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Article

Diversity and community structure of oribatid mites (Acari: Oribatida) in the dominant habitats of Machakhela National Park (Georgia, Caucasus)

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ABSTRACT
Diversity and distribution of oribatid mites in the unique, relict Colchic rainforests of Machakhela National Park (MNP), which is UNESCO world heritage have been surveyed. Oribatid mite communities were investigated at six sites of Machakhela National Park (West part of Georgia) in the most common habitat types of Colchic forests: Alder (*Alnus barbata*) forest and mixed forest with chestnut (*Castanea sativa*), beech (*Fagus orientalis*) and hornbeam (*Carpinus* sp.). A total of 81 species of Oribatid mites were identified and a complete checklist of species is provided. The subgenus *Ctenobelba* (*Caucasiobelba*) Subías & Shtanchaeva, 2010, with the species *C.* (*C.*) *urhani* Baran, 2015, is recorded for the first time from Georgia. Furthermore, eight species of ptyctimous mites (*Oribotritia krivolutskyi*, *Acrotritia duplicata*, *Phthiracarus incertus*, *P. peristomaticus*, *P. scitus*, *Steganacarus incomptus*, *Austrophthiracarus pavidus*, *Atropacarus perversus*) were found that are omitted in the recently published annotated checklists of Georgian oribatid mites, so the number of moss mites registered in the country's territory increased to 572. The results of our study clearly demonstrated differences in the oribatid mite community of the Colchic forests in the protected area of the Machakhela National Park. The cluster analysis separated mite communities of alder and Colchis mixed broadleaf forests. Species richness, Shannon index, and evenness differed significantly between the two forest habitats. The results of one-way ANOVA showed that species abundance did not differ between the two habitat types. The results of the SIMPER analysis ranked nine species of Oribatid mites responsible for the difference in the mite community diversities in the studied forest habitats. These species do not belong to the category of abundant species, however they are strongly associated with each target forest habitat. We compared the results of our study with the results of earlier studies concerning the distribution and diversity of the oribatid mite communities in Mtirala and Kolkheti National Parks. Mtirala National Park was the most species rich site and had the largest species overlap with both Machakhela and Kolkheti National Parks. Machakhela and Kolkheti National Parks had fewer overlapping species. It also showed that the compared sites from the National Park territory with the most humid microclimate hold higher levels of species richness. The preciseness of the result of the comparison might be low because of uneven sampling, however, it gives a reasonable basis to assume that the humidity is the important factor determining the distribution character of mites also in Colchis forest habitats as it is on the larger geographical scale.

KEYWORDS: Checklist, Colchis forest, comparative study, *Ctenobelba*, distribution, oribatid mites, new record.

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INTRODUCTION

The Caucasus region is considered one of the 25 global biodiversity hotspots with an exceptional concentration of endemic species but also remarkable habitat loss (Myers *et al.* 2000). The Centre of biodiversity in this region is the colchic deciduous rainforests, comprising a highly diverse flora and fauna with endemic and relict species that have survived the glacial cycles of the ice age. These forests are a well-known refugium with many relict plants, representing the etalon of heritage of the natural history of Georgia; broadleaf forests of Colchic are descendants of ancient boreal Tertiary period flora (Arabuli *et al*. 2007). Colchic forests are humid temperate deciduous rainforests with an annual rainfall of 2000–4500 mm and a mean annual temperature of 15 °C at coast level; they are among the oldest nemoral broad-leaved forests globally (Zazanashvili *et al.* 2004). In 2021, by the decision of World Heritage Committee of UNESCO "Colchic Rainforests and Wetlands" with unique ecosystems and rich biodiversity were added to the World Heritage List (UNESCO 2023). Machakhela is a National Park, established in the Adjara region (West part of Georgia) in 2012 with the main purpose to maintain the biodiversity and ecosystems of ancient deciduous Colchic rain-forests, covering 95% of the forest habitats in park area (Dolukhanov 2010).

The soil environment, very important for the vegetation above the ground, is extremely diverse and contributes a wide range of ecosystem services that are essential to life on earth and the sustainable function of ecosystem; soil organisms have direct and indirect impacts on the land; they improve soil fertility and ecosystem stability (Barrios 2007).

Abiotic factors, such as temperature, soil structure, water content and pH, have been shown to affect soil Mesostigmata communities (Manu *et al.* 2016). Climate change affects the structure of soil microarthropod communities, changes in soil moisture content, either as direct effect of changes in precipitation or as indirect effect of warming and elevated (CO_2) treatments (Kardol *et al*. 2011).

