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Diversity of soil mite communities in different habitats of Saskhori quarries, Georgia

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The Saskhori quarry belongs to the Heidelberg Cement Company and is located to the west of the same-named village and approximately 12.5 km to the southeast of Kaspi. To the north of the extraction site, the river Kura meanders. The surroundings are characterized by pastures, steppes, arable land, scrublands and woodland in different stages (Restoration concept of Saskhori quarry, 2012). The mining of the area has not yet started (as of February 2018) and therefore native habitats including oligo to mesotrophic grasslands and steppes, secondary mixed forests and scrublands typical to semi-arid eastern Georgian climate zones (Nakhutsrishvili 2012) still exist. Although the dry grasslands of east Georgia (such as Saskhori area) have been under continuous anthropogenic disturbance for centuries (active grazing mostly by cows and sheep), they still harbor numerous rare and endangered plant species (Nakhutsrishvili 2012). Unfortunately, invertebrates are generally poorly studied in Georgia and it is unknown what species might occur. Even the relatively well studied groups, such as oribatid mites (Acari, Oribatida) are scarcely sampled from the region (Murvanidze and Mumladze 2016). In the present article, our aim was to investigate species diversity of oribatid mites in the area designated to mining purposes in order to assess potential loss of unique species complexes(if any) and establish a background for future monitoring purposes. The choice of study taxa was based on the importance of soil mites as dominant inhabitants of soil ecosystems which play a crucial role in soil ecosystem functioning. Since mites are relatively well studied in Georgia, we can use them as a surrogate for the valuation of the studied area in terms of biodiversity conservation.

During the field survey, several different habitats were identified, including (a) early-stage natural and semi-natural deciduous woodlands and regrowth, (b) degraded (overgrazed) steppes, (c) hemi-xerophitic shrub stands and (d) perennial calcareous-oligotrophic grassland. In all these habitats we made an inventory of plant species using non-standard transects (Table 1). In particular, all the encountered species were recorded during the half day movement along the transect crossing over all the major habitats. Such investigations were performed four times during the vegetation periods of 2017 (March, May, June, and July).

Table 1. Dominant plant species encountered in each habitat (the list is arranged in an alphabetical order).

Deciduous woodland	**Hemi-xeropitic shrubland**	**Heavily grazed dry grassland**	**Perennial calcareous and oligotrophic grasslands**
Berberis iberica Stev. et Fisch	*Achillea biebersteinii* (L.)	*Achillea millefolium* L.	*Anhusa arvensis orientalis* Fisch.
Carpinus orientalis Mill.	*Achillea millefolium* (L.)	*Adonis flammea* Jacq.	*Astragalus brachycarpus* L.
Cotinus coggygria Scop.	*Aegilops lorentii* (L.)	*Aegilops biuncialis* Vis.	*Bothriochloa ischaemum* Keng.
Cotoneaster racemiflorus C. Koch	*Asparagus officinalis* (L.)	*Alyssum alysoides* L.	*Cardus* sp.
Elaeagnus rhamnoides L.	*Astragalus* spp.	*Anhusa arvensis* subsp. *orientalis* Fisch.	*Consolida orientalis* (J. Gay.)
Juniperus communis L.	*Dictamnus albus* (L.)	*Anthoxanthum odoratum* L.	*Echium maculatum* (L.)
Paliurus spina-christi Mil	*Echinops sphaerocephalus* (L.)	*Artemisia lerchiana* Web.	*Erodium cicutarium* L.
Quercus iberica Stev.	*Eryngium caeruleum* M. Bieb	*Botriochloa* sp.	*Euphorbia boissieriana* Pokh.
Rhamnus pallasii F. et M. *Pyrus cf. caucasica* A. Fed	*Fragaria vesca* (L.)	*Bromus tectorum* L.	*Fumaria vaillantii* Loisel.
Vibrunum lantana L.	*Hypericum perforatum* (L.)	*Cirsium* sp.	*Leucanthemum vulgare* Lam.
	Inula orientalis (L.)	*Echinaria capitata* L.	*Linumaus triacum* (L.)
	Ophrys fuciflora (F.W.Schmidt) Moench	*Tragopogon* sp.	*Lolium perenne* L.
	Paliurus spina-christi Mill.	*Eryngium caeruleum* M. Bieb.	*Lolium* sp.
	Plantago major (L.)	*Eryngium campestre* L.	*Orobanche lutea* Baumg.
	Potentila recta L.	*Galium verum* L.	*Scutellaria orientalis* L.
	Scabiosa sp.	*Hordeum* sp.	*Sisymbrium loeselii* L.
	Scutellaria orientalis (L.)	*Hypericum perforatum* L.	*Teucrium polium* L.
	Taraxacum officinale (Wgg.)	*Inula orientalis* (Lam.)	*Thymus transcaucasicus* (Ron.)
	Ziziphora puschkinii Adam	*Leucanthemum vulgare* (L.)	*Trifolium pretense* L.
		Lotus transcaucasicus Cuprian	*Veronica* sp.
		Medicago minima (Grufb.)	
		Medicago orbicularis (L.)	
		Phleum phleoides L. (F. Karst)	
		Poa sp.	
		Stipa pulcherrima (L.)	
		Teucrium polium L.	
		Thymus transcaucasicus (Ron.)	
		Xeranthemum squarosum Boiss.	
		Vici sp.	

