Symphypleonid and neelipleonid springtails (Hexapoda, Collembola, Symphypleona and Neelipleona) from caves of the Grand Duchy of Luxembourg

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Zusammenfassung

Springschwänze oder Collembolen sind mit die häufigste Tierordnung in Höhlen-Ökosystemen. Von 2007 bis 2011 wurde die Höhlenfauna von 82 Höhlen und künstlichen Hohlräumen des Großherzogtums Luxemburg untersucht. Dabei wurden Barberfallen aufgestellt und Handaufsammlungen durchführt. Unter den rund 90.000 gesammelten Tieren wurden sechs symphypleonide und eine neelipleonide Springschwanzart mit insgesamt 2915 Einzeltieren erfasst. Von diesen 7 Arten gelten die folgenden als eutroglophil: *Arrhopalites principalis* Stach, 1945, *Arrhopalites pygmaeus* (Wankel, 1860), *Disparrhopalites patrizii* (Cassagnau & Delamare Deboutteville, 1953) und *Neelus murinus* Folsom. Sie beinhalten mehr als 98 % aller gesammelten Inidividuen. Die verbleibenden drei Arten gelten als eutrogloxen. Zu ihnen gehören die beiden epedaphischen Arten *Sminthurinus concolor* (Meinert, 1896) mit 25 Individuen aus drei Standorten und *Sminthurinus reticulatus* Cassagnau, 1964 mit 23 Individuen von zwei Standorten. Ferner wurde die epineustische Art *Sminthurides parvulus* (Krausbauer, 1898) mit nur 5 Individuen an einem Standort gefunden. Neu für Luxemburg sind *Disparrhopalites patrizii*, *Sminthurinus reticulatus* und *Sminthurides parvulus*.

Abstract

Springtails or Collembola are amongst the most abundant hexapod orders in cave ecosystems. From 2007 to 2010 the cave fauna of 82 caves and artificial caverns in the Grand Duchy of Luxembourg was investigated using pitfall trapping and hand sampling. From a total of 90,000 animals six symphypleonid and one neelipleonid springtail species with 2915 individuals were caught. From these seven species *Arrhopalites principalis* Stach, 1945, *Arrhopalites pygmaeus* (Wankel, 1860), *Disparrhopalites patrizii* (Cassagnau & Delamare Deboutteville, 1953) and *Neelus murinus* Folsom, 1896 are classified as eutroglophile and imply more than 98% of the catched individuals. The remaining three species are classified as eutrogloxene. These include the two epedaphic species *Sminthurinus concolor* (Meinert, 1896) with 24 individuals from three locations and *Sminthurinus reticulatus* Cassagnau, 1964 with 23 individuals from two locations. Furthermore the epineustic species *Sminthurides parvulus* (Krausbauer, 1898) with only five individuals from one location was detected. New for Luxembourg are *Disparrhopalites patrizii*, *Sminthurinus reticulatus* and *Sminthurides parvulus*.

Résumé

Les collemboles font partie des ordre d'animaux les plus fréquents dans les écosystèmes cavernicoles. Entre 2007 et 2011, la faune cavernicole de 82 cavités naturelles et artificielles du grand-duché de Luxembourg a été étudiée. Les méthodes appliquées comprenaient des pièges Barber et des collectes à la main. Parmi les 90 000 spécimens d'animaux collectés, six espèces de collemboles symphypleonides et une espèce de collembole neelipleonide ont été identifiées, avec un nombre total de 2915 individus. Parmi ces 7 espèces, les suivantes sont classées comme subtroglophiles: *Arrhopalites principalis* Stach, 1945, *Arrhopalites pygmaeus* (Wankel, 1860), *Disparrhopalites patrizii* (Cassagnau & Delamare Deboutteville, 1953) et *Neelus murinus* Folsom. Elles comprennent plus de 98% de tous les individus collectés. Les autres trois espèces sont eutrogloxènes. Parmi eux se trouvent les deux espèces édaphiques *Sminthurinus concolor* (Meinert, 1896) avec 25 individus venant de trois sites et *Sminthurinus reticulatus* Cassagnau, 1964, avec 23 individus de deux sites. Par ailleurs, l'espèce epineustique *Sminthurides parvulus* (Krausbauer, 1898) a été trouvée dans un seul site avec seulement trois individus. Les espèces *Disparrhopalites patrizii, Sminthurinus reticulatus* et *Sminthurides parvulus* sont nouvelles pour le Luxembourg.

1 Introduction

The presence of springtails in caves was early described by Wright & Haliday (1857) and Carpenter (1897). Springtails are very sensitive to humidity and temperature changes. In many caves humidity is close to 100% and temperature vary little from 9°C, thus surface species that make their way into these habitats enter a frost-free environment with little or no climatic variation (Thibaud 1970; Hopkin 1997). Collembolan cave biogeography is a series of vicariance events following cave invasions by widespread species, followed by dispersionist episodes from newly adapted cave forms (Christiansen & Culver 1987). Species which occur in caves show several differences in reproduction, physiology and behavior in comparison to non-cave adapted species (Thibaud & Vannier 1986, Barra 1991). These include for example lower fecundity and slower embryonic and post embryonic development (Lee & Thibaud 1987, Lee & Kim 1995), increased levels of fat but decreased water content and ability to regulate water loss (Vannier & Thibaud 1978, 1984, Vannier & Verdier 1981, Thibaud & Vannier 1986).