Oribatid mites are the most abundant and the species-richest group of soil arthropods; they are distributed all over the world from the Arctic to the Antarctic, in temperate, arid and tropical regions; about 10,000 species of the mites have been described worldwide and densities can be up to 300,000 individuals in one square meter (Norton 1990). Oribatid mites mainly live in the organic layer of soil and represent important saprophagous organisms (Norton 1990; Behan-Pelletier 1999). They are very sensitive to habitat succession and other disturbances, such as land use, fires and chemical pollution by metals or synthetic products (Behan-Pelletier 1999; Migliorini *et al*. 2002, 2005). The assessment of the abundance and diversity of oribatid mites is difficult due to their small size, cryptic way of life in soil and difficult morphological determination; therefore, diversity and abundance pattern in many regions remain poorly known and mite diversity is substantially underestimated (Schatz and Behan-Pelletier 2008).

Compared to vertebrates, invertebrate animals are much less studied, although their diversity is much higher. According to Karppinen *et al*. (1987), the oribatid mite fauna is very diverse in the Caucasus region and represented by 725 taxa (species and subspecies) in the areas of the Caucasus and Crimea. The catalog of Caucasian oribatid mites (Subías and Shtanchaeva 2010a) reported 1026 species and subspecies, which belong to 296 genera and 97 families. Knowledge of Georgian oribatid fauna is extensive, and numerous data, like checklists, are available. Djaparidze (1963) published the first list of oribatid mites. Darejanashvili (1964) recorded 71 species in Tbilisi and its neighboring areas. Later, Djaparidze (1966) registered 43 species of oribatid mites on Trialeti Range and Darejanashvili (1967) discovered 68 species in the Borjom-Bakuriani gorge. The annotated list with 283 species of Georgian oribatid mites was published by Reck (1976). One of the most diverse and well-investigated regions of oribatid mite fauna is the Gombori Range, which records half number of species (221 species) known from the whole territory of Georgia (Arabuli 2004). The recent annotated lists of oribatid mites included 534 (Murvanidze and Mumladze 2016) and 562 (Murvanidze *et al.* 2023) species from the whole country.

Our research was based on the material of oribatid mites collected in Machakhela National Park, which is unique for its Colchic type of vegetation. The Colchic forest with its relict and endemic plant species creates a shelter for many animal species including invertebrates; this type of habitat is distributed in Adjara region within the territory of Georgia (Arabuli *et al*. 2007; Zazanashvili 2009; Murvanidze *et al*. 2011). The primary purpose of this paper was to present the species composition of oribatid mites in main habitats and ecosystems of Machakhela National Park and a checklist of the identified taxa from the study territory.

The Colchic forests of Machakhela National Park have been insufficiently surveyed and the data of oribatid mite fauna is poor (Gratiashvili *et al.* 2022). Our research was the attempt to study the taxonomic diversity of oribatid mites distributed in National Park territory. In this paper, we provide the research results on oribatid mite community, a georeferenced checklist and new records of oribatid mite fauna of Georgia and Caucasus. We also provide a baseline comparison of the diversity of the oribatid mite communities in the two most common habitats of the national park, Alder forest (*Alnetum*) and Colchic mixed broadleaf forests in this study.

MATERIAL AND METHODS

Study area

The research was carried out in Machakhela National Park, Khelvachauri Municipality, West Georgia. Machakhela National Park is located on an 8733-ha area and was given the status of a protected area in 2012. The park holds seven villages and although the total human population is small within the park (680 households and 975 permanent residents according to the population census done in 2014 by the National Statistics Office of Georgia), over 35% of the protected area is considered to be under strong anthropogenic impact in the recent period. The Colchic type of forests of Adjara distributed on the territory of Machakhela National Park are majorly formed by alder and mixed broadleaf forests. The Colchic type forests are evergreen shrubs and several herbaceous plant species which form the unique vegetation community of the forests (Zazanashvili *et al.* 2004).

Field surveys were conducted in July 2020. The material was collected on six sites distributed within two types of forest habitats: 1. Humid forest dominated by alder (*Alnus barbata*) [Habitat code: 91E0*01 based on the 'Habitats of Georgia' (Akhalkatsi and Tarkhnishvili 2012); reference habitat type in the EUNIS habitat classification: 'Mixed riparian floodplain and gallery woodland', code: G1.2 (Davies *et al.* 2004)]; and 2. Colchic relic broad-leaved mixed forest (Local code of habitat: 9BCGE*; reference habitat type in the EUNIS habitat classification: Thermophilous deciduous woodland, code: G1.7) with chestnut (*Castanea sativa*), beech (*Fagus orientalis*) and hornbeam (*Carpinus betulus*) (Table 1). For each habitat type, three experimental plots (30 × 30 m in size) with a homogeneous vegetation structure were selected and coded with letters: KK1, KK2, KK3, KK4, KK5 and KK6 (Fig. 1).

Sampling and oribatid determination

We used a standard protocol for the survey of oribatid mites. Three soil samples (10 × 10 × 10 cm) in each site (18 samples in total) were randomly collected and stored in plastic bags. Oribatid mites were extracted using Berlese-funnel apparatus for 10 days and specimens were preserved in 70% ethanol. Adult individuals were scanned using a stereoscopic microscope and mounted onto temporary microscopic slides in lactic acid on cavity slides for the taxonomical identification and determination of their quantity in the samples. After the preparation, samples were preserved in the collection of the Institute of Zoology of Ilia State University, Georgia.

