Mirím. Out of these, 92% could be identified to their developmental stages. *E. janetscheki* was only found in the soil and never caught on tree trunks or in the canopy. No specimens were captured in ground photo-eclectors. In the primary upland forest, palpigrads represented 0.2% and in the secondary upland forest 0.6% of the total arthropods extracted from soil samples within 12 months (Acari and Collembola omitted; *cf.* Morais 1985; Rodrigues 1986). Their abundance in 0–7 cm soil depth was comparable to that of the Schizomida (Fig. 1). Most specimens of *E. janetscheki* inhabited the mineral subsoil (Fig. 2: 3.5–7 cm) and a few (22–26%) the organic layer (0–3.5 cm depth). An average of 120.1 ± 50.8 ind./m^2/month was recorded in the secondary upland forest and 29.4 ± 20.2 ind./m^2/month in the primary upland forest (0–7 cm depth). More than 50% of the total catch in both forests was represented by adults (Fig. 2). Sex ratio (adult males to females) in the secondary forest was 1:1.8 (81% of the total adults could be sexed).

In the secondary upland forest, the monthly abundance of *E. janetscheki* in the mineral subsoil (3.5–7 cm depth) was negatively correlated with soil temperature, i.e., catch numbers (in particular of subadults) decreased with increasing temperatures (total catch: $r = -0.7454$, $P < 0.01$; adults: $r = -0.5926$, $P < 0.05$; subadults: $r = -0.8614$, $P < 0.001$; $n = 12$, respectively). In the primary upland forest our data indicated a negative correlation of adults with the soil moisture content in the mineral subsoil ($r = -0.5670$, $P < 0.1$, $n = 12$). The total catches of specimens obtained during the dry season and the rainy season were similar: 66% versus 34% in the primary upland forest and 61% versus 39% in the secondary upland forest, respectively. However, there was no distinct reproductive period in the secondary forest (where *E. janetscheki* was more abundant) because juveniles as well as adults (both sexes) occurred throughout the year (Fig.3). These results indicate a plurivoltine mode of life.

DISCUSSION

Comparable data on the abundance and vertical distribution of the soil fauna in three different upland forest types of Central Amazonia were given by Adis and collaborators (Adis et al. 1987a,b; 1989a,b; Ribeiro 1994). Arthropods were collected to a soil depth of 14 cm during rainy and dry seasons and extracted with the Kempson method as de-

