SHORT COMMUNICATION

Morphological adaptations of Porrhomma spiders (Araneae: Linyphiidae) inhabiting soil

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Abstract. We studied occurrence and morphological adaptations of two species of Porrhomma down to 135 cm soil depth. Porrhomma microps Simon 1884 inhabited soil layers at depths between 5 and 135 cm. Porrhomma aff. myops was found at depths of 35–95 cm. Specimens of both species were depigmented and had highly reduced eyes. Compared with the epigean P. pygmaeum (Blackwall 1834), P. myops, which inhabits scree and caves, exhibits significantly longer legs. We interpret it as an example of troglomorphism. Compared with the epigean P. pygmaeum, P. aff. myops is found deep in the soil and exhibits a significantly smaller cephalothorax. We interpret this as edaphomorphism. We assume the edaphomorphic population of P. aff. myops to be permanent soil dwellers.

Keywords: Araneae, soil profile, troglomorphisms, edaphomorphisms

Spiders inhabit a wide spectrum of underground habitats such as inner spaces in stony debris, scree layers in slope accumulations, fissure networks of the bedrock, karst and pseudokarst caves (Růžička 1999; Culver & Pipan 2009; Giachino & Vailati 2010). Numerous studies have been devoted to the cave arachnofauna (e.g., Deeleman-Reinhold 1978; Paquin & Duperré 2009), and some studies have concerned spiders that inhabit the deep scree layers (Růžička et al. 1995; Růžička & Klimeš 2005). Other shallow underground habitats, known as superficial subterranean habitats, have also been investigated (Pipan et al. 2011; Deltchev et al. 2011). However, spiders occurring deep in soils have not yet been investigated. It has been assumed for a long time that spiders are not true soil inhabitants sensu Dunger (1983). But, very recently we (V. Laška unpublished) have found spiders deep in soil layers. How are these species adapted to life in the soil?

Zacharda (1979), studying the morphological adaptations of rhagidiid mites, distinguished two different classes of adaptations to life in the underground environment: edaphomorphism covers adaptations to life in the soil environment; and troglomorphism covers adaptations to life in the cave environment. Depigmentation, desclerotization, and the atrophy (even loss) of the eyes are characteristic for both types of adaptations. The shortening of appendages as well as shrinking of the body is typical for edaphomorphic species, whereas the elongation of appendages is typical for troglomorphic species. Christiansen (1992) surveyed the studies on troglomorphic species and concluded that the troglomorphic features are subject to selection and are therefore adaptive.

The tendency for colonization of shallow and deep subterranean space is characteristic of numerous species of the genus Porrhomma. Several species groups within this genus have been recognized. The microphthalamum group has been newly established, and the European species were revised by Růžička (2009). The pygmaeum group of the genus Porrhomma was studied by Bourne (1978). We studied occurrence of two Porrhomma species in the soil by means of subterranean traps. We then compared their morphology with other closely related species of the genus in order to identify adaptations for life in the soil.

We collected spiders at two sites: 1) A beech forest (49°39’N, 16°03’E) near Skuteč, Eastern Bohemia, where the soil is composed of a thick layer of leaf litter covering an A-horizon (ca 15 cm), passing to a thick clay soil layer above arenaceous marl bedrock; 2) A floodplain hardwood forest (49°39’N, 17°11’E) dominated by Fraxinus, Quercus and Tilia on the bank of the Morava River near wet meadow, Litovelské Pomoraví Protected Landscape Area, Central Moravia. The soil there is a fluviosoil on gravels. The detritus fermentation layer is ca 3 cm thick. At both sites spiders were collected using subterranean traps (Schlick-Steiner & Steiner 2000) consisting of a set of removable plastic containers (volume of each = 250 ml) on a central metal axis. The containers were filled with a 4% formaldehyde solution and emptied at 6-wk intervals. Two traps with 14 containers were placed in the beech forest on 4 April 2008–20 April 2009; the deepest sampling depth was 135 cm. One trap with 10 containers was placed in the floodplain forest on 6 March–13 November 2008; the deepest sampling depth was 95 cm.

Material used for comparison came from various sites in the Czech Republic. Porrhomma myops Simon 1884 was collected in bare scree at Úštěk Zámeck Mt., Jezernecká hora Mt., Týrov, Přísečné Mt., Kamenc Mt., Břidlíčka Mt., Suš Mt., Králíčky Sněžník Mt., Blansko; and in cave scree in Kateřinská cave, Horní v Chobotu cave and Ledové Služe caves. Porrhomma microps (Roewer 1931) was collected in the soil in the same beech forest as above during our previous study and in forest litter in Lanžhot. Porrhomma pygmaeum (Blackwall 1834) was collected in wetlands in Mišov, Tréboň, Suchdol nad Lužnicí, Chlum u Třeboně-Lutová, Sedlec, and Milotice.

Specimens were measured using a BX-40 compound microscope. All measurements are in millimeters. Abbreviations: Cth = cephalothorax, Mt I = metatarsus of the first leg, PME – posterior median eye. Voucher specimens are deposited in the collection of V. Růžička at the Biology Centre, České Budějovice.

Porrhomma microps occurred at depths of 65–135 cm (mean = 80 cm) in the beech forest, and in the floodplain forest it was found at depths of 5–45 cm (mean = 20 cm). All specimens were pale with highly reduced eyes (Table 1). Porrhomma microps is known as an inhabitant of leaf litter (Buchar & Růžička 2002). Specimens from both microhabitats exhibited similar Mt I/Cth width ratio (t = 1.2, df = 33, P = 0.229, Fig. 1).

Porrhomma aff. myops was found at depths of 35–95 cm (mean = 80 cm) in the floodplain forest. It was pale and also had highly reduced eyes (Table 1). At this locality P. aff. myops was found significantly deeper in the soil profile than P. microps (t = −4.9, df =
Table 1.—Overview of characteristics for study Porromma species. See text for abbreviations. Mean (SD) is given for measurements.

| Species     | Microhabitat | No. of specimens | PME | PME-PME interdistance | Cth width | Mt I length |
|-------------|--------------|------------------|-----|------------------------|-----------|-------------|
| P. microps  | litter       | 10               | 0.035 | 0.050                  | 0.843 (0.052) | 0.973 (0.058) |
| P. microps  | soil         | 25               | 0.030 | 0.050                  | 0.861 (0.034) | 0.951 (0.043) |
| P. aff. myops | soil        | 8                | 0.015 | 0.040                  | 0.574 (0.009) | 0.499 (0.012) |
| P. myops    | scree        | 26               | 0.025 | 0.045                  | 0.686 (0.031) | 0.862 (0.057) |
| P. pygmaeum | soil surface | 31               | 0.050 | 0.050                  | 0.670 (0.020) | 0.562 (0.033) |

10, $P < 0.001$). Additionally, the cephalothorax width of $P.$ aff. myops was significantly smaller than that of $P.$ microps ($t = -22.7$, $df = 10$, $P < 0.001$, Table 1).

In comparison with Porromma myops, an inhabitant of scree and caves (Buchar & Růžička 2002), the specimens of $P.$ aff. myops from the deep soil layer exhibited a significantly different Mt I/Cth width ratio ($t = 20.8$, $df = 32$, $P < 0.001$, Fig. 2).

We compared $P.$ myops from scree and $P.$ aff. myops from the deeper soil layers with the closely related Porromma pygmaeum. This species is epigeic and pigmented, with fully developed eyes. Both morphotypes of $P.$ myops were distinguished from $P.$ pygmaeum by reduction of the eyes (Table 1). Furthermore, there was a significant difference ($t = 31.6$, $df = 55$, $P < 0.001$) in the Mt I/Cth width ratio between $P.$ myops and $P.$ pygmaeum (Table 1). Porromma myops inhabiting scree exhibited relatively longer metatarsi of the first legs. We interpret this adaptation as a troglomorphism. There was a significant difference ($t = -9.3$, $df = 37$, $P < 0.001$) between the cephalothorax width of $P.$ aff. myops and $P.$ pygmaeum (Table 1). Porromma aff. myops inhabiting soil exhibited a smaller cephalothorax, which we interpret as an edaphomorphism.

Previously Růžička (1996) documented the occurrence of two other troglomorphic species in underground spaces (fissure caves, talus caves) in a decaying gneiss massif. Specifically, Improphantes improbulus (Simon 1929) inhabited the spaces at depths of about 0.5–5 m, and Porromma egeria Simon 1884 inhabited spaces at depths from 5 to 10 m. In this study, we documented the occurrence of two microphthalmous species from the genus Porromma in the soil profile.

The leg elongation is characteristic for invertebrates inhabiting subterranean habitats fashioned by spaces larger than their body dimensions. It has been documented in a series of closely related cave spiders from the genus Troglohyphantes (Deeleman-Reinhold 1978), in a series of cave spiders from the genus Nesticus (Kratochvíl 1933, 1978), in two linyphiid subspecies Bathypantes eumenis buchari (L. Koch 1879) and Wabanoides uralensis lithodytes Schikora 2004 (Růžička 1988, Schikora 2004), in subterranean populations of Leptophantes improbulus Simon 1929, and Theonoe minutissima (O. Pickard-Cambridge 1879) (V. Růžička 1998). Leg elongation has been also found in Sclerobuninae harvestmen from deep stony debris (Derkarabetian et al. 2010). J. Růžička (1998) documented a gradient of increasing length of body appendages from epigean – to rock debris dwelling – through cave-dwelling species of Chelura (Coleoptera).

The interstices in the deeper soil layers are of comparable dimensions to invertebrate body dimensions, and body diminution (compared with their epigean relatives) is characteristic for soil inhabitants. In addition to the troglomorphic $P.$ myops, we found edaphomorphic $P.$ aff. myops. Since the specimens of $P.$ aff. myops were collected at similar depth throughout the season, we consider the population of $P.$ aff. myops to be a permanent soil dweller sensu Dunger (1983).

Figure 1.—Relationship between the cephalothorax width and the length of metatarsus I in Porromma microps. Specimens from leaf litter (full circles); specimens from soil (open circles).

Figure 2.—Relationship between cephalothorax width and length of metatarsus I in Porromma myops (specimens from scree and caves, full circles) and Porromma aff. myops (specimens from soil, open circles).
ACKNOWLEDGMENTS

This study was supported by the National Research Programme II (project No. 2B 06101) and by the Biology Centre, Institute of Entomology, AS CR (project No. Z50070508).

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Manuscript received 22 September 2010, revised 22 February 2011.