The following keys were used for the taxonomical identification of the mites: Ghilarov and Krivolutsky (1975), Balogh and Mahunka (1983), Weigmann (2006), Shtanchaeva and Subías (2009), and Niedbała (2011). A list of oribatid mites was produced in systematic order; in the checklist, each species is given with the codes of sampling sites. The superfamily and family names

follow the nomenclature of Schatz *et al.* (2011); genus and species names are in accordance with Subías (2004) and Weigmann (2006). Identification was made using a Micros light microscope Pink MC50.

Table 1. General description of the sampling sites in Machakhela National Park.

Site code	UTM zone	E	N	Altitude (m a.s.l.)	Vegetation type
KK1	37 T	728907	4600970	806	Alder forest (*Alnus barbata*); undergrowth: Fern, Blackberry, Rhododendron (*Rhododendron ponticum*), *Sambucus ebulus*.
KK2	37 T	728552	4600854	732	Alder forest (*Alnus barbata*); undergrowth: Fern, Blackberry, Rhododendron (*Rhododendron ponticum*), *Sambucus ebulus*.
KK3	37 T	728330	4600483	603	Alder forest (*Alnus barbata*); undergrowth: Fern, Blackberry, Rhododendron (*Rhododendron ponticum*), *Sambucus ebulus*.
KK4	37 T	728570	4600471	551	Colchic relic broad-leaved mixed forest with chestnut (*Castanea Sativa*), beech (*Fagus orientalis*) and hornbeam (*Carpinus betulus*); undergrowth: Fern, Blackberry, Rhododendron (*Rhododendron* sp.), *Sambucus ebulus*.
KK5	37 T	728704	4600380	518	Colchic relic broad-leaved mixed forest with chestnut (*Castanea Sativa*), beech (*Fagus orientalis*) and hornbeam (*Carpinus betulus*); undergrowth: Fern, Blackberry, Rhododendron (*Rhododendron* sp.) *Sambucus ebulus*.
KK6	37 T	728758	4600293	489	Colchic relic broad-leaved mixed forest with chestnut (*Castanea Sativa*), beech (*Fagus orientalis*) and hornbeam (*Carpinus betulus*); undergrowth: Fern, Blackberry, Rhododendron (*Rhododendron* sp.), *Sambucus ebulus*.

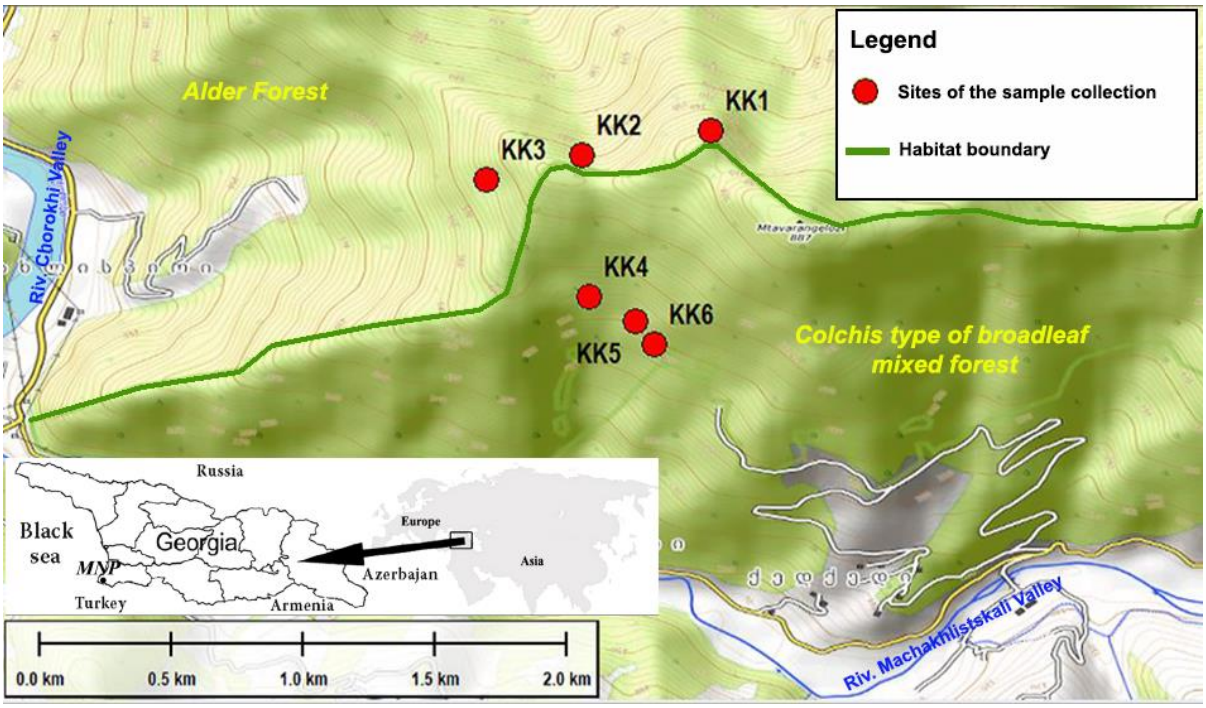

Figure 1. Distribution of the sites of the sample collection of the oribatid mite diversity in the Machakhela National Park.

