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Diversity of the oribatid mite fauna (Acari, Oribatida) in two dry meadows in Styria (Austria)

Stefanie Lazarus* and Günther Krisper

Institute of Zoology, University of Graz, Universitätsplatz 2, 8010 Graz, Austria
* Corresponding author, e-mail: stefanie-lazarus@gmx.at

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Abstract

The oribatid mite fauna of two dry meadows has been studied and compared (Peggauer Wand, Zigöllerkogel). In autumn and summer at both sites, 10 samples were taken, and a total of 19,931 mites were identified, representing 42 families, 57 genera and 85 species. Mean abundance varied from 36,840 individuals m^{-2} up to 59,990 individuals m^{-2}. The two habitats differed qualitatively in the composition of their oribatid mites. Individuals of Oppiidae were most abundant in all sample units. Very frequent taxa were Quadroppiidae and Suctobelbidae as well as Ceratozetidae. Most species exhibited a clumped distribution. Species richness was higher on Peggauer Wand. Differences in diversity were conspicuous between summer and autumn on Zigöllerkogel, whereas the presence of species on Peggauer Wand was more balanced. The composition of oribatid mite fauna of these two habitats differs remarkably (Sørensen-coefficient 0.55). Concerning their ecological requirements the collected species are classified as follows: 23.5% xerothermophilous, 21.2% euryoecious, 23.5% silvicolous, 10.6% praticolous, muscicolous, and hygrophilous, 21.2% ‘unknown’. A comparison with published data of other dry habitats shows that each site harbours its own species community, probably depending on landform configuration, microclimate, and association of plants.

Keywords ecology | soil zoology | biodiversity | oribatid mites

1. Introduction

Dry meadows develop on locations characterized by dominating phases of strong drought, especially in combination with thin soil layers above the C-horizon. Such extreme habitats show drought resistant vegetation with an interesting composition of plant species specialized in resisting drought-stress. Dry meadows are a highly endangered biotope in Central Europe. Their specific flora and fauna are of great importance for conservation. There are few studies on the oribatid mite fauna of dry habitats in Austria (Pschorn-Walcher 1953, Schatz 1995, 1996, Schatz & Fischer 2007, Perlinger & Schatz 2009), and from the south-eastern of the country, which is zoogeographically influenced by the Pannonian and Dinaric regions. The aim of this study is a comparison of the oribatid mite fauna of two different dry meadows in the southern province of Styria.

2. Materials and methods

2.1. Description of study sites

The two habitats are approximately 25 km apart and the subsoil of both sites consists of Palaeozoic limestone (Schöcklkalk).

A) Peggauer Wand (hereafter denoted as PW): N of Graz, E of Peggau, N 47°12.24’, E 15°21.02’; W-exposed cliff of the limestone plateau ‘Tannebene’. The sample area is situated on a ledge near the top of the cliff, 550 m a.s.l. The inclination of the ledge is about 25 degrees. The xerothermic vegetation consists of *Sesleria albicans* and *Euphorbia cyparissias* with additional occurrence of *Lotus corniculatus*, *Anthericum ramosum*, *Polygala chamaebuxus,* and *Cyclamen purpurascens*. In the morning the eastern side of the ledge is bordered and shadowed by *Tilia cordata*, *Fagus*

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sylvatica and *Crataegus monogyna*. On rocky places *Sedum album* and *Sempervivum* sp. occur.

B) Zigöllerkogel (hereafter denoted as ZK): Hill close to Köflach, N 47°04.25', E 15°04.62'; SE-exposed slope, inclined 35 degrees, 602 m a.s.l. The xerothermic vegetation exhibits submediterranean floral elements. Remarkable are *Brachypodium pinnatum*, *Allium senescens*, *Bothriochloa ischaemum*, *Festuca rupicola*, *Galium verum*, and *Euphorbia cyparissias*. This dry meadow is bordered by *Pinus sylvestris*, at the bottom of the slope mixed up with *Picea abies*.

2.2. Sampling

At each site (once in summer and once in autumn) ten soil samples were collected at 1-meter intervals along a line transect at the same contour line. Each of these 40 samples was 10 × 10 × 5 cm in size. Samples between the seasons were taken in close proximity to each other. Soil fauna was extracted by Berlese-Tullgren funnels over a period of seven days. Oudemans' solution (870 ml ethanol 70 %, 50 ml glycerol, 80 ml ethanoic acid) was used as fixative. For preservation the material was transferred and stored in ethanol (70 %).