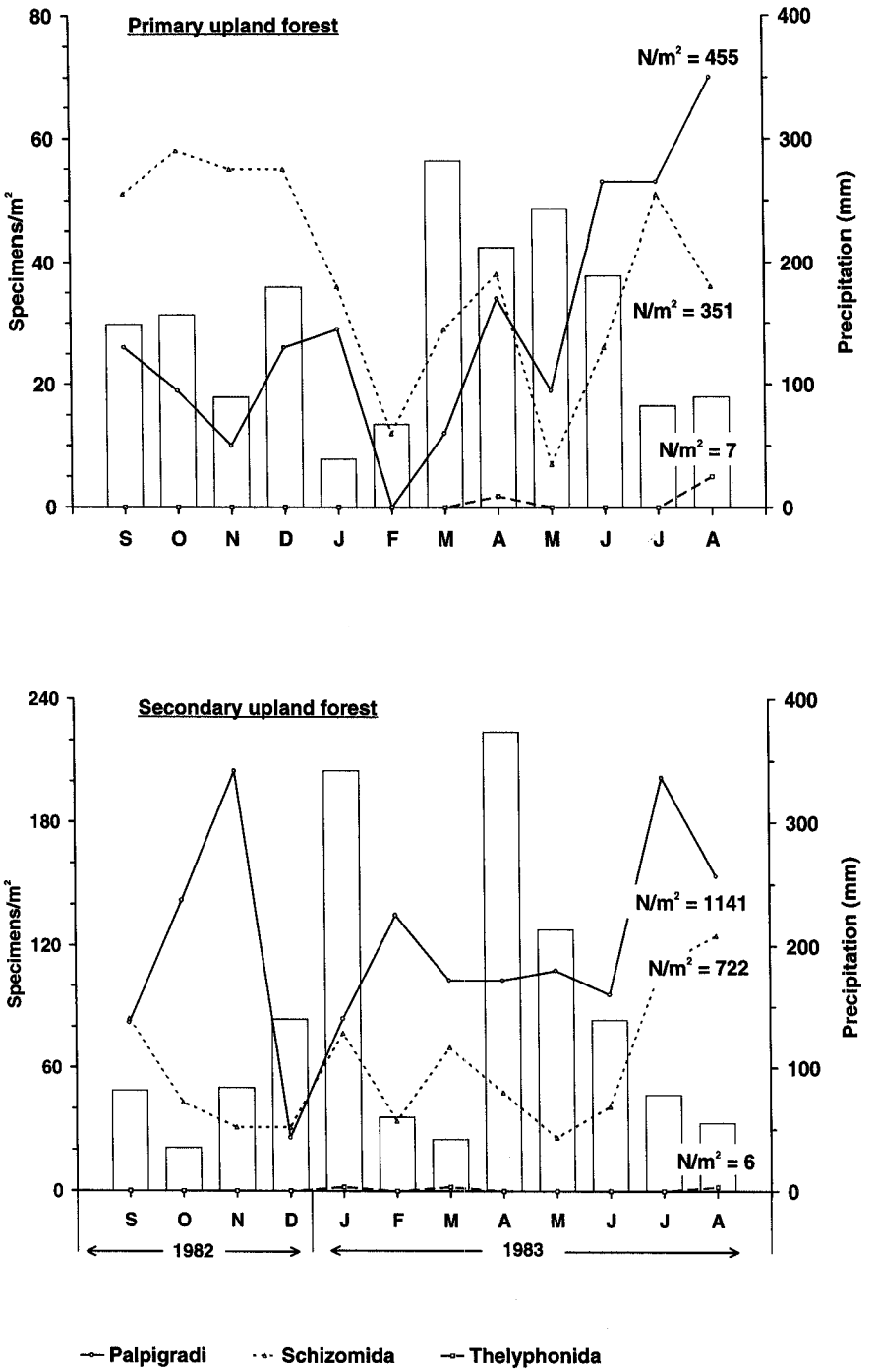

Figure 1.—Distribution of Palpigradi, Schizomida and Thelyphonida in the soil. Samples taken monthly at 0–7 cm depth between September 1982 and August 1983 in two upland forests near Manaus. (Total catch = 100% in each forest type; n = total number of specimens). Total precipitation per month given between sampling dates (= at the end of each month in the primary upland forest and in the middle of each month in the secondary upland forest). The low rainfall observed in early 1983 was due to a strong El Niño event (see Adis & Latif 1996).

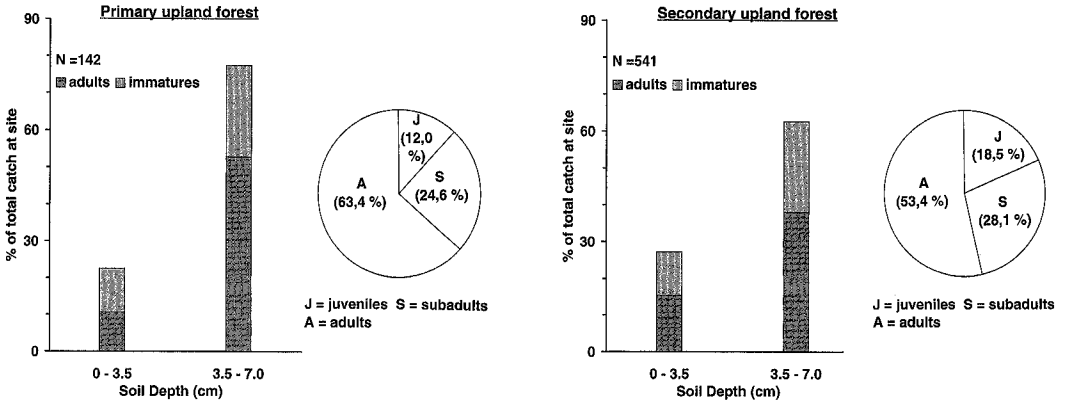

Figure 2.—Distribution of *Eukeonenia janetscheki* in the soil according to soil depth, and percentage of all developmental stages in two upland forests near Manaus. (Total catch = 100% in each forest type). Samples taken monthly at 0–3.5 and 3.5–7 cm depths between September 1982 and August 1983. *n* = total number of specimens.

scribed above. Between 75% and 92% of all arthropods were found to inhabit the top 7 cm when Acari and Collembola were included in the total catch numbers and 69%–84% when they were omitted. Data on Palpigradi (= *E. janetscheki*; see Condé 1997) are now available.