Only a few investigations about springtails in Luxembourg exist. The work of N. Stomp and W. Weiner has given us a better understanding of the springtail fauna of Luxembourg. They presented some remarkable findings of the Luxembourg sandstone region (Lias Hettangien) (Stomp & Weiner 2005) and described new species like *Orchesella erpeldingae* and *Superodontella euro* (Stomp 1968a, 1968b, 1969, Stomp & Weiner 1994, Weiner & Stomp 1995, 2001, 2003). Further investigations about some species of the genus *Orchesella* are by Stomp (1967) as well as Reiffers & Arendt (1995). Stomp & Weiner (2005) report *Arrhopalites pygmaeus* from Grotte de Ste Barbe and from the Däiwelslach (Devils cave) near Kopstal.

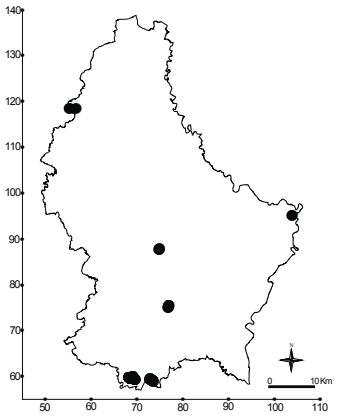

Fig. 1: Caves with *Neelus murinus* in Luxembourg.

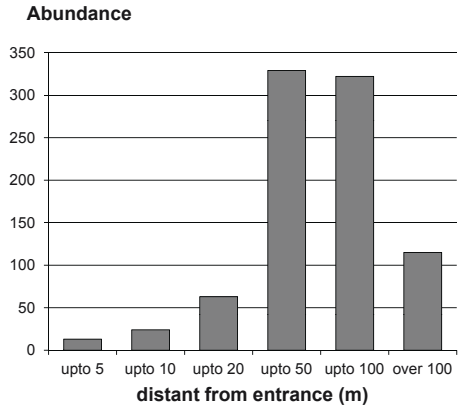

Fig. 2: Numbers *of Neelus murinus* caught at different distances from the entrance Luxembourg caves.

In this contribution seven symphypleonid and neelipleonid springtail species of different caves and locations in Luxembourg are presented.

2 Neelipleona

2.1 Neelidae

Neelus murinus Folsom, 1896

This small blind species has a total length of 0.7 mm, is yellowish coloured and shows a holarctic distribution. *N. murinus* lives preferably in moist soil and moss (Bretfeld 1999) and according to Massoud & Thibaud (1973) it is troglophile. It was found in Mexico up to 2800 m altitude (Bonet 1947).

Altogether 875 individuals were detected in 16 caves, with the main distribution and abundance in the iron ore mines of Rumelange (676 ind.) and Dudelange (178). Further single individuals were found in caves or mines of Niederwampach (3), Mersch (5) and Girsterklaus (2) as well as in the town fortification of Luxembourg City (11).

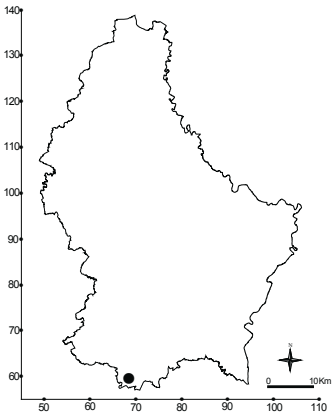

Fig. 3: Caves with *Sminthurides parvulus* in Luxembourg.

3 Symphypleona

3.1 Sminthurididae

Sminthurides parvulus (Krausbauer, 1898)

This blue-violet species with 8+8 ommatidia has a total length 0.55 mm in females and 0.3 mm in males. In the genus *Sminthurides* all of the

Fig. 4: Female of *Sminthurides parvulus* with the five-segmented forth antennal segment.