For oribatid mites, we sampled three subplots per habitat, for degraded steppes two subplots were sampled (Table 2, Fig. 1). Degraded steppes represent small, heavily damaged, less calcareous part of perennial grassland; so that in total, we had more samples from grassland areas, than from other habitats. In each subplot, four samples (soil core of $10cm^3$) were collected from March to October of 2017. Soil samples were labeled, taken in the laboratory and invertebrates were extracted during one week using modified Berlese-Tullgren extractor. Extraction was performed for 24 hours and individuals were stored in 70% ethanol. For species determination, temporary cavity slides were prepared using lactic acid. Only adult individuals were identified to species level. For identification of oribatid mites, keys of Ghilarov and Krivolutsky (1975) and Weigmann (2006) and for identification of mesostigmatic mite keys of Ghilarov and Bregetova (1977) and Karg (1993) were used. Voucher species were stored in the collection of the Agricultural University of Georgia. For oribatid mites, we followed family classification and nomenclature of Schatz *et al*. (2011) and for mesostigmatids – family classification and nomenclature of Lindquist *et al*. (2009). The diversity indexes were calculated using PAST and according to Magurran (2004).

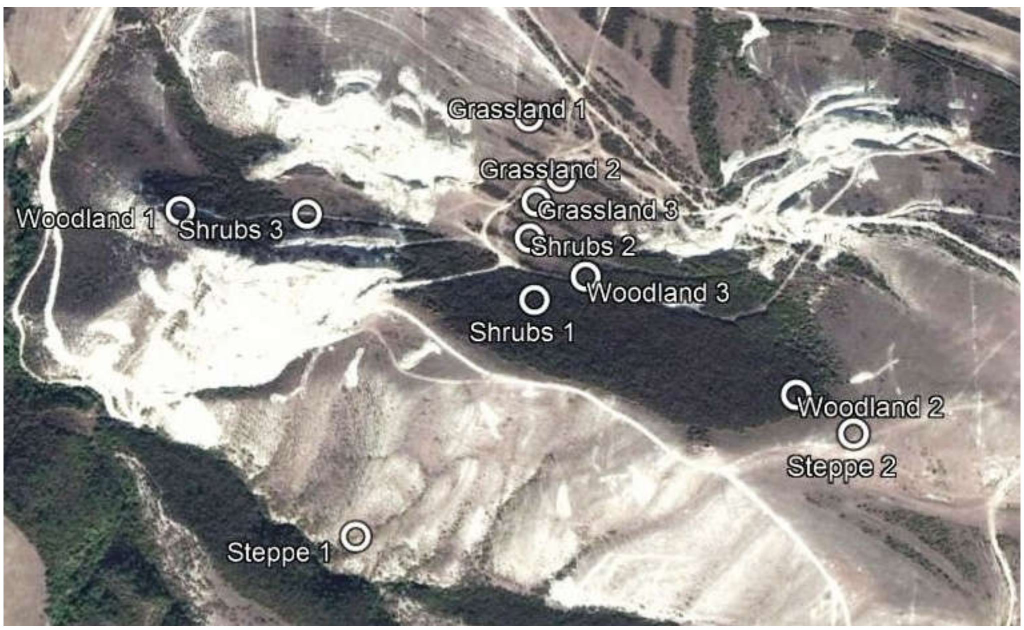

Figure 1. Map of soil sampling locations on Saskhori quarries.