Data analysis

We calculated Sørensen–Dice (Dice 1945; Sørensen 1948) coefficients of the similarity of the diversity; species richness, and abundance; Shannon index of diversity and evenness to estimate and compare the diversity of the mites between the sites of the sample collection and the forest habitats. One-way ANOVA was used to compare the means of Shannon's index of diversity, evenness, species richness, and abundance between the two investigated habitats. A cluster analysis was conducted using the algorithm of the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) and Dice (Sørensen–Dice) similarity metrics as an amalgamation rule of the dendrogram branches for grouping the site-measured diversity of the mites.

We employed an analysis of the similarity percentages (SIMPER) (Clarke 1993) in the study to assess which taxa are primarily responsible for an observed difference between groups of samples. The method uses the average percent contribution of the individual species to determine the difference between compared groups. The analysis was conducted on the basis of the Bray-Curtis dissimilarity metrics as a rule of a distance measure between the diversities of compared habitats. Statistical analysis was performed using the MS Excel 2019 platform, a recent version of the statistical software PAST (PAleontological STatistics (v. 4.09); Hammer *et al.* 2001), and in SPSS v. 24.

RESULTS AND DISCUSSION

Faunistic studies

Eighty-one Oribatid mite species were recorded in the study area. Fifty-three species recorded in humid forest dominated by alder (*Alnus barbata*), among them 23 species only occurred in this habitat. Fifty-eight species were found in Colchic relic broad-leaved mixed forest with chestnut (*Castanea sativa*), beech (*Fagus orientalis*) and hornbeam (*Carpinus betulus*), with 28 species in this habitat exclusively. Seven species occurred in almost all sampling sites. These are: *Phthiracarus* (*Ph.*) *ferrugineus*, *Parachipteria georgica*, *Oppiella subpectinata*, *Minunthozetes pseudofusiger*, *Hermanniella granulata*, *Metabelba pulverulenta* and *Hypochthonius luteus*. The most diverse and numerous site by species and individuals was KK4 - Mixed forest (46 species, 1323 individuals), it was followed by KK2 - Alder forest (37 species, 526 individuals), and the fewest number of species and individuals were registered in KK1 (18 species, 57 individuals).

New record of oribatid mite species for Georgian fauna

The subgenus *Ctenobelba* (*Caucasiobelba*) Subías & Shtanchaeva, 2010 and species *Ctenobelba* (*Caucasiobelba*) *urhani* Baran, 2015 were recorded for the first time within oribatid mite fauna of Georgia; *C.* (*C.*) *urhani* was registered in one sampling site (KK4- Mixed forest with chestnut (*Castanea Sativa*), beech (*Fagus orientalis*) and hornbeam (*Carpinus betulus*), 37 T 728570; 4600471), one individual was collected from that soil sample. Before our research, the species was recorded only from Turkiye where the species originated and was described (Baran 2015).

Balogh (1943) established the genus *Ctenobelba*, with *Eremobelba pectinigera* Berlese, 1908 as type species. Currently, Ctenobelbidae comprises one genus, four subgenera and 34 species (Ermilov *et al*. 2014; Subías 2022). The subgenus *Ctenobelba* (*Caucasiobelba*) represented with two species: *C.* (*C.*) *reticulata* was described by Subías and Shtanchaeva (2010) from Samur (Dagestan); later, Baran (2015) described a new species *C.* (*C.*) *urhani* from Sakarya, Turkiye.

The characteristic of these two species (*C.* (*C.*) *reticulata* and *C.* (*C.*) *urhani*) known from the subgenus are very similar to each other. The morphological characteristics are not complete in the original descriptions of these species (Subías and Shtanchaeva 2010b; Baran 2015). Due to the brief description of these species, it is impossible to make clear differences between them.

Oribatid mite species missed in the annotated checklists of Georgia

During our study we registered the following eight species of ptyctimous mites: *Oribotritia krivolutskyi*, *Acrotritia duplicata*, *Phthiracarus incertus* Niedbała, 1983, *P. peristomaticus*, *P. scitus*, *Steganacarus* (*Steganacarus*) *incomptus*, *Austrophthiracarus pavidus*, and *Atropacarus* (*Atropacarus*) *perversus* that are omitted in the recently published annotated checklists of Georgian oribatid mites (Murvanidze and Mumladze 2016; Murvanidze *et al.* 2023).

***Oribotritia krivolutskyi* Liu, Niedbała & Starý, 2010 –** recorded in one location KK4 - Mixed forest, 3 individuals were collected from the soil samples.