2.3. Determination

Only adults of Oribatida were identified. Specimens were mounted in cavity slides (using lactic acid) or in permanent slides (using Hoyers' liquid) for determination. The taxa were determined using the keys of Weigmann (2006) and Ghilarov & Krivolutsky (1975); for certain taxa it was necessary to go back to original descriptions. The determination up to species level was not possible for the taxa Suctobelbidae, *Berniniella, Oppiella,* and *Quadroppia* due to the high number of individuals, unknown intraspecific morphologic variation as well as missing conformity with the keys. Undescribed species are assumed in the genera *Liochthonius, Cultroribula, Oribatella*, and the family Tegoribatidae. For species-list see Appendix.

Table 1. Number of individuals and determined species, genera and families (**PW** – Peggauer Wand, **ZK** – Zigöllerkogel, **s** – summer, **a** – autumn).

		s	a	total
PW	individuals	3,684	5,999	9,683
	families	31	28	34
	genera	43	39	47
	species	58	52	66
ZK	individuals	5,125	5,123	10,248
	families	26	28	30
	genera	34	37	39
	species	44	45	51

2.4. Statistical analysis

Dispersion of individuals of each species was calculated after Dunger & Fiedler (1997). Relative abundance and division into dominance classes are defined as follows: abundant ≥ 10 %, common 5–9.99 %, frequent 3–4.99 %, occasional 1–2.99 %, and rare < 1 %.

Community structures were studied by calculating Shannon's diversity index (H_s), Evenness (E), Simpson-index (D), and Sørensen-coefficient (Ss). Cluster analysis (unweighted pair-group method using arithmetic means (UPGMA)) based on Jaccard-index and the analysis of similarities (ANOSIM), to test the significance of differences between the four groups of samples based on Bray-Curtis dissimilarity as distance measure, was computed using the software package PAST (Hammer et al. 2001).

3. Results

In total 19,931 individuals were collected belonging to 42 families, 57 genera and 85 species. On PW the mean abundance reached 36,840 individuals m^{-2} in summer and 59,990 individuals m^{-2} in autumn; on ZK 51,250 individuals m^{-2} in summer and 51,230 individuals m^{-2} in autumn. The two habitats differ qualitatively in the composition of their oribatid fauna (see Tab. 1). Specimens of Oppiidae are most abundant in all of the four sample units. Almost half of all collected individuals belong to this family. The Quadroppiidae and Suctobelbidae as well as Ceratozetidae are also very frequent. Seven families in Peggau and four families on ZK were represented by only one or two specimens. In total, 16 species were recorded by only one individual (18.82 % of all species).

The most frequently occurring taxa (present in all samples) on PW were *Fosseremus laciniatus*, *Ctenobelba pectinigera, Eupelops torulosus, Achipteria coleoptrata*, *Micropia minus longisetosa*, the family Suctobelbidae, and the genera *Phthiracarus* sp., *Berniniella, Oppiella,* and *Quadroppia*. Similarly, the most frequent taxa on ZK were *Liochthonius* cf. *laetepictus, Fosseremus laciniatus, Cultroribula* sp., *Dissorhina ornata*, *Oppiella* sp., *Peloptulus phaenotus*, and the representatives of the family Suctobelbidae.

In general only few taxa were abundant, as most were occasional or rare, but the two sites differ in regard to their abundant taxa (Fig. 1). Furthermore, within one habitat, dominance structure shifted between the seasons; only the most abundant taxa retain their leading position.

Most of the species showed aggregated distributions and only taxa occurring as a single specimen among all samples of one site and season showed a random distribution (see Tab 2).

Table 2. Dispersion of species (**PW** – Peggauer Wand, **ZK** – Zigöllerkogel).

dispersion	PW_{summer} species	%	PW_{autumn} species	%	ZK_{summer} species	%	ZK_{autumn} species	%
regularly	6	10.35	4	7.69	4	9.09	3	6.67
randomly	10	17.24	9	17.31	11	25.00	5	11.11
aggregated	42	72.41	39	75.00	29	65.91	37	82.22