Table 2. Sampling locations on Saskhori quarries

MapID	Lattitude	Longitude	Habitat
1	41.84267	44.52476	Deciduous woodland
2	41.84083	44.53277	Deciduous woodland
3	41.84204	44.52991	Deciduous woodland
4	41.84179	44.52930	Hemi-xerophitic shrubland
5	41.84231	44.52935	Hemi-xerophitic shrubland
6	41.84256	44.52625	Hemi-xerophitic shrubland
7	41.83955	44.52707	Heavily grazed dry grassland (steppe)
8	41.84064	44.53296	Heavily grazed dry grassland (steppe)
9	41.84355	44.52923	Perennial calcareous and oligotrophic grasslands
10	41.84299	44.52965	Perennial calcareous and oligotrophic grasslands
11	41.84272	44.52939	Perennial calcareous and oligotrophic grasslands

Fifty one oribatid mites and nine mesostigmatic species were identified in total (Table 3). Three gamasoid mites were identified to the morphospecies level. From mesostigmatic taxa, eight belong to the cohort Gamasina and one species belongs to the cohort Uropodina. Two species of mesostigmatic mites *Zercon monigenus* Błaszak, 1972 (Gamasina) and *Trachytes stammeni* Hirschmann and Zirngiebl-Nicol, 1969 (Uropodina) are new records for Caucasian fauna and two more species –*Proprioseiopsis messor* (Wainstein, 1960) and *Neoseiulus montanus* (Wainstein, 1962a) (both Gamasina) are new for Georgia. However, thenumber of singletons (21) and doubletons (19) was quite high. Only two oribatid species –*Xenillus tegeocranus* (Hermann, 1804) and *Scheloribates laevigatus* (C.L. Koch, 1835) were recorded in all four types of habitats.

Table 3. List of oribatid and mesostigmatic mites in different habitats of Saskhori quarry with total numbers of individuals and indication of their ecological preferences

Infraorders	Superfamilies	Species	Forest	Shrubs	Steppe	Grassland	Ecology*
		Oribatida					
Enarthronota	Hypochthonioidea	*Hypochthoniella minutissima*	1	0	0	1	acidic forest and bog soils
		Sphaerochthonius splendidus	54	0	0	0	dry urban and forest soils
Mixonomata	Epilohmannioidea	*Epilohmannia cylindrica*	0	0	0	4	dry soils
	Euphthiracarpodea	*Acrotritia ardua*	10	0	0	9	ubiquitous
		Steganacarus carinatus	2	0	0	0	ubiquitous
		Steganacarus ochraceus	48	0	0	4	Forest soils
Desmonomata	Crotonioidea	*Camisia horrida*	2	0	0	0	soil, moss, arboricolar
		Camisia lapponica	1	0	0	0	forest soils
		Camisia segnis	1	0	0	0	arboricolous, rare in forest and meadow soils
		Nothrus annauniensis	0	0	0	3	forest soils
	Hermannielloidea	*Hermanniella punctulata*	3	0	0	0	forest soils
	Neoliodoidea	*Poroliodes farinosus*	0	5	0	0	arboricolous, rare in forest and meadow soils
	Plateremaeidea	*Aleurodamaeus setosus*	8	11	0	17	forest soils
		Arthrodamaeus femoratus	0	4	0	0	meadow and forest soils
		Licnobelba latiflabellata	3	0	0	0	forest soils
	Dameoidea	*Belba dubinini*	0	0	0	1	forest soils
		Metabelba monilipeda	5	0	0	6	forest soils
	Ameroidea	*Damaeolus ornatissimus*	0	0	0	4	ubiquitous
		Fosseremus laciniatus	1	0	0	2	forest soils

Table 3. Continued.