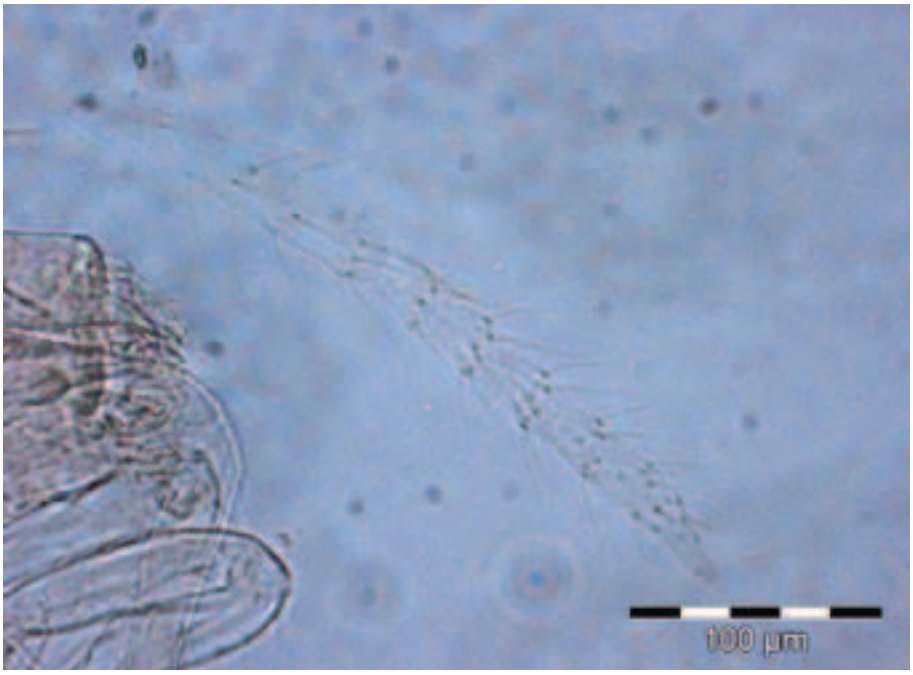

Fig. 5: Fourth antennal segment of *Arrhopalites principalis* with six subsegments.

European species are classified as epineustic, which means that the main occurrence of the specimen is on water surfaces of different water bodies (Palissa 2000). Therefore the modified mucrones (end parts of the furca) of these species are broad and flat to jump on the water surface. The maximum lifespan in this genus is 30 to 50 days and females are only able to fertilize once during their life (Blancquaert & Mertens 1977, Blancquaert 1981, Blancquaert & al. 1981). The male antenna is modified to grasp the female during mating with special curved and modified spines on the second and third antennal segment. Females of *S. parvulus* show a subdivision of the fourth antennal segment into five subsegments with the basal one being the longest (Nosek 1962)

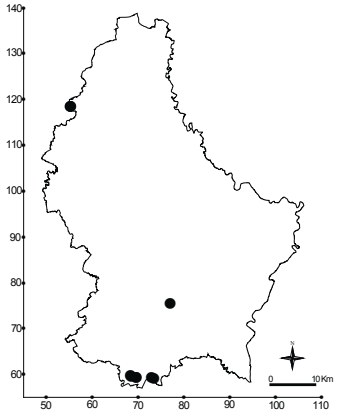

Fig. 6: Caves with *Arrhopalites principalis* in Luxembourg.

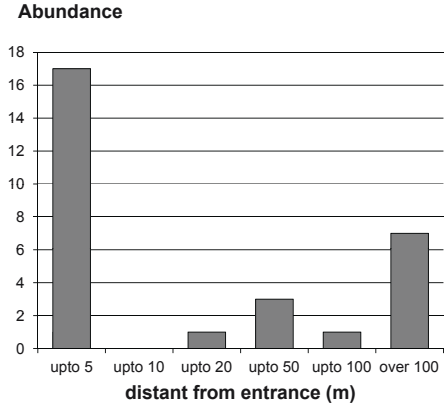

Fig. 7: Numbers *of Arrhopalites principalis* caught at different distances from the entrance Luxembourg caves.

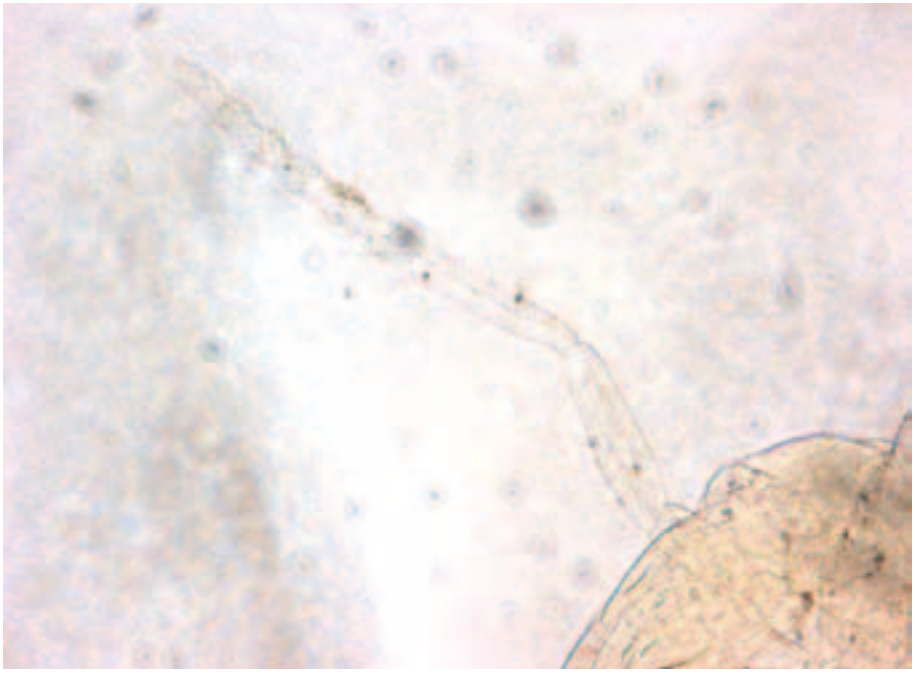

Fig. 8: Fourth antennal segment of *Arrhopalites pygmaeus* with five subsegments.

(figure 4). This species occurs in Europe and lives near and on fresh waters, in wet moss and litter up to 2600 m altitude in the Pyrenees (Cassagnau 1961; Bretfeld 1999).

S. parvulus was found only one time with five individuals in the entrance area of the iron ore mine Laange Gronn X near Rumelange. Thus it can be classified as eutrogloxene.

3.2 Arrhopalitidae

Arrhopalites principalis Stach, 1945

A. principalis has a total length of 1 mm with a brownish to bluish-grey colour and 1+1 dark ommatidia (Bretfeld 1999). The fourth antennal segment is divided into six subsegments (figure 5).

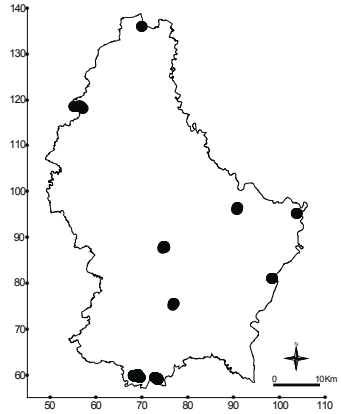

Fig. 9: Caves with *Arrhopalites pygmaeus* in Luxembourg.

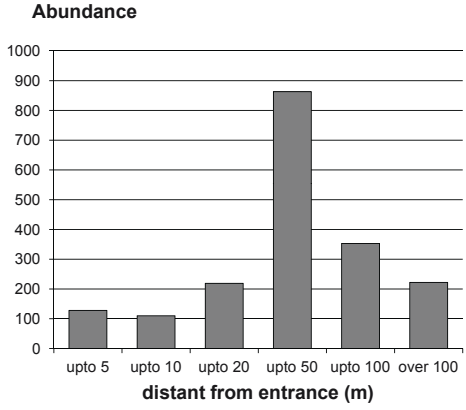

Fig.10: Numbers *of Arrhopalites pygmaeus* caught at different distances from the entrance Luxembourg caves.

This species has a Holarctic occurrence and live in damp moss, litter, soil down to 15 cm and is classified as troglophile (Massoud & Thibaud 1973). In the United States it was found up to an altitude of 3900 m (Fjellberg 1984).

In this investigation *A. principalis* was infrequently found in caves and mines of Niederwampach (17 ind.), Rumelange (9), Dudelange (2) and in the town fortification of Luxembourg City (1). But the occurrence of this species up to a depth of 160 m confirms the classification of Massoud and Thibaud (1973) as troglophile.

Arrhopalites pygmaeus (Wankel, 1860)

The white or less rusty red coloured *A. pygmaeus* has a total length of 1.2 mm and more or less pigmented 1+1 ommatidia (Bretfeld 1999). The fourth antennal segment is divided into five subsegments (figure 8). It shows a Holarctic occurrence and lives usually in cooler and moister climates of Europe (Bretfeld 1999). *A. pygmaeus* was often found in caves of Hungary (Stach 1945; Dányi 2011), but this species was also found in damp moss, litter and soil of open habitats and is therefore classified as troglophile or eutroglophile (Leruth 1939; Rusek 1972; Massoud & Thibaud 1973; Zaenker 2001, 2002, 2003, 2007, Stomp & Weiner 2005). However Strinati (1965), Skalski & Skalska (1969), Dobat (1975, 1978), Schulz (1992, 1994), Bernasconi (1994) and Fischer (1999) classified *A. pygmaeus* as troglobiont. Other authors prefer the classification trogloxene to eutroglobiont for this species (Eckert & al. 1998; Eckert 1999; Eckert & Palissa 1999; Weber 2004). Gisin (1960) found *A. pygmaeus* exclusively in caves and after Plachter (1976) it is strongly related to caves. He found *A. pygmaeus* in caves the entire year and demonstrated the reproduction of this species in cave habitats. For this reason the classification of *A. pygmaeus* is very difficult and not finally solved at this time.

Altogether 1895 individuals were caught at almost all sampled locations and different kinds of caves and mines, thus it was the most abundant species of this investigation.

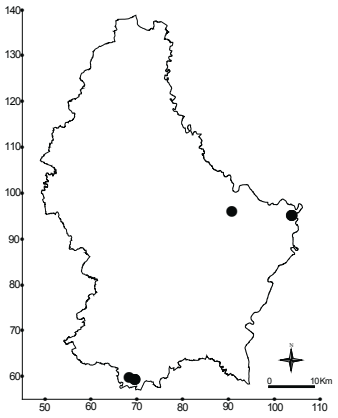

Fig. 11: Caves with *Sminthurinus concolor* in Luxembourg.