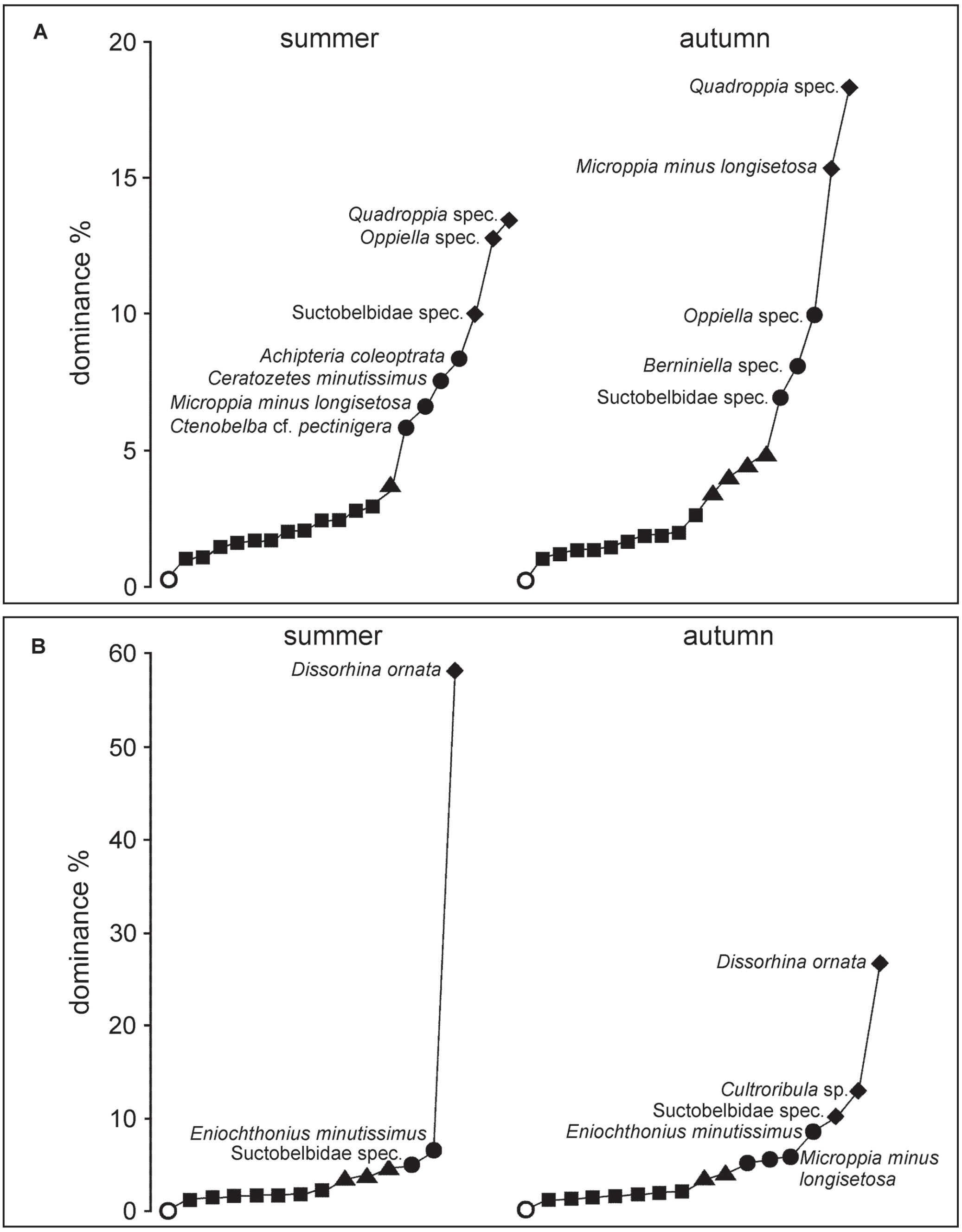

Figure 1. Relative abundance of oribatid mites in dry meadows on Peggauer Wand (**A**) and Zigöllerkogel (**B**); please note different value ranges of dominances. Symbols: ○ = summarisation of all rare species, ■ = occasional, ▲ = frequent, ● = common, ◆ = abundant.

In general, species richness was higher on PW than on ZK. The calculated diversity by the Shannon-index is relatively high on PW and closer to maximum diversity than on ZK. Consequently, the values for evenness are also different in a similar manner. Seasonal diversity differences are remarkable on ZK whereas they are more balanced on PW. The oribatid mite community shows high Simpson-index values near to 1 on PW indicating a high diversity in general (see Tab 3 for comparisons).