Infraorders	Superfamilies	Species	Forest	Shrubs	Steppe	Grassland	Ecology*
		Oribatida					
	Zetorchestoidea	*Zetorchestes micronychus*	8	3	0	1	Forest soils
	Gustavioidea	*Gustavia microcephala*	3	0	0	1	forest soils
		Dorycranosus splendens	3	2	0	13	forest soils
		Liacarus brevilamellatus	1	11	0	11	forest soils
		Xenillus tegeocranus	9	6	1	22	Forest soils, moss, litter
		Ceratoppia quadridentata	0	2	0	16	forest soils
	Carabodoidea	*Austrocarabodes foliaceisetus georgiensis*	10	2	0	5	dry steppe soil
	Oppioidea	*Graptoppia foveolata*	0	0	0	2	unclear
		Oppiella fallax	0	46	0	21	ubiquitous
		Oppiella similifallax	0	0	0	26	ubiquitous
		Ramusella clavipectinata	18	0	0	5	ubiquitous
		Suctobelebella subtrigona	2	0	0	11	ubiquitous
	Tectocepheoidea	*Tectocepheus punctulatus*	28	0	0	2	forest soils
		Tectocepheus velatus	5	2	0	16	ubiquitous
	Phenopelopoidea	*Eupelops acromios*	0	0	0	5	ubiquitous
		Eupelops tardus	3	0	0	0	forest soils and alpine meadows
		Peloptulus phaenotus	0	6	0	23	ubiquitous
	Achipterioidea	*Parachipteria fanzagoi*	0	11	0	0	forest soils
	Oripodoidea	*Haplozetes elegans*	0	4	0	0	forest soils
		Haplozetes longisacculus	0	11	0	32	degraded and dry
		Protoribates capucinus	3	0	0	10	ubiquitous
		Oribatula (Zygoribatula) cognata	0	27	0	62	ubiquitous
		Oribatula tibialis	54	2	0	11	ubiquitous
		Scheloribates laevigatus	1	15	1	18	ubiquitous
		Scheloribates latipes	10	2	0	2	ubiquitous

Table 3. Continued.

Infraorders	Superfamilies	Species	Forest	Shrubs	Steppe	Grassland	Ecology*
		Oribatida					
	Ceratozetoidea	*Ceratozetes conjunctus*	0	2	0	1	alpine meadow and forest soils
		Trichoribates naltschicki	0	0	2	3	forest soils
		Trichoribates trimaculatus	0	4	0	0	ubiquitous
		Minunthozetes pseudofusiger	12	0	0	1	ubiquitous
		Punctoribates punctum	0	0	0	3	ubiquitous
	Galumnoidea	*Galumna alata*	1	29	0	76	ubiquitous
		Pergalumna nervosa	0	0	0	40	forest and meadow soils
		Mesostigmata					
Gamasina	Zerconoidea	*Prozercon satapliae*	5	0	0	0	forest soil and litter
		Zercon montigenus	2	0	0	2	Litter in the forest
	Parasitoidea	*Pergamasus* (*Triadogamasus*) sp.	3	0	0	1	
	Phytoseioidea	*Ambliseius* sp. 1	0	0	0	1	
		Ameroseius sp. 2	4	1	0	1	
		Neoseiulus montanus	1	0	0	0	Forest soil
		Proprioseiopsis messor	0	1	0	0	Meadow soils
	Dermanyssoidea	*Geolaelaps aculeifer*	9	7	0	8	Meadow soils
Uropodina	Polyaspidoidea	*Trachytes stammeni*	2	0	0	0	Soil and litter

* Ecology of oribatid and mesostigmatic mite species was determined after Weigmann (2006), Karg (1993) and based on personal experience.

From oribatid mites, two species belong to the infraorder Enarthronota and four species to the infraorder Mixonomata. The rest of fauna, 45 species belong to the infraorder Desmonomata. Within Desmonomata, eight species belong to the superfamily Oripodoidea, five species to the superfamilies Gustavioidea, Oppioidea and Ceratozetoidea and four species to the superfamily Crotonioidea. The rest of superfamilies are represented by a minor number of species.

The highest number of species was recorded for perennial calcareous and oligotrophic grassland sites (43), which were followed by forests (37) and shrubs (25). Degraded steppes were extremely poor in soil mite species – only three oribatid species and no mesostigmatans were recorded. The lowest dominance (0.06) and highest Simpson's index of diversity (1-D = 0.93) were also recorded for grasslands. Uneven distribution (with low Evenness indices) of mites was suggested for all habitats (except degraded steppe) (Table 4).

Table 4. Diversity indexes for oribatid and mesostigmatid mites of Saskhori quarry

	Woodland	Shrubs	Steppe	Grassland
Taxa_S	37	25	3	43
Individuals	335	326	4	501
Dominance_D	0.09052	0.1574	0.375	0.06568
Simpson_1-D	0.9095	0.8426	0.625	0.9343
Evenness_e^H/S	0.4797	0.431	0.9428	0.53

Most of the identified mites (19 species) belong to the ubiquitous and forest species, eight species belong to the meadow specialists and only minor numbers of species belong to the xerophile and arboricolar ones (Table 3).

Among the studied habitats, perennial calcareous and oligotrophic grasslands were the richest habitats represented by 43 mite species. *Oribatula* (*Zygoribatula*) *cognata* (Oudemans, 1902) and *Galumna alata* (Hermann, 1804) were most abundant. Overall spectrum of soil mites in grassland habitat was represented by ubiquitous species which numerically dominated over forest species. Ubiquitous species also showed higher numbers of individuals compared to the forest species (Table 3).

Woodland habitats were also quite rich with 37 mite species dominated by typical forest or ubiquitous species [such as *Ramusella clavipecinata* (Michael, 1885), *Oribatula tibialis* (Nicolet, 1885), *Tectocepheus punctulatus* Djaparidze, 1985, *Minunthozetes pseudofusiger* (Schweizer, 1922)]. A rare exception was finding high numbers of *Austrocarabodes foliaceisetus georgiensis* Murvanidze & Weigmann 2007 in the forest which is usually known to prefer dry steppe soils (Murvanidze and Weigmann 2007; Murvanidze and Todria 2015). *Sphaerochthonius splendidus* (Berlese, 1904) and *Steganacarus* (*A.*) *ochraceus* (Niedbała, 1983) were found in highest abundance (Table 3).

In contrast, hemi-xerophitic shrub stands were relatively poor with mite fauna, represented by 25 ubiquitous or meadow specific species with the highest abundance for *Oppiella fallax* (Paoli, 1908) (Table 3). Grassland habitats were extremely poor showing only three species. *Scheloribates laevigatus* (C.L. Koch, 1935) is known as having wide ecological tolerance, while *Xenillus tegeocranus* (Hermann, 1904) and *Trichoribates naltschiki* (Schaldybina, 1971) are usually found in forest and meadow soils (Table 3).

Oribatid species representatives of Brachypylina dominated over the lower oribatids and within Brachypylina Gymnonota species were present in higher numbers (22) than Poronota (18). Poronota and the genus *Tectocepheus* are known to dominate in anthropogenically modified sites (Maraun and Scheu 2000) and reach relative high densities in disturbed habitats like dumps (Skubala 1995). The small proportion of Poronotic species and the lower number of *Tectocepheus* individuals in the studied material indicates low anthropogenic disturbance for all Saskhori habitats except steppes (which were heavily overgrazed). During previous studies performed in urban and industrial sites of Georgia, species like *Punctoribates punctum* (C.L. Koch, 1839) together with *Tectocepheus velatus* (Michael, 1880) and *Sch. laevigatus* were found numerously in abandoned quarries, post-industrial dumps, ruderal and urban soils (Murvanidze *et al*. 2011, 2013; Murvanidze and Todria 2015). Their moderate numbers in forest and grassland sites indicate low anthropogenic disturbance for studied sites.

Representatives of Oppiidae are known to be abundant in forest soils whereas in disturbed habitats like fields their density is usually low (Maraun and Scheu 2000). They are known to be able to occupy a wide range of ecological niches and colonize a wide spectrum of ecosystems (Stefaniak and Seniczak 1981). Our previous studies showed that they were less affected by anthropogenic disturbances (Murvanidze *et al*. 2011) and dominated urban ecosystems. In present habitats all Oppioidea were found in grasslands, in woodland there were only two species present, one species – in shrubs and they were completely absent from steppes.

Species common of dry soils like *S. splendidus*, *Epilohmannia cylindrica* (Berlese, 1904), *A. foliaceisetus georgiensis* and *Haplozetes longisacculus* Murvanidze & Weigmann 2012 were continuously found in studied habitats.

In spite of a low number of identified taxa of mesostigmatic mites, four new records for Georgia and two new records for the Caucasus were registered. Species of the infraorder Uropodina were not known from the Caucasus before our investigation (Ghilarov and Bregetova 1977) and therefore finding these species (e.g. *T. stammeni*) can be considered as starting point for regional mesostigmatic investigation. Four new records from nine identified taxa in semi-natural habitats of Saskhori area indicate an existence of many yet unknown species in Georgia.

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