Before our research, the species was reported from Batumi Botanical Garden, soil and litter, 01.06.1971, leg. D.A. Krivolutsky (1 individual); Batumi Nature Reserve, soil and litter, 08.05.1971, leg. D.A. Krivolutsky (1individual); Kintrishi Nature Reserve, spruce forest, litter and soil, 04.05.1971, leg. D.A. Krivolutsky (1 individual) (Niedbała 2012, 2015; Niedbała and Liu 2018).

***Acrotritia duplicata* (Grandjean, 1953) –** recorded in one location KK2 - Alder forest, 7 individuals were collected from the soil samples.

Before our research, the species was reported from Adjara, near Keda, moss in mixed forest, 18.04.1959, leg. N.D. Atchekan (17 individuals); Adjara, near Keda, litter chestnut forest, 09.1975, leg. S.S. Druk (1 individual) (Niedbała 2012, 2015; Niedbała and Liu 2018).

***Phthiracarus incertus* Niedbała, 1983 –** recorded in two locations KK4 - Mixed forest, 4 individuals were collected from the soil samples and KK6 - Mixed forest, 3 specimens were collected from the soil samples.

Before our research, the species was reported from Abkhazia, Picunda peninsula, mosses in deciduous forest, 08.10.1968, leg. L.G. Sitnikova (30 individuals); Adjara, Batumi Botanical Garden, litter, 17.04.1959, leg. N.D. Atchekan (5 individuals); Adjara, Batumi Botanical Garden, litter under trees and bushes, 17.04.1959, leg. N.D. Atchekan (7 individuals); Adjara, near Keda, moss in mixed forest, 18.04.1959, leg. N.D. Atchekan (83 individuals); Ch. De Kartalinie, 10 km N of Tbilisi, at 1100 m a.s.l., mosses in deciduous forest, 20.09.1974, leg. N.I. Djaparidze (1 individual) (Niedbała 1983, 2012, 2015; Niedbała and Liu 2018).

***Phthiracarus peristomaticus* Willmann, 1951 –** recorded in one location KK2 - Alder forest, 5 individuals were collected from the soil samples.

Before our research, the species was reported from Adjara, Batumi, under bamboo, 17.04.1960, leg. N.G. Bregetova and I. A. Ivanov (6 individuals) (Niedbała 2012, 2015; Niedbała and Liu 2018).

***Phthiracarus scitus* Niedbała, 1983 –** recorded in one location KK1 - Alder forest, 2 individuals were collected from the soil samples.

Before our research, the species was reported from Adjara, Batumi, Batumi Botanical Garden, litter, 17.04.1959, leg. N.D. Atchekan (14 individuals); Elkhovske Vorota, litter in deciduous forest, 23.05.1962, leg. J.G. Razumova (4 individuals); Elkhovske Vorota, mosses, 23.05.1962, leg. J.G. Razumova (5 individuals) (Niedbała 1983, 2012, 2015; Niedbała and Liu 2018).

***Steganacarus incomptus* Niedbała, 1983 –** recorded in one location KK3 - Alder forest, 1 individual was collected from the soil sample.

Before our research, the species was reported from Adjara, Colchic National Park, Anaklja, Alnus barbata, swamp forest, 11.07.2005, leg. E. Kvavadze (4 individuals) (Niedbała 1983, 2012, 2015; Niedbała and Liu 2018).

***Austrophthiracarus pavidus* (Berlese, 1913) –** recorded in one location KK6 - Mixed forest, 2 individuals were collected from the soil samples.

Before our research, the species reported from Adjara, near Keda, moss in mixed forest, 18.04.1959, leg. N.D. Atchekan (22 individuals); Ch. De Kartalinie, 10 km N of Tbilisi, at 1100 m a.s.l., litter in deciduous forest, 20.09.1974, leg. N.I. Djaparidze (21 individuals); 65 km from Tbilisi, in beech wood, 17.12.1955, leg. L. Dubinina (2 individuals); 65 km from Tbilisi, in

deciduous forest, 17.12.1955, leg. L. Dubinina (2 individuals); near Tbilisi, in the forest, 1964, leg. D.A. Krivolutsky (6 individuals) (Niedbała 2012, 2015; Niedbała and Liu 2018).

***Atropacarus* (*Atropacarus*) *perversus* (Niedbała, 1983) –** recorded in one location KK5 - Mixed forest, 3 individuals were collected from the soil samples.

Before our research, the species was reported from Adjara, Batumi, Batumi Botanical Garden, litter under trees and bushes, 17.04.1959, leg. N.D. Atchekan (4 individuals) (Niedbała 1983, 2012, 2015; Niedbała and Liu 2018).

Eighty-one oribatid mite species recorded from the Machakhela National Park belong to 55 genera, 41 families and 27 superfamilies. The faunistic list of oribatid mites comprises the identified species with its geographical coordinates and distribution within the park territory presented in Appendix.

The recently published checklist of oribatid mites from Georgia reported 563 species (Murvanidze *et al*. 2023). In the present publication, one species is a new record for the country and eight species were missing from the list, so the number of known species of oribatid mites increased to 572 for Georgia.