The Sørensen-coefficient shows the similarity of samples by comparing the appearance of species. A high conformity of the oribatid mite fauna exists within both habitats in both of the two different seasons. On the contrary the two habitats themselves differ remarkably, as demonstrated by the Sørensen-coefficient (0.55) (Tab. 4). Cluster analysis was performed to compare the species community of both habitats and all samples, using the Jaccard-index. The similarity of the samples and habitats was determined by matching the appearance of the different species. The samples of each habitat form

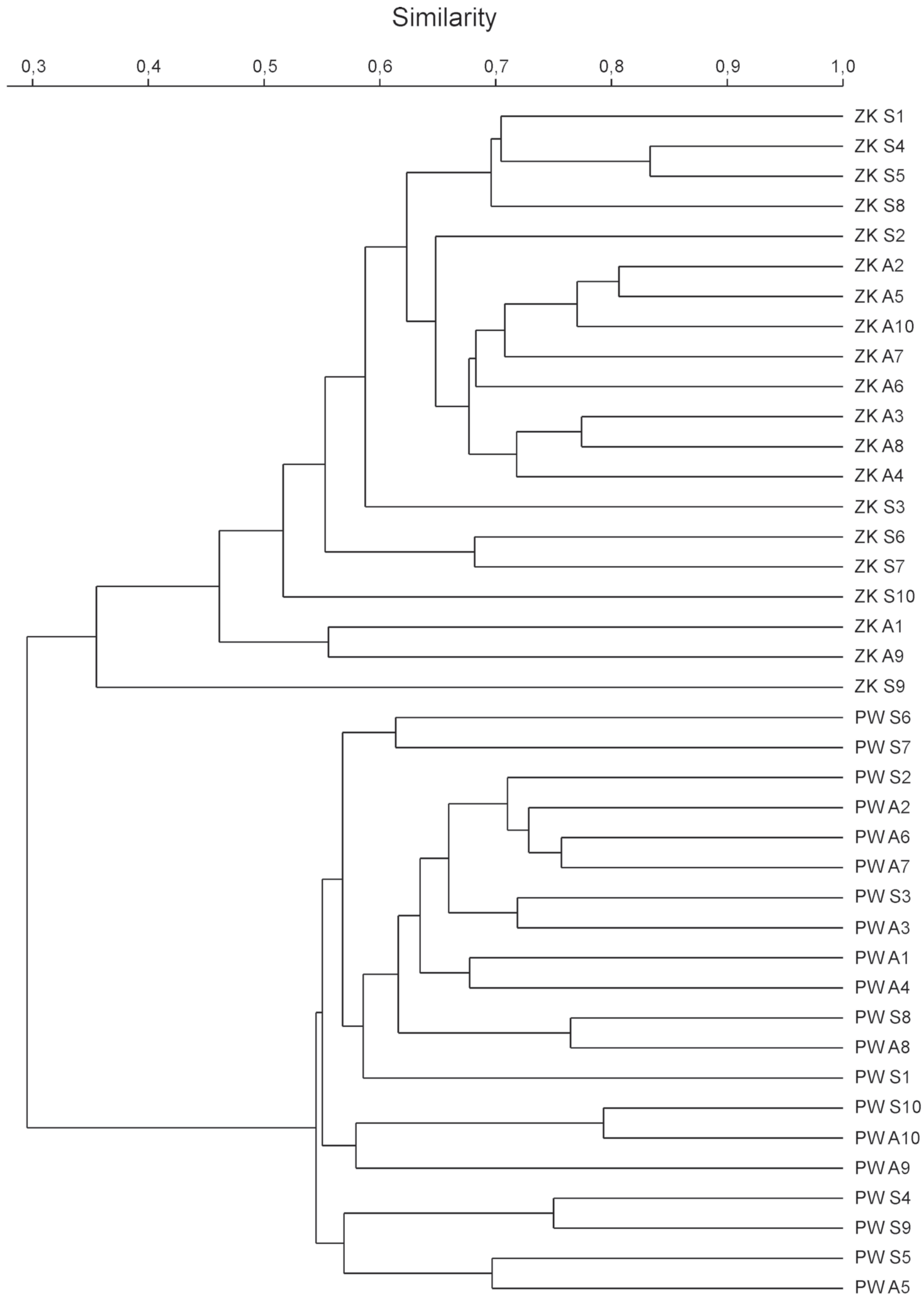

Figure 2. Group-Average-Dendrogram of similarity for all samples in both habitats. **PW_S** – Peggauer Wand summer, **PW_A** – Peggauer Wand autumn, **ZK_S** – Zigöllerkogel summer, **ZK_A** – Zigöllerkogel autumn; numbers indicating subsamples of transect.

their own cluster (Fig. 2). Sample ZK S9 shows the lowest similarity to all other ZK-samples caused by a very low number of species. The analysis of dissimilarities between the four groups of samples shows significant differences between PW and ZK (Table 5).