One study was conducted in 1985/86 in a secondary upland forest on yellow latosoil at the INPA campus in Manaus, where the vegetation was previously cut but unburned (Adis et al. 1987a,b). Palpigrads represented 0.2–0.3% of the total arthropods when Acari and Collembola are included (dry season: 50.448 ind./m^2, rainy season: 63.850 ind./m^2) and 0.9% when they are omitted from the total catch numbers (dry season: 11.934 ind./m^2, rainy season: 17.886 ind./m^2). In the mineral subsoil (7–14 cm depth), the abundance of palpigrads was higher during the dry season (62% of the total catch; 62.6 ind./m^2) but lower during the rainy season (44% of the total catch; 72.2 ind./m^2) when compared to the top 7 cm.

Another study was made in 1990/91 in a secondary upland forest on yellow latosoil, about 50 km north of Manaus, where the vegetation was previously cut and burned (Ribeiro 1994). Palpigrads represented 0.1–0.2% of the total arthropods when Acari and Collembola are included (dry season: 33.915 ind./m^2, rainy season: 19.696 ind./m^2) and 0.4–0.6% when they are omitted from the total catch numbers (dry season: 7.180 ind./m^2, rainy season: 7.777 ind./m^2). In the mineral subsoil (7–14 cm depth), the abundance of palpigrads was lower during the dry season (33% of the total catch; 9.6 ind./m^2) but higher during the rainy season (78% of the total catch; 33.7 ind./m^2) when compared to the top 7 cm.

A third study was conducted in 1988 in a primary forest on white sand soil, about 45 km north of Manaus (Adis et al. 1989a,b). Palpigrads represented 0.1–0.2% of the total arthropods when Acari and Collembola are included (dry season: 57.703 ind./m^2, rainy season: 74.255 ind./m^2) and 0.5–0.9% when they are omitted from the total catch numbers (dry season: 14.119 ind./m^2, rainy season: 15.023 ind./m^2). The abundance of palpigrads in the mineral subsoil (7–14 cm depth) was higher during the dry season (86% of the total catch; 57.8 ind./m^2) and during the rainy season (89% of the total catch; 120.3 ind./m^2) when compared to the top 7 cm.

To which depth *E. janetscheki* occurs in the soil of the Central Amazonian upland forests is unknown. First studies below 14 cm soil depth in a primary forest on yellow latosoil and on white sand soil 45 km north of Manaus showed that soil layers in 20–30 cm depth were dominated by social insects, in particular Isoptera. Palpigradi were not found below 10 cm soil depth, probably due to handsorting of the soil samples (Harada & Bandeira 1994a,b). In Costa Rica, palpigrads were found during the rainy season in 15–20 cm soil depth with abundances of 350 ind./m^2 in a forest and 75 ind./m^2 in a coffee plantation. They represented 1.4% (800 ind./m^2) and

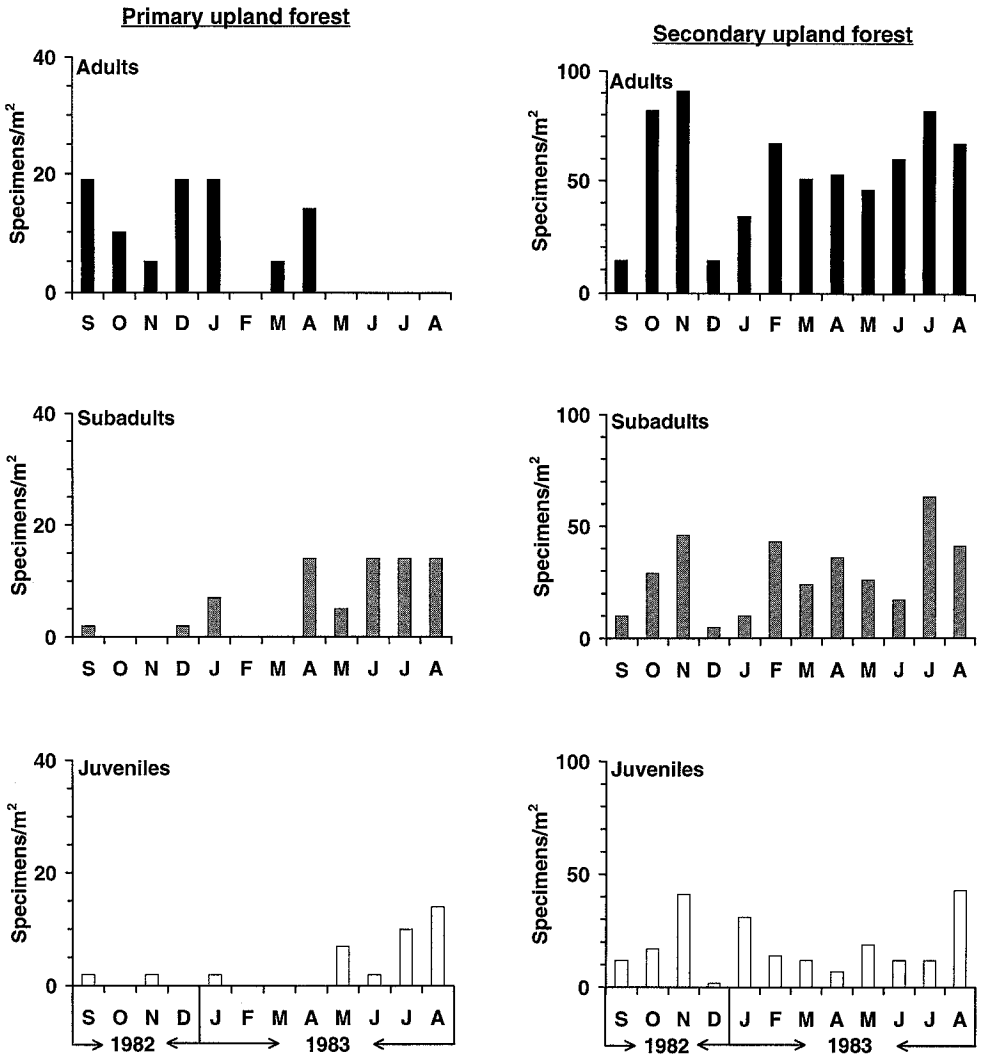

Figure 3.—Temporal occurrence of developmental stages of *Eukoenenia janetscheki* in the soil (N/m² in 0–7 cm depth) in two upland forests types near Manaus. Monthly samples taken between September 1982 and August 1983.

0.3% (188 ind./m²) of the total arthropods collected to a depth of 20 cm, respectively (Serafino & Merino 1978). In Israel, *Eukoenenia mirabilis* (Grassi & Calandruccio 1885) was sampled to a soil depth of 15 cm in pine and oak forests. The 71 ind./m² represented 0.07% of the total microarthropods obtained (Broza et al. 1993). In Californian pine forests palpigrads were detected to a depth of 1.18 m (Price 1975).

The absence of *E. janetscheki* in samples from ground photo-eclectors in Central Amazonia also indicates that the species is not active on the soil surface. This conclusion is supported by another study in the primary upland forest at Reserva Ducke, in which no specimens were collected in 20 baited pitfall traps and in three or more ground photo-eclectors during a sample period of 12 month (Penny & Arias 1982).

Palpigrads are considered to be hygrophilous, photophobic, euedaphic inhabitants of soils or troglobites (Condé 1986, 1996; Janetschek 1957; Mahnert & Janetschek 1970; Gruner 1993). *E. janetscheki* was not found in the soil of man-made pastures (0–14 cm depth) adjacent to upland forests in Central Amazonia. One reason might be the low hu-

midity and high temperature of the soil around noon, particularly during the dry season (Adis & Franklin, unpubl. data). The abundance of *E. janetscheki* in the mineral subsoil of the primary upland forest at Reserva Ducke and of the secondary upland forest at Rio Tarumã Mirím was influenced by both abiotic factors. Serafino & Merino (1978) found no palpigrads in the soil of a pasture in Costa Rica as well.

E. janetscheki was also not found in Central Amazonian inundation forests (Adis & Schubart 1984, Adis & Ribeiro 1989). The presence of non-winged terricolous arthropods in this biotope requires flood resistance, horizontal migration according to the high-water line or vertical migration onto the trunk or into the canopy in response to annual flooding of 5–7 months duration. Reproduction cycle and duration of life stages have to be synchronized with the periodic fluctuations in water-level (Adis 1997; Adis et al. 1988, 1997b). At present, our field data indicate that *E. janetscheki* does not meet two of these premises: the species was not collected on or above the soil surface and it had no distinct reproductive period.

A predominance of females over males was reported for the European palpigrad species *Eukoenenia mirabilis* (Gruner 1993; Condé 1996). In *E. janetscheki* almost twice as many females as males were captured in the primary upland forest at Reserva Ducke. The number of females in three species of Symphyla from the same forest and from the secondary upland forest at Rio Tarumã Mirím was even 2–4 times higher than of males (Adis et al. 1997b). Predominance of females assures the continuation of a species, and it probably increases the chance to locate spermatophores deposited by males in the soil.

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