Data analysis of oribatid mites' distribution and community structure

The analysis of the distribution of the abundance of the oribatid mites showed that the abundance of the mite species slightly differs between the alder and broad-leafed mixed forest habitats. More specifically, the highest abundance of oribatid mite was found in the Colchic type of the mixed broadleaf forest KK4. A large proportion of the individuals found in this plot was only one species *Oppiella nasuta*. It was a single case of the occurrence of this species in the sample, however it significantly impacted the overall level of the species abundance in this site (Table 2).

Table 2. Descriptive statistics of the variability of the number of individuals (abundance) of oribatid mites at the sampled site and in the total sample.

Variables	Alder forest			Mixed broadleaf forest			Total
	Site KK1	Site KK2	Site KK3	Site KK4	Site KK5	Site KK6	
Average	0.70	6.49	2.47	11.26	1.62	1.25	28.86
Standard Deviation	1.77	14.12	7.02	22.78	4.87	3.00	56.30
Total number of samples (10 m^3)	18	37	22	46	19	24	81
Confidence coefficient	1.96	1.96	1.96	1.96	1.96	1.96	1.96
Margin of error	1.15	5.58	3.85	17.36	3.70	1.66	12.26
Upper bound of 95% confid. Interval	4.32	18.32	10.85	44.70	10.43	5.62	41.12
Lower bound of 95% confid. Interval	2.01	7.16	3.15	9.98	3.02	2.29	16.60
Minimum	1	1	1	1	1	1	4
Maximum	9	63	36	114	29	19	338
Range	8	62	35	113	28	18	334
Abundance per m^2 (total number × 100)	900	6300	3600	11400	2900	1900	33800

However, the results of the One-Way ANOVA test showed that the variability of the species abundance between sampled sites was insignificant ($F = 1.390$ $P = 0.256$ [$P < 0.05$]) which means oribatid mite abundance is not habitat-specific (Table 4).

The most abundant species in the total samples were *Oppiella nasuta* and *Chamobates caucasicus* Shaldybina, 1969. The abundance of these species was over 35% higher in the Colchis

type of mixed broadleaf forest than in the alder forest (Fig. 2). The species *Conchogneta dalebalearica*, *Oppiella subpectinata*, *Dissorhina ornata*, *Punctoribates punctum*, *Oribatula tibialis*, and *Phthiracarus ferrugineus* were the most abundant and frequent in both types of habitats.