Table 3. Comparison of diversity: H_s – diversity, H_{max} – maximum diversity, E – evenness, D – Simpson-index, **s** – summer, **a** – autumn.

	PW			ZK		
	s	**a**	**total**	**s**	**a**	**total**
species	58	52	66	44	45	51
H_{max}	4.06	3.95	4.19	3.78	3.81	3.93
H_s	3.00	2.59	2.82	1.63	2.53	2.16
E	0.74	0.66	0.67	0.43	0.66	0.55
D	0.93	0.87	0.90	0.57	0.86	0.75

Table 4. Sørensen-coefficient (*Ss*). **s** – species only found in summer, **a** – species only found in autumn, **PW** – species only found on Peggauer Wand, **ZK** – species only found on Zigöllerkogel, **PW+ZK** – species found in both habitats.

	Number of species			*Ss*
	s	**a**	**s & a**	
PW	13	9	44	0.80
ZK	8	7	36	0.83
	PW	**ZK**	**PW+ZK**	***Ss***
Total species no.	**34**	**19**	**32**	**0.55**

Table 5. *R-values* of the analysis of similarities (ANOSIM) to test the significance of differences between the four groups of samples based on Bray-Curtis dissimilarity as distance measure. High R-values near 1 indicate dissimilarity between groups.

	PW_{summer}	PW_{autumn}	ZK_{summer}	ZK_{autumn}
PW_{summer}	0	0,05556	0,86040	0,97730
PW_{autumn}	0,05556	0	0,86560	0,94290
ZK_{summer}	0,86040	0,86560	0	0,30820
ZK_{autumn}	0,97730	0,94290	0,30820	0

4. Discussion

In the temperate zone dry areas show a relatively high diversity of oribatid mite species despite of–at least sometimes–relatively extreme environmental conditions (Huhta et al. 2010). Although these two dry meadows investigated are not far away from each other in linear distance and they are located at a similar altitude, the β-diversity is remarkably different with respect to both the plant and the mite communities. There is not only a difference in the number of oribatid mite species (66 on PW versus 51 on ZK) but also in the composition of the species community. The Group-Average-Dendrogram of the cluster analysis clearly demonstrates the independency of these two habitats.

According to the ecological characterisation of species given by Schatz (1983) and Weigmann (2006), only 23.5 % of the species in this study are classified as xerothermophilous, 21.2 % are euryoecious, 23.5 % silvicolous (most of them on PW because of the neighbouring forest), 10.6 % praticolous, muscicolous, and hygrophilous, and with ‘unknown’ requirements 21.2 %. Astonishingly, some of the euryoecious species were only found on one of the sampling sites. This concerns *Liochthonius muscorum* and *Oribatula tibialis* on PW, and *Heminothrus targonii*, *Dissorhina ornata, Protoribates capucinus* on ZK (see Appendix).

Schatz (1996) extracted 86 species from grass sods collected on south-exposed slopes in Eastern Tyrol. Five xerothermophilous species out of 21 of the Styrian samples—*Sellnickochthonius hungaricus*, *Poecilochthonius italicus*, *Ctenobelba pectinigera, Microzetorchestes emeryi*, and *Eupelops acromios*—are also reported by Schatz (1996).

In Lower Austria, Schatz & Fischer (2007) investigated six dry meadows and found 46 species in sod-samples. In the latter study, the most abundant species was a euryoecious one, *Dissorhina ornata,* the same as on ZK. Only five of the ‘xerobiont’ species reported by Schatz & Fischer (2007) occurred also on PW and/or ZK (*Phthiracarus laevigatus*, *Arthrodamaeus femoratus*, *Tectocepheus velatus alatus*, *Passalozetes perforatus*, *Eupelops acromios*).

Perlinger & Schatz (2009) sampled eight dry sites in Carinthia, and revealed 142 oribatid mite species with 44 of them classified as ‘xerobiont’. In total, 42 species found on PW and ZK were found by Perlinger & Schatz (2007) among which eleven were ‘xerobiont’ species (*Ph. laevigatus, A. femoratus, Damaeolus asperatus*, *C. pectinigera, Ramusella insculpta*, *Machuella bilineata*, *Provertex kuehnelti*, *P. perforatus, E. acromios, Peloptulus phaenotus*, *Ceratozetes minutissimus*).

The above comparisons show that the oribatid mite fauna differs remarkably between the investigated dry habitats in both small and wider geographical scales. The reasons are most likely multifactorial involving various ecological conditions. Important abiotic factors are probably the hill slope and exposure, factors energy absorption of soil depends on. Furthermore, small scale differences in the water holding capacity of soil might be of importance in the aggregation of species. As for biotic factors, the different plant communities influence the nutritional resources in these habitats. Moreover, the impact of surrounding habitats is impossible to assess without additional extensive studies. Apart from ecological parameters the comparability of the various studies suffers from differing sampling strategies e.g. sample size, number, and substrate (mosses, litter, or sods). Evidently, there is a lack of exact knowledge concerning the autecology and distribution of soil dwelling oribatid mite species complicating the comparison and interpretation of data. Typically, in the cited papers above as well as in the course of the current study, the first records of species were reported for a region or a country (see Krisper & Lazarus 2014). Therefore, it would be necessary and still worthwhile to investigate extensively the communities of oribatid mites in special habitats.

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Appendix – List of species.

family	species	a	er
Achipteriidae	*Achipteria coleptrata* (Linné, 1785)	+	eur
Ameridae	*Amerus* cf. *polonicus* Kulczynski, 1902	ZK	sil
Astegistidae	*Cultroribula bicultrata* (Berlese, 1905)	PW	sil
	Cultroribula sp.	ZK	uk
Autognetidae	*Conchogneta dalecarlica* (Forsslund, 1947)	PW	sil
Brachychthoniidae	*Liochthonius brevis* (Michael, 1888)	+	eur
	Liochthonius horridus (Sellnick, 1948)	ZK	sil
	Liochthonius cf. *laetepictus* Berlese, 1910	+	uk
	Liochthonius leptaleus Moritz, 1976	ZK	sil
	Liochthonius muscorum Forrslund, 1964	PW	eur
	Liochthonius propinquus Niedbala, 1972	ZK	uk
	Liochthonius cf. *sellnicki* (Thor, 1930)	PW	prat
	Liochthonius sp.1	PW	uk
	Liochthonius strenzkei Forrslund, 1942	PW	prat
	Poecilochthonius cf. *italicus* (Berlese, 1910)	+	xer
	Sellnickochthonius hungaricus (Balogh, 1943)	+	sil
	Sellnickochthonius immaculatus (Forsslund, 1942)	+	eur
	Sellnickochthonius oesziae (Balogh & Mahunka, 1979)	+	prat
	Sellnickochthonius zelawaiensis (Sellnick, 1928)	ZK	sil
Caleremaeidae	*Caleremaeus monilipes* (Michael, 1882)	PW	sil
Camisiidae	*Camisia spinifer* (C.L. Koch, 1835)	PW	sil
	Heminothrus targonii (Berlese, 1885)	ZK	eur
Carabodidae	*Carabodes coreaceus* C.L. Koch, 1835	+	eur
	Carabodes ornatus Storkan, 1925	PW	sil
Cepheidae	*Cepheus cepheiformis* (Nicolet, 1855)	PW	sil
Ceratozetidae	*Ceratozetes mediocris* Berlese, 1908	PW	hyg
	Ceratozetes minutissimus Willmann, 1951	PW	xer
	Ceratozetoides cf. *cisalpinus* (Berlese, 1908)	PW	uk
	Trichoribates incisellus (Kramer, 1897)	+	eur
Ctenobelbidae	*Ctenobelba* cf. *pectinigera* (Berlese, 1908)	+	xer
Cymbaeremaeidae	*Cymbaeremaeus cymba* (Nicolet, 1855)	PW	xer
Damaeidae	*Metabelba* cf. *pulverosa Strenzke, 1953*	+	eur
Damaeolidae	*Damaeolus asperatus* (Berlese, 1904)	+	xer
	Fosseremus laciniatus (Berlese, 1905)	+	eur
Eniochthoniidae	*Eniochthonius minutissimus* (Berlese, 1903)	ZK	sil
Epilohmanniidae	*Epilohmannia minima* Schuster, 1960	PW	xer
Euphthiracaridae	*Rhysotritia ardua* (C.L. Koch, 1841)	+	eur
Gehypochthoniidae	*Gehypochthonius rhadamanthus* Jacot, 1936	ZK	uk
Gymnodamaeidae	*Arthrodamaeus femoratus* (C.L. Koch, 1839)	ZK	xer
Haplozetidae	*Protoribates capucinus* Berlese, 1908	ZK	eur
Hermanniidae	*Hermannia gibba* (C.L. Koch, 1839)	PW	sil
Hermanniellidae	*Hermanniella dolosa* Grandjean, 1931	PW	sil
	Hermanniella punctulata Berlese, 1908	PW	sil