3.3 Katiannidae

Sminthurinus concolor (Meinert, 1896)

S. concolor is black-violet coloured with 8+8 ommatidia and has a total length of 1.5 mm (Bretfeld 1999). The occurrence of this species is Palaearctic with some isolated records in Luxembourg (Stomp 1969, 2005). *S. concolor* lives in humid habitats near or on the soil and in moss (Bretfeld 1999). Therefore it can be classified as eutrogloxene.

In this investigation specimen were found in the entrance area of the iron ore mine Minière Hutbierg (14 ind.) and the iron ore mine Minière Weltschegrond I (1 individual) near Rumelange, in a gypsum mine near Girsterklaus (8 individuals) and in the Keltenhiel cave near Muellerthal (1 ind.). It can be classified as eutrogloxene.

Sminthurinus reticulatus Cassagnau, 1964

The background colour of *S. reticulatus* is yellow with bluish green lateral and cross stripes on the abdomen. The eye patches consist of 8+8 ommatidia and adults have a total length of 0.7 mm (Bretfeld 1999). Between the eye there is a dark band, which leaves the area around the eye patches unpigmented (Fjellberg 2007). *S. reticulatus* lives preferably in soil and moss, but also on fields and dry meadows (Böhle 1991; Bretfeld 1999), thus it can be classified as eutrogloxene.

21 individuals of this species were detected in two Laangebierg iron ore mines near Dudelange and 1 individual in each of in the former railway tunnels Tussentunnel I and II.

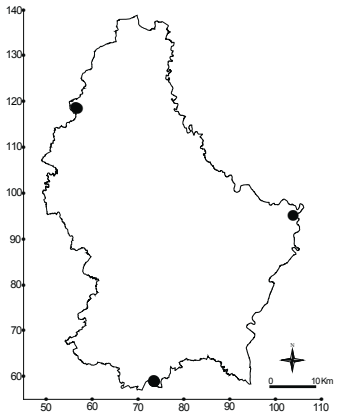

Fig. 12: Caves with *Sminthurinus reticulatus* in Luxembourg.

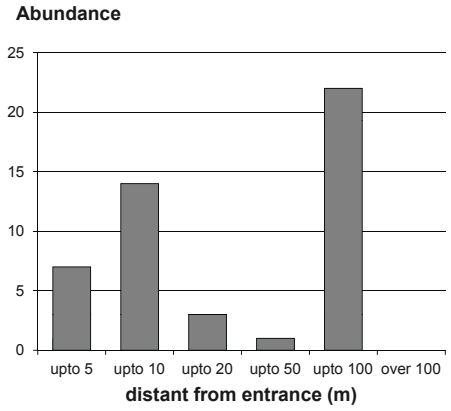

Fig. 13: Numbers *of Sminthurinus reticulatus* caught at different distances from the entrance Luxembourg caves.

3.4 Sminthuridae

Disparrhopalites patrizii (Cassagnau & Delamare Deboutteville, 1953)

D. patrizii is a rare white coloured species with sometimes weak dorsal pigment on the large abdomen (Bretfeld 1999). The eye patches (8+8 ommatidia) are dark blue (figure 15) and the fourth antennal segment consists of 12 subsegments. *D. patrizii* is classified as hygrophile (Dallai & Malatesta 1982) and was often found in caves of different European countries (Delamare Deboutteville & Bassot 1957; Gough 1972; Gama 1988). Christian (1999) collected this species in the catacombs of St. Stephans Cathedral in Vienna. But it was also found on open habitats of South Italy and Germany (Dallai 1973; Schleuter 1985). Thus it can be classified as eutroglophile. With one exception (one individual in the Kelsbaach cave near Machtum) the 62 individuals of *D. patrizii* were caught in the town fortifications (Fort Berlaimont, Fort Louvigny and Fort Lambert) of Luxembourg City.

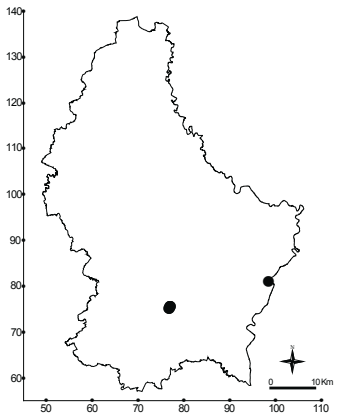

Fig. 14: Caves with *Disparrhopalites patrizii* in Luxembourg.

4 Acknowledgments

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5 References

Barra J.A. 1991. - Biologie et structures adaptives des Collemboles Entomobryomorphes cavernicoles. Rev. Ecol. Biol. Sol 28: 189-195.

Bernasconi R. 1994. – Suisse. Encyclopaedia biospeologica, 1: 809-818, Moulis, Bucarest.