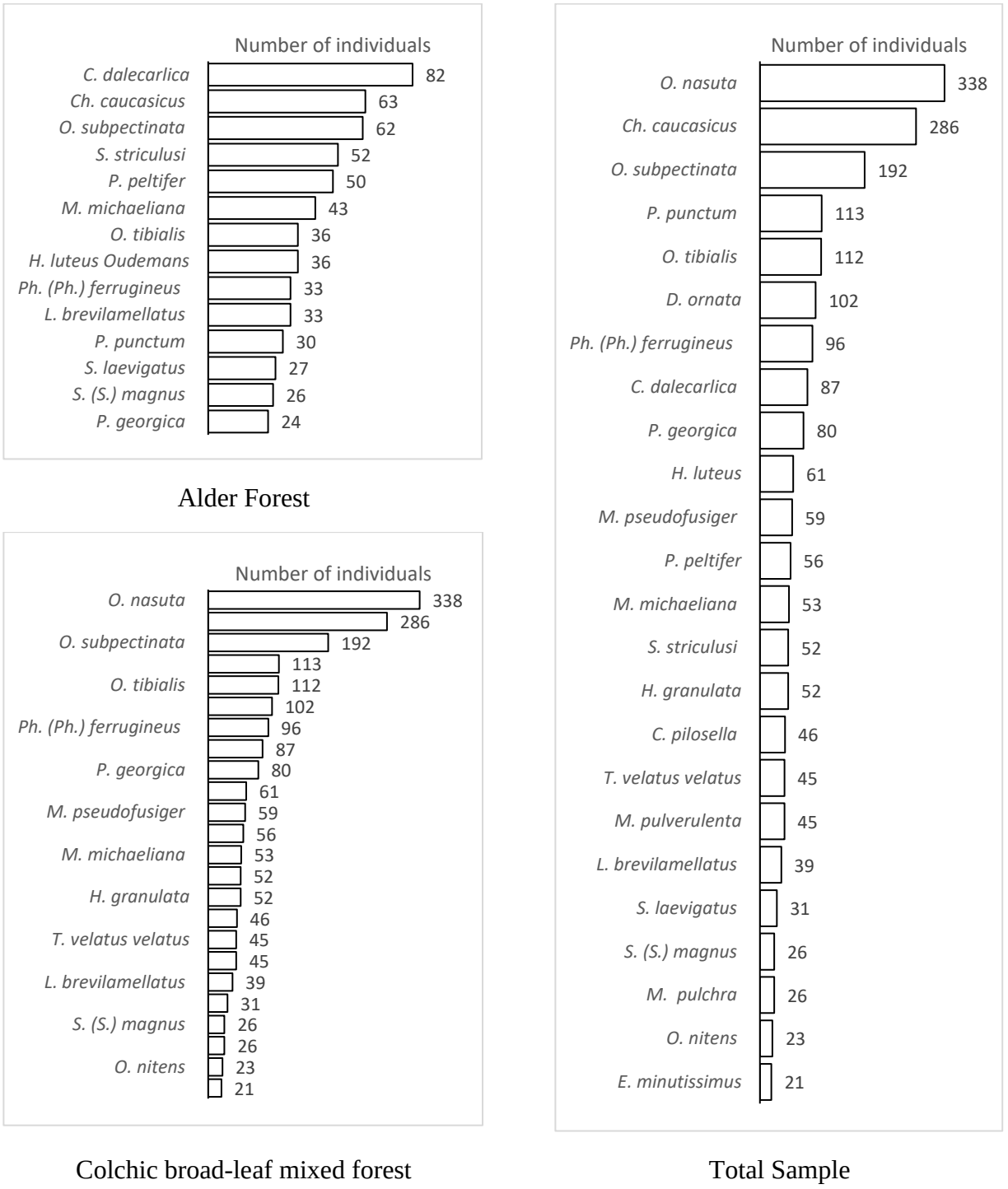

Figure 2. Species abundances ranked from highest to lowest abundance [sum of individuals from nine samples for each habitat type and 19 total.

Sørensen–Dice similarity coefficient showed an overall similarity of 30.8% between the habitat types (from 25.0% to 55.8%) and the mean similarity to 38.4% between the diversities registered at

the sites (Table 3). Similarity of oribatid mite between alder forest and Colchis type of the mixed broadleaved forest amounted to 54%.

Table 3. The Sørensen–Dice similarity coefficient of oribatid mite between alder forest and Colchis type of the mixed broadleaved forest.

Habitats and sites		Alder forest			Mixed broadleaved forest		
		KK1	KK2	KK3	KK4	KK5	KK6
Alder	KK1	100	32.7	35	25	27.3	28.5
	KK2		100	44	23.3	25.7	26.2
	KK3			100	55.8	53.6	52.1
Mixed	KK4				100	36.9	54.2
	KK5					100	55.8
	KK6						100

As the results of the calculation of the Sørensen–Dice similarity coefficient also shows (Table 3), species composition in the alder forests are more similar to each other than to the Colchis broadleaf mixed forests. However, communities of the mixed forest (KK4, KK5, KK6) were generally more similar to each other that the communities within the Alder forest sites. The mite community KK3 in the alder forest has a transitional position between both forest habitats (Table 3).

The results of the cluster analysis supported the results of the calculation of the Sørensen–Dice similarity coefficient by separating the communities of the different forest habitats. The cluster analysis conducted using the incidence data of the mite species on surveyed sites shows that the mite community occurring on one of the sites of mixed broadleaf forest (KK3) has a transitional position between the diversities of two habitat types due to its species composition. The dendrogram also shows that there is a more distant relation between the taxonomic diversity of the mite communities registered on the sites of the Colchis type of mixed broadleaf forest than the sites of the alder forest (Fig. 3).

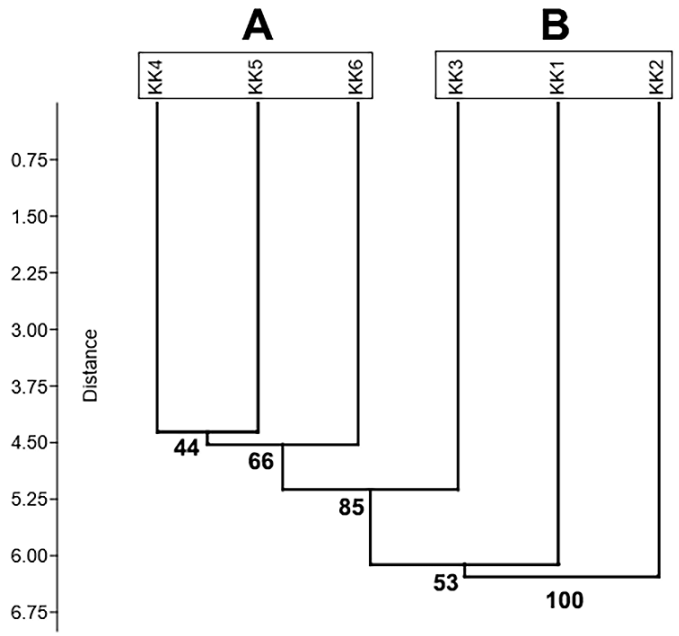

Figure 3. The results of the cluster analysis of the different forest habitats in Machakhela National Park.