family	species	a	er
Liacaridae	*Dorycranosus curtipilis* (Willmann, 1935)	PW	xer
	Xenillus cf. *tegeocranus* (Hermann, 1804)	PW	uk
	Xenillus tegeocranus (Hermann, 1804)	+	eur
Machuellidae	*Machuella bilineata* Weigmann, 1976	+	xer
Mycobatidae	*Mycobates carli* Schweizer, 1922	PW	musc
Nanhermanniidae	*Nanhermannia nana* (Nicolet, 1855)	PW	hyg
Nothridae	*Nothrus anauniensis* Canestrini & Fanzago, 1867	+	eur
Oppiidae	*Berniniella* spec.	+	uk
	Dissorhina ornata (Oudemans, 1900)	ZK	eur
	Microppia minus longisetosa Subías & Rodriguez, 1988	+	uk
	Oppiella spec.	+	uk
	Ramusella cf. *insculpta* (Paoli, 1908)	+	xer
Oribatellidae	*Ophidiotrichus vindobonensis* Piffl, 1961	PW	xer
	Oribatella hungarica Balogh, 1943	+	uk
	Oribatella quadricornuta Michael, 1880	ZK	xer
	Oribatella sp.	ZK	uk
Oribatulidae	*Oribatula longelamellata* Schweizer, 1956	ZK	musc
	Oribatula tibialis (Nicolet, 1855)	PW	eur
Passalozetidae	*Passalozetes perforatus* (Berlese, 1910)	ZK	xer
Peloppiidae	*Ceratoppia quadridentata* (Haller, 1882)	+	eur
Phenopelopidae	*Eupelops acromios* (Hermann, 1804)	PW	xer
	Eupelops cf. *torulosus* (C.L. Koch, 1839)	+	uk
	Eupelops plicatus (C.L. Koch, 1835)	PW	sil
	Eupelops torulosus (C.L. Koch, 1839)	PW	sil
	Peloptulus phaenotus (C.L. Koch, 1844)	+	hyg
Phthiracaridae	*Phthiracarus laevigatus* (C.L. Koch, 1844)	PW	xer
	Phthiracarus sp.	+	uk
	Steganacarus clavigerus (Berlese, 1904)	ZK	sil
	Steganacarus phyllophorus (Berlese, 1904)	PW	xer
Quadroppiidae	*Quadroppia* spec.	+	uk
Scheloribatidae	*Scheloribates quintus* Wunderle, Beck & Woas, 1990	PW	sil
Scutoverticidae	*Provertex kuehnelti* Mihelcic, 1959	PW	xer
Suctobelbidae	Suctobelbidae spec.	+	uk
Tectocepheidae	*Tectocepheus minor* Berlese, 1903	+	hyg
	Tectocepheus velatus alatus Berlese, 1913	+	xer
	Tectocepheus velatus sarekensis Trägardh, 1910	+	eur
	Tectocepheus velatus tenuis Knülle, 1954	PW	xer
	Tectocepheus velatus velatus (Michael, 1880)	+	eur
Tegoribatidae	*Neophysobates* sp.	ZK	uk
Trhypochtoniidae	*Trhypochthonius silvestris europaeus* Weigmann & Raspotnig, 2009	ZK	uk
Zetorchestidae	*Microzetorchestes emeryi* (Coggi, 1898)	PW	xer
	Zetorchestes falzonii Coggi, 1898	PW	sil

List of collected species and ecological requirements. **a = appearance**: **PW** – Peggauer Wand, **ZK** – Zigöllerkogel, **+** – **both habitats**. **er = ecological requirement**: **eur** – euryoecious, **hyg** – hygrophilous, **musc** – muscicolous, **prat** – praticolous, **sil** – silvicolous, **uk** – unknown, **xer** – xerothermophilous.