Blancquaert J.P. & Mertens J. 1977. - Mating behaviour in *Sphaeridia pumilis* (Collembola). Pedobiologia 17: 343-349.

Blancquaert J.P. 1981. - Mating behaviour in some Sminthurididae (Collembola) with reference to the systematics of Symphypleona. Pedobiologia 22: 1-4.

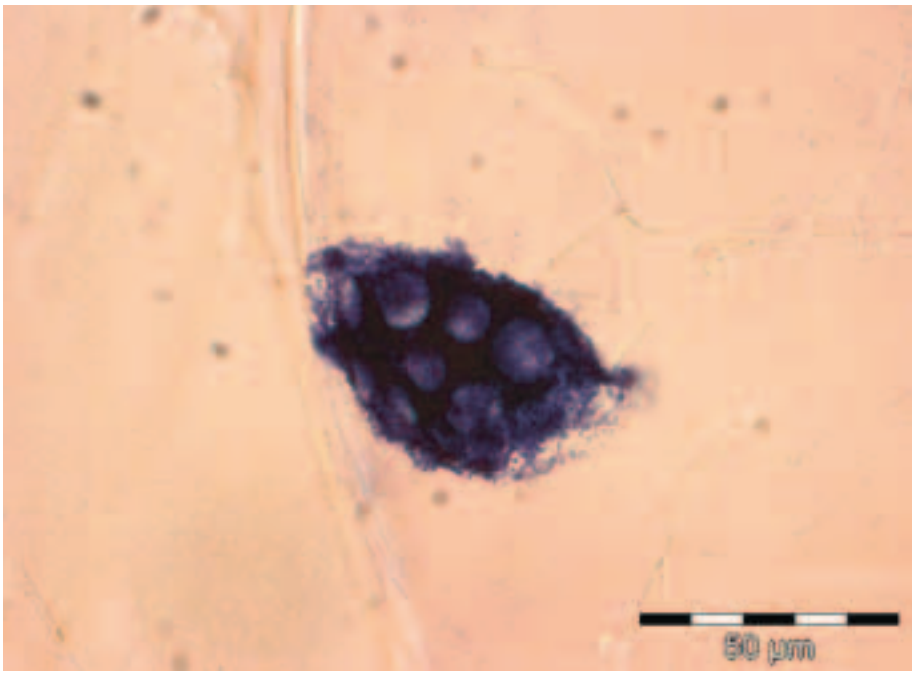

Fig. 15: Dark eye patch with 8 ommatidia of *Disparrhopalites patrizii*.

Blancquaert J.P., Coessens R. & Mertens J. 1981. - Life history of some Symphypleona (Collembola) under experimental conditions. II. Post-embryonal development and reproduction. . Rev. Ecol. Biol. Sol 18: 373-390.

Bonet F. 1947. - Monografía de la familia Neelidae (Collembola). Rev. Soc. Mexic. Hist. Natur. 8: 131-192.

Bretfeld G. 1999. - Symphypleona, in Dunger W. (ed), Synopses on Palaearctic Collembola, Volume 2, Abhandlungen und Berichte Naturkundemuseum Görlitz 71: 1-318.

Carpenter G. H. 1897. - The Collembola of Mitchelstown cave. Irish Naturalist 6: 225-231.

Cassagnau P. 1961. - Écologie du sol dans les Pyrénées centrales. Les biocénoses des Collemboles. Actualités Sci. Industr. 1283, Paris, Hermann: 1-235.

Christian E. 1999. - Die Fauna der Katakomben des Wiener Stephansdomes. Verh. Zool.-Bot. Ges. Österreich 135: 41-60.

Christiansen K. & Culver, D. 1987. - Biogeography and the distribution of cave Collembola. Journal of Biogeography 14: 459-477.

Dallai R. & Malatesta E. 1982. - Recerche sui Collemboli. XXVI. Collemboli cavernicoli italiani. Lavori Soc. Ital. Biogeogr. (NS) 7: 173-194.

Dallai R. 1973. - Recerche sui Collemboli. XVII. Le Isole Eolie. Lavori Soc. Ital. Biogeogr. (NS) 3: 481-590.

Dányi L. 2011. - Cave dwelling springtails (Collembola) of Hungary: A review. Soil Organisms 83(3): 419-432.

Delamare Debouteville C. & Bassot J.-M. 1957. - Collemboles Symphypléones de Madère et remarques biogéographiques. Vie et Milieu 8: 76-86.

Dobat K. 1975. Die Höhlenfauna der Schwäbischen Alb mit Einschluss des Dinkelberges, des Schwarzwaldes und des Wutachgebietes. Abhandlungen zur Karst- und Höhlenkunde, Reihe D, Paläontologie, Zoologie, 2: 260 - 381, München.

Dobat K. 1978. - Die Höhlenfauna der Fränkischen Alb. Abhandlungen zur Karst- und Höhlenkunde, Reihe D, Paläontologie, Zoologie, 3: 11-240, München.

Eckert R. & Palissa, A. 1999. - Beiträge zur Collembolenfauna von Höhlen der deutschen Mittel-

gebirge (Harz, Kyffhäuser, Thüringer Wald, Zittauer Gebige) (Insecta: Collembola). Beiträge zur Entomologie 49(1): 211-255, Berlin.

Eckert R. 1999. - Kriterien zum Grad der Höhlenbindung von in Höhlen anzutreffenden Tieren - eine umfassende Untersuchung der Arthropodenfauna von Höhlen im Harz, Kyffhäuser, Thüringer Wald und Zittauer Gebirge. Mitt. des Verb. der dt. Höhlen- und Karstforscher 45(2): 62-65, München.

Eckert R., Moritz M., Palissa A., Gruner, H.-E., Schmidt C. 1998. - Beiträge zur Arthropodenfauna (Spinnen und Weberknechte, Springschwänze, Asseln) der Höhlen deutscher Mittelgebirge (Harz, Kyffhäuser, Thüringer Wald, Zittauer Gebirge). Höhlenforschung in Thüringen. Mitteilungsblatt des Thüringer Höhlenvereins e.V., 11: 1-87, Eisenach.

Fischer C. 1999. - Aktueller Stand der Collembolennachweise aus der Sontheimer Höhle (7524/02) bei Heroldstatt-Sontheim/Schwäbische Alb. Mitt. des Verb. der dt. Höhlen- und Karstforscher, 45(2):60-61, München.

Fjellberg A. 1984. - Collembola from the Colorado Front Range, USA. Arctic and Alpine Research 16: 193-208.

Fjellberg A. 2007. - The Collembola of Fennoscandia and Denmark. Part II: Entomobryomorpha and Symphypleona. Fauna Entomologica Scandinavica 42: 1-264.

Gama M.M. da 1988. - Colémbolos das Canárias (Insectos, Apterygotas). Actas III congr. Ibérico Ent. 1988: 73-89.

Gisin H. 1960. - Collembolenfauna Europas. Museum d' Histoire Naturelle, Genève, 312 p.

Gough H.J. 1972. - Three new species of Collembola new to British list. Ent. Monthly Mag. 107: 139-140.

Hopkin S.P. 1997. - Biology of the springtails. Oxford University Press, Oxford, 330 p.

Lee B.H. & Kim J.T. 1995. - Population dynamics of the springtail, *Gulgastrura reticulosa* (Insecta, Collembola) from a Korean cave. Special Bulletin of the Japanese Society of Coleopterologists, Tokyo 4: 183-188.

Lee B.H. & Thibaud J.M. 1987. - A critical review of the taxonomy of *Gulgastrura reticulosa*, a cave springtail from Korea. Systematic Entomology 12: 73-79.

Leruth R. 1939. - La Biologie du domaine souterrain et la Faune cavernicole de la Belgique. Memoires du Musee royal d' histoire naturelle de Belgique, 87: 1 - 506, Bruxelles.

Massoud Z. & Thibaud J.M. 1973. - Essai de classification des Collemboles " cavernicoles" européens. Intern. Speleol. 1973, V, sub-section Db: Karst Zoology: 141-157.

Nosek J. 1962. - The Apterygotes from Czechoslovakian soils. IV. Collembola: Sminthuridae. Zool. Listy 11: 335-354.

Palissa A. 2000. - Collembola, in Schwoerbel J. & Zwick P. (eds), Süßwasserfauna von Mitteleuropa Band 10, Spektrum Akademischer Verlag, Heidelberg, 166 p.

Plachter H. 1976. - Vergleichende Untersuchungen zur Ökologie und Biologie der Fauna fränkischer Karsthöhlen. Zulassungsarbeit zur wissenschaftlichen Prüfung für das höhere Lehramt: 1-137 + Anl., Erlangen.

Reiffers J. & Arendt, A. 1995. - Contribution à la connaissance de la faune des Collemboles du genre Orchesella au Luxembourg (Insecta, Collembola). Bull. Soc. nat. luxemb. 96: 117-120.

Rusek J. 1972. - Die Collembolenfauna der Höhlen des Mährischen Karstes. Věstn. Čes. Spol. Zool. 36: 54-72.

Schleuter M. 1985. - Zur Kenntnis der Collembolenfauna des Naturparkes Kottenforst-Ville: Das Artenspektrum. Decheniana 138: 149-156.

Schulz H.J. (1992): Cave collembola from the Harz and Kyffhäuser mountains (Germany). VIII International Colloquium on Apterygota, Helsinki, Finland, 17-19 August, 1992, program and abstracts: 61, Helsinki.

Schulz H.J. (1994): Cave collembola from the Harz and Kyffhäuser mountains (Germany). Acta Zoologica Fennica, 195: 124-128, Helsinki.

Skalksi A. & Skalska B. (1969): The recent fauna of the Polish caves. Actes du IVe Congrès International de Spéléologie en Yougoslavie (12-26 IX 1965), 4-5: 211-223, Ljubljana.

Stach J. 1945. - The species of the genus Arrhopalites occurring in European caves. Acta Musei Historiae Naturalis, Krkow 1: 1-47.

Stomp N. & Weiner W.M. 1994. - Redescription of *Plutomurus unidentatus* (Börner, 1901) (Collembola, Tomoceridae). Bull. Soc. nat. luxemb. 95: 359-364.

Stomp N. & Weiner W.M. 2005. - Some remarkable species of Collembola (Insecta, Apterygota) of the Luxembourg sandstone area. Ferrantia 44: 227-232.

Stomp N. 1967. - Les populations de Collemboles des hêtraies du grès de Luxembourg. Mémoire scientifique, unpublished.

Stomp N. 1968a. - Deux nouvelles espèces d' *Orchesella* de la région du grès de Luxembourg. (Insecta, Collembola, Entomobryidae). Arch. Inst. G.-D. Sciences 33 (1967): 259-273.

Stomp N. 1968b. - *Tetracanthella hygropetrica luxemburgensis* n. sp. de la région du grès de Luxembourg. Bull. Mus. Nat. Hist. Nat. Paris 40: 734-741.

Stomp N. 1969. - *Sminthurinus concolor* (Meinert, 1896) au Grand-Duché de Luxembourg (Insecta, Collembola). Bull. Soc. nat. luxemb. 70 (1965): 175-184.

Strinati P. 1965. - Faune cavernicole de la Suisse. Éditions du Centre National de la Recherche Scientifique : 1-484.

Thibaud J.M. & Vannier 1986. - Caracterisations biologique et ecophysiologique des insectes Collemboles cavernicoles, in Dallai R. (ed), 2nd International Seminar on Apterygota, University of Siena, Siena: 129-137.

Thibaud J.M. 1970. - Biologie et écologie des Collemboles Hypogastruridae édaphiques et cavernicoles. Mémoires du Muséum Nationale d' Histoire Naturelles, Zoologie 61A: 83-201.

Vannier G. & Thibaud J.M. 1978. - Réduction ou perte totale de la capacité de régulation hydriques chez les espèces de Collemboles cavernicoles appartenant à la famille Tomoceridae. Bulletin de la Société Ecophysiologie 3: 124-126.

Vannier G. & Thibaud J.M. 1984. - Consequences de la vie cavernicole sur l' ecophysiologie et la biologie de l' insecte Collembole *Tomocerus catalanus* Denis. Mémoires de Biospéologie 11: 221-231.

Vannier G. & Verdier B. 1981. - Criteres ecophysiologiques (transpiration, respiration) permettant de separer une espèce souterraine d' une espèce de surface chez les Insectes Collemboles. Rev. Ecol. Biol. Sol 18: 531-549.

Weber D. (2004): Höhlenfaunenerfassung im Pfälzerwald. Bund für Umwelt- und Naturschutz (BUND) Landesverband Rheinland-Pfalz e.V., Biodiversität im Biosphärenreservat Pfälzerwald - Status und Perspektiven -: 124-137, Mainz.

Weiner W.M. & Stomp N. 1995. - Redescription of *Protaphorura eichhorni* (Gisin, 1954) (Collembola, Onychiurinae). Bull. Soc. nat. luxemb. 96: 121-126.

Weiner W.M. & Stomp N. 2001. - New species of *Hymenaphorura* Bagnall, 1949 (Collembola, Onychiuridae) from Luxembourg. Bull. Soc. nat. luxemb. 101: 179-182.

Weiner W.M. & Stomp N. 2003. - *Superodontella euro* sp.n. (Collembola, Odontellidae) from Luxembourg. Bull. Soc. nat. luxemb. 103: 69-72.

Wright E.P. & Haliday A.H. 1857. - Notes on a visit to Mitchelstown caves. Natural History Review 4: 231-241.

Zaenker S. 2001. - Das Biospeläologische Kataster Hessen. Die Fauna der Höhlen, künstlichen Hohlräume und Quellen. Abhandlungen zur Karst- und Höhlenkunde, 32: CD-Version, München.

Zaenker S. 2002. - Die rezente Höhlenfauna der Altensteiner Höhle unter Berücksichtigung der Quellenfauna im Ausfluss des Höhlenbaches – Die Schauhöhle Altenstein in Schweina. Natur- und Kulturgeschichte eines Geotops (2002): 135 – 143, Jena.

Zaenker S. 2003. - Die rezente Höhlenfauna der Altensteiner Höhle unter Berücksichtigung der Quellenfauna im Ausfluss des Höhlenbaches. Der Grottenolm – Mitteilungsheft des Höhlenforscherclubs Bad Hersfeld e.V. 14(1): 10-21, Fulda.

Zaenker S. 2007. - Das Biospeläologische Kataster Hessen. Die Fauna der Höhlen, künstlichen Hohlräume und Quellen. unveröffentlicht (Fortschreibung von Zaenker 2001).