Table 4. The results of one-way ANOVA of Shannon's index of diversity ($P < 0.05$), evenness ($P < 0.001$), and species richness ($P < 0.05$) between the Alder forest and Colchis mixed broadleaf forest. S.S., sum of squares; M.S., mean square.

				S.S.	df	M.S.	F	Sig.
Species richness	Between Groups	(Combined)		186.889	1	186.89	12.718	0.003
		Linear Term	Contrast	186.889	1	186.89	12.718	0.003
	Within Groups			235.111	16	14.694		
	Total			422.000	17			
Species abundance	Between Groups	(Combined)		33110.22	1	33110.2	1.390	0.256
		Linear Term	Contrast	33110.22	1	33110.2	1.390	0.256
	Within Groups			381095.56	16	23818.5		
	Total			414205.78	17			
Shannon_H	Between Groups	(Combined)		0.324	1	0.324	10.237	0.006
		Linear Term	Contrast	0.324	1	0.324	10.237	0.006
	Within Groups			0.506	16	0.032		
	Total			0.830	17			
Evenness	Between Groups	(Combined)		0.317	1	0.317	20.304	0.000
		Linear Term	Contrast	0.317	1	0.317	20.304	0.000
	Within Groups			0.250	16	0.016		
	Total			0.567	17			

The results of one-way ANOVA showed that Shannon's index of diversity ($P < 0.05$), evenness ($P < 0.001$), and species richness ($P < 0.05$) differed significantly between the Alder forest and Colchis mixed broadleaf forest. There was no significant difference in species abundance between the two habitat types (Table 4).

The results of the SIMPER analysis showed that none of the mite species has a significantly high value of average dissimilarity (%) and contribution (%), however, these results ranked up nine species (with a contribution power higher than 2% and average abundance in the sampled habitats greater than 20 individuals): *Quadroppia quadricarinata* (Michael, 1885), *Tectocepheus velatus velatus* (Michael, 1880), *Xenillus tegeocranus* (Hermann, 1804), *Steganacarus magnus anomalus* (Berlese, 1883), *Suctobelba trigona* (Michael, 1888), *Phthiracarus incertus*, *Carabodes femoralis* (Nicolet, 1855), and *Scheloribates laevigatus* (C.L. Koch, 1835). These taxa can be considered the responsible species for the difference in the diversity of the mite populations of the alder and Colchis mixed broadleaf forest. The site-specific general indicators of the oribatid mite diversity are shown in Table 5.

Descriptive statistics (Table 2) and distribution character of the diversity of the mite community measured by Shannon's index of diversity (H') and Evenness (E_{var}) (Table 6) indicated that the two sites of the sample collection KK1 of the alder forest and KK6 of the Colchis type of

the mixed broadleaf forest hold the highest species richness. The abundance of mite species was also more evenly distributed at these sites than at the other surveyed sites which also means that there were no distinctly dominant species here. In contrast, single sites of both habitats (KK2 and KK4) had the lowest values of evenness and the highest values of Shannon's index respectively, and these sites showed the most abundant species *O. nasuta* and *Ch. caucasicus* within all surveyed sites (Fig. 2). This result explains the insignificant effect of species abundance and stronger impact of the species incidence on the specificity of the diversity of mite communities of the studied habitats.

Table 5. The results of the SIMPER analysis. The table provides results in ≤ 50% of the cumulative range for brevity, mean abundances are provided for 10 cm^3 sampling area.

Taxon	Av. diss.	Cont. (%)	Cumul. (%)	Mean abund. in alder forest	Mean abund. in mixed broadleaf forest
Quadroppia* (*Q.*) *quadricarinata	0.96	2.90	2.898	215.0	433.0
Tectocepheus velatus velatus	0.96	2.90	5.795	215.0	150.0
Xenillus tegeocranus	0.67	2.03	7.828	215.0	71.6
Steganacarus* (*S.*) *magnus anomalus	0.67	2.03	9.86	215.0	71.6
Suctobelba trigona	0.67	2.03	11.89	215.0	71.6
Phthiracarus* (*P.*) *incertus	0.67	2.03	13.92	215.0	71.6
Carabodes femoralis	0.67	2.03	15.96	215.0	71.6
Scheloribates laevigatus	0.67	2.03	17.99	93.3	71.6
***Euzetes globulus* (Nicolet, 1855)**	0.65	1.97	19.96	215.0	71.6
***Hermanniella multipora* Sitnikova, 1973**	0.65	1.97	21.93	215.0	71.6
***Oppia nitens* C.L. Koch, 1836**	0.65	1.97	23.9	215.0	71.6
***Heminothrus* (*Platynothrus*) *peltifer* (C.L. Koch, 1839)**	0.58	1.77	25.67	183.0	143.0
***Hypochthoniella minutissima* (Berlese, 1904)**	0.55	1.66	27.33	143.0	71.6
***Gustavia microcephala* (Nicolet, 1855)**	0.52	1.56	28.9	71.6	143.0
***Amerus troisii* (Berlese, 1883)**	0.52	1.56	30.46	71.6	143.0
***Liacarus brevