On abundance, phenology and natural history of Geophilomorpha from a mixedwater inundation forest in Central Amazonia (Chilopoda)

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Five terricolous species of Geophilomorpha were collected in a mixedwater inundation forest near Manaus/AM, Brazil: *Ribautia (Schizoribautia) difficilis* Pereira et al., 1995, *Ribautia (S.) centralis* (Silvestri, 1907) (Geophilidae), *Schendylurus continuus* Pereira et al., 1995, *S. janauarius* Pereira et al., 1995 and *Pectiniunguis ascendens* Pereira et al., 1994 (Schendylidae). Reproduction occurred in the soil. *R. (S.) difficilis* and *P. ascendens* inhabit the first 7.0 cm, whereas *R. (S.) centralis*, *S. continuus* and *S. janauarius* live to a soil depth of 10.5 cm. *P. ascendens* and *S. janauarius* were most abundant, representing 39.1 % and 28.3 % of all catches, respectively (n = 22.1 ± 21.7 ind./m²/month on average). A survival strategy observed as a reaction to the flood period was that all these terricolous species pass the aquatic phase of several months' duration on trees by means of vertical migrations. Our data reconfirm that the mixedwater inundation forest represents an ecotone: *S. continuus* is also found in non-flooded primary upland forests near Manaus, whereas *P. ascendens* and *R. (S.) centralis* occur in a blackwater inundation forest in the lower basin of the Negro River as well.

Keywords: phenology, adaptation, inundation, centipede, Chilopoda, Geophilomorpha, Amazon, Neotropics

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Introduction

Forests in the Central Amazon region are divided into non-flooded upland forests and inundation forests (Braga 1979). The period of flooding (= aquatic phase) in seasonal inundation forests (Prance 1979) varies from 5 to 7 months a year and is caused by a monomodal flood pulse (Junk et al. 1989). Terrestrial invertebrates that inhabit these forests stay in the area and make use of various survival strategies or, when possible, migrate to adjacent upland (= terra firme) forests before the beginning aquatic phase (Adis 1997). In this study we present the reaction of Geophilomorpha to flooding as well as the abundance and phenology of the species found in a seasonal mixedwater inundation forest near the city of Manaus in the northern region of Brazil.

Study area, material and methods

The experimental area was at Lago Janauarí (03°20'S, 60°17'W), located on a strip of land between the Negro and Solimões Rivers, about 10 km from Manaus. The region was influenced by blackwater of the Negro River during low water-level and by whitewater of the Solimões River during the high water period. Terrestrial arthropods were collected from July 1987 to June 1988. The study area was inundated until the end of July 1987 and from June 1988 onwards (terrestrial phase: August 1987–May 1988). The Geophilomorpha were monitored in the soil and at the soil surface (terrestrial phase) as well as on the lower part of tree trunks (terrestrial and aquatic phases):

During the terrestrial phase, six soil samples were taken monthly, along a transect. The combined area represented 0.21 m^2. Each sample, 14 cm in depth, was subdivided into four subsamples of 3.5 cm each. Geophilomorpha were extracted from subsamples following a modified method of Kempson (Adis 1987). Four ground photo-eclectors (= emergence traps) were placed on the forest floor to collect Geophilomorpha from the soil surface. The vertical migration of Geophilomorpha on tree trunks was detected by weekly samples with arboreal photo-eclectors (= trunk traps) directed upwards and downwards on one tree trunk each. Further information on sampling techniques and the study site are given in Adis (1981) and Adis et al. (1996).

In addition, the presence of Geophilomorpha was checked in soil samples which were taken under water at the end of the aquatic phase (late August 1988) as described above and subsequently extracted by means of a flotation method via sugar water (for methodology see Adis et al. 1989). The presence of Geophilomorpha in tree crowns was tested by fogging canopies with natural pyrethrum during the aquatic phase (early August 1979; cf. Erwin 1983).

Collection data were statistically evaluated by means of linear correlation (Cavalli-Sforza 1972) with local abiotic factors (temperature, pH and humidity of the soil, as well as temperature and relative humidity of the air and precipitation).

Seasonal inundation forests in Central Amazonia 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 taxonomic work for this paper was done by L.A. Pereira, A. Minelli and F. Barbieri (cf. Pereira et al. 1994, 1995), the collection and evaluation of field data by J. Adis, J.W. de Morais and E. Berti-Filho. Geophilomorpha sampled were classified as juveniles, subadults, adult males and females.

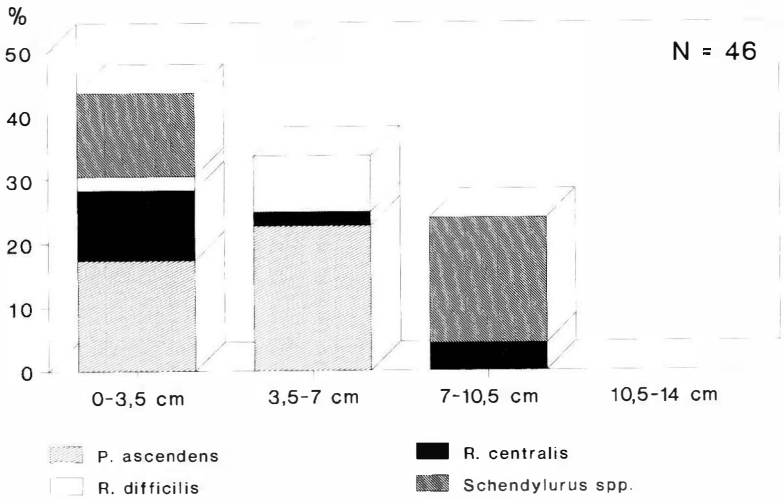

Fig. 1: Distribution of Geophilomorpha species in the soil. Monthly samples taken every 3.5 cm to a depth of 14 cm between August, 1987 and April, 1988 (terrestrial phase) in a seasonal mixed-water inundation forest of Central Amazonia. Total catch = 100%. *Schendylurus* spp. = *S. janauarius* + *S. continuus* (see text for further information).

Results and discussion

A total of 106 Geophilomorpha were sampled from the experimental area, of which 43% were obtained in the soil, 2% from the soil surface and 55% from trees (6% in upwards directed and 45% in downwards directed arboreal photo-eclectors and 4% in the canopy).

Only 0.3% of the total Arthropoda extracted from the soil (Acari and Collembola omitted; cf. Morais 1995) were Geophilomorpha (n=46). Of these, 39.1% were constituted by *Pectiniunguis ascendens* Pereira et al., 1994 (Schendylidae), 28.3% by *Schendylurus janauarius* Pereira et al., 1995 (Schendylidae), 17.4% by *Ribautia (Schizoribautia) centralis* (Silvestri, 1907) (Geophilidae), 10.9% by *Ribautia (S.) difficilis* Pereira et al., 1995 (Geophilidae) and 4.3% by *Schendylurus continuus* Pereira et al., 1995 (Schendylidae). Geophilomorpha were most frequent within the uppermost 7 cm of soil depth (Fig. 1). Their greatest abundance occurred six weeks after inundation of the forest had ended, with 30.5% of the total catch being extracted from the soil (67.4 ind./m^2; Fig. 2). Averages of 23 ± 30 ind./m^2/month were collected in the dry season and 22 ± 15 ind./m^2/month in the rainy season. Of the total Geophilomorpha extracted from the soil, 43.5% (10 ± 13 ind./m^2/month on average) were constituted by immatures, 8.7% each (2 ± 3 ind./m^2/month on average) by subadults and adult males, and 23.9% (3 ± 5 ind./m^2/month on average) by adult females. For the remaining 15.3%, the stage of development could not be determined. No Geophilomorpha were found in soil materials taken underwater during the aquatic phase. Four specimens were obtained by fogging the canopy during the aquatic phase.

Pectiniunguis ascendens

This species is a soil inhabitant that lives within the top 7 cm (Fig. 1) and survives the aquatic phase on trees. It was the most abundant species in the soil, being represented with 9 ± 16 ind./m^2/month on average. The first immature specimens in the soil appeared six weeks after forest inundation had ended (Sept. 1987), which indicated the beginning of the reprodutive period (Figs. 2, 3). The greatest abundance occurred during the dry season with an average of 14 ± 26 ind./m^2/month, while the rainy season had only 6 ± 3 ind./m^2/month on average. Of the total specimens extracted from the soil (n=18), 67% were represented by immatures, 6% by subadults and 16% by adults (5 % males, 11% females). For the remaining 11%, the developmental stage could not be determined. No significant correlations were obtained between the vertical distribution in the soil and the local abiotic factors.

The number of specimens captured in arboreal

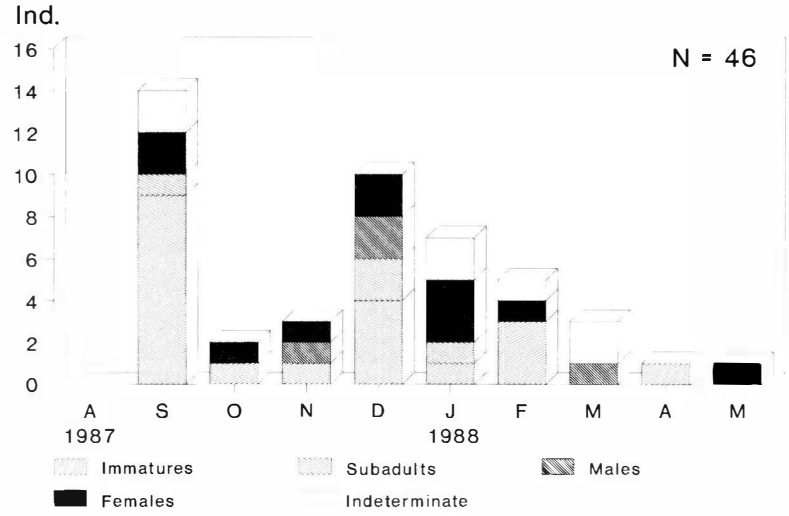

Fig. 2. Distribution of developmental stages of Geophilomorpha in monthly soil samples (0–14 cm soil depth) taken between August, 1987 and April, 1988 (terrestrial phase) in a seasonal mixed-water inundation forest of Central Amazonia.

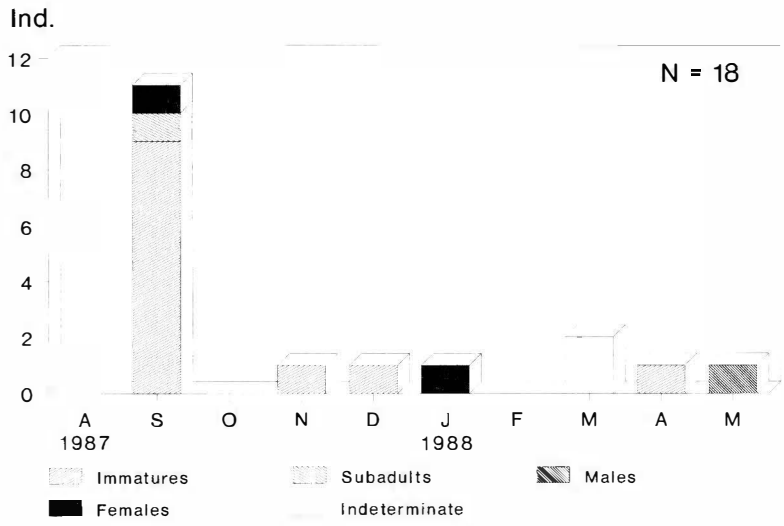

Fig. 3. Developmental stages of *Pectiniunguis ascendens* in monthly soil samples (0–14 cm soil depth) taken between August, 1987 and April, 1988 (terrestrial phase) in a seasonal mixedwater inundation forest of Central Amazonia.

photo-eclectors was not high enough to define a period of vertical migration between soil and trees. However, ecological studies undertaken by Adis et al. (1997) in a seasonal blackwater inundation forest Manaus revealed that adults of *P. ascendens* move to the trunk region at the beginning of the rainy season (in December), which is 3–4 months before forest inundation, and return to the soil when the aquatic phase has ended.

Schendylurus continuus and Schendylurus janauarius

Representatives of these two species are soil inhabitants and live to a depth of 10.5 cm (Fig. 1: *Schendylurus* spp.). *Schendylurus janauarius* showed an average abundance of 7 ± 9 ind./m^2/month. Its greatest abundance was found in the rainy season (9 ± 11 ind./m^2/month on average), while in the dry season 2 ± 5 ind./m^2/month were collected. First immature specimens in the soil, indicating the reproductive period, occurred in December 1987, the beginning of the rainy season. The abundance of *S. continuus* was low (1 ± 2 ind./m^2/month on average).

No specimens were collected during upward migration on the tree trunk. One single specimen of S. *janauarius* was detected during downward migration at the end of the aquatic phase, indicating that representatives of this genus probably survive flooding of the soil on trees.

Ribautia (Schizoribautia) centralis

This species is a soil inhabitant which lives to a depth of 10.5 cm (Fig. 1) and survives the aquatic phase on trees. Average abundance was 4 ± 5 ind./m^2/month. Adult specimens (n=2) were captured while climbing upwards on the trees at the beginning of the aquatic phase. Adults returned to the soil after inundation of the forest had ended (n=34) and where the reproductive period took place. Our data reconfirm the phenology found for this species in a blackwater seasonal inundation forest near Manaus (Adis et. al. 1997).

Ribautia (Schizoribautia) difficilis

This species was collected by soil extraction within the first 7 cm of depth (Fig. 1). Its abundance was low (2 ± 3 ind./m^2 /month on average). Four females were collected by fogging the canopy during the aquatic phase. Ten specimens (mostly adults of both sexes) were captured in arboreal photo-eclectors when they returned to the forest floor at the end of the aquatic phase.

Conclusions

R. (*S.*) *difficilis* and *P. ascendens* inhabit the uppermost 7.0 cm, whereas *R.* (*S.*) centralis, *S. continuus* and *S. janauarius* live to a soil depth of 10.5 cm. *P. ascendens* and *S. janauarius* were most abundant, representing 39.1 % and 28.3 % of all catches, respectively (n = 22.1 ± 21.7 ind./m^2/ month on average). Reproduction of all species occurred in the soil.

The strategy of these terricolous species of Geophilomorpha to survive forest inundation is to pass the aquatic phase of several months duration on trees by means of vertical migrations (= "terricolous migrants" according to Adis 1997).

Our data reconfirm that the seasonal mixedwater inundation forest represents an ecotone (cf. Adis 1992): *Schendylurus continuus* is also found in non-flooded primary upland forests while *Pectiniunguis ascendens* and *Ribautia* (*S.*) *centralis* occur in a seasonal blackwater inundation forest in the lower basin of the Negro River as well (Adis et al. 1997).

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References

Adis, J. 1981. Comparative ecological studies of the terrestrial arthropod fauna in Central Amazonian inundation forests. — Amazoniana 7(2):87–173.

Adis, J. 1987. Extraction of arthropods from neotropical soils with a modified Kempson apparatus. — J. Tropic. Ecology 3(2):131–138.

Adis, J. 1992. Überlebensstrategien terrestrischer Invertebraten in Überschwemmungswäldern Zentralamazoniens. — Verh. naturwiss. Ver. Hamburg (NF) 33:21–114.

Adis, J. 1997. Terrestrial invertebrates: Survival strategies, group spectrum, dominance and activity patterns. Pp. 223–317 *in* Junk, W. J. (Ed.): The Central Amazon floodplain. Ecology of a pulsing system. Ecological Studies 126, 525 pp. Berlin.

Adis, J., Messner, B. & Groth, I. 1989. Zur Überflutungsresistenz und zum Spinnvermögen von Japygiden (Diplura). — Zool. Jb. Anat. 199(3/4):371–382.

Adis, J., Morais, J. W. de & Scheller, U. 1996. On abundance, phenology and natural history of Symphyla from a mixedwater inundation forest in Central Amazonia, Brazil. Pp. 607–616 *in* Geoffroy, J.-J., Mauriès, J.-P. & Nguyen Duy-Jacquemin, M. (Eds.): Acta Myriapodologica. — Mém. Mus. natn. Hist. nat. 169, 687 pp. Paris.

Adis, J., Barbieri, F., Minelli, A. & Pereira, L. A. 1997. Behavioural and morphological adaptations of Geophilomorpha centipedes in a periodically inundated Amazonian forest. — Stud. Neotrop. Fauna Environ.: in press.

Braga, P.I.S. 1979. Subdivisão fitogenética, tipos de vegetação, conservação e inventário florístico da floresta amazônica. — Acta Amazonica 9(4):53–80.

Cavalli-Sforza, L. 1972. Grundzüge biologisch-medizinischer Statistik. 212 pp. Stuttgart.

Erwin, T. L. 1983. Beetles and other insects of tropical forest canopies at Manaus, Brazil, sampled by insecticidal fogging. Pp.59–75 *in* Sutton, S. L., Whitmore, T. C. & Chadwick, A. C. (Eds.): Tropical rain forest: ecology and management. Proceedings of the Tropical Rain Forest Symposium (Leeds 1982). 498 pp. Oxford.

Junk, W. J., Bayley, P. B. & Sparks, R. E. 1989. The flood pulse concept in river floodplain systems. — Can. Spec. Publ. Fish. Aquat. Sci. 106:110–127.

Morais, J. W. de 1995. Abundância, distribuição vertical e fenologia da fauna de Arthropoda de uma região de água mista, próxima de Manaus, AM. Ph.D. thesis. Escola Superior de Agricultura 'Luiz de Queiroz', Univ. São Paulo. 226 pp. Piracicaba, Brazil.

Pereira, L. A., Minelli, A. & Barbieri, F. 1994. New and little known geophilomorph centipedes from Amazonian inundation forests near Manaus, Brazil (Chilopoda, Geophilomorpha). — Amazoniana 13(1/2):163–204.

Pereira, L. A., Minelli, A. & Barbieri, F. 1995. Description of nine new centipede species from Amazonia and related matters on Neotropical geophilomorphs (Chilopoda: Geophilomorpha). — Amazoniana 13(3/4):325–416.

Prance, G.T. 1979. Notes on the vegetation of Amazonia III. The terminology of Amazonian forest types subject to inundation. — Brittonia 31(1):26–38.

Ribeiro, M. de N. G. & Adis, J. 1984. Local rainfall variability – a potential bias for bioecological studies in the Central Amazon. — Acta Amazonica 14(1/2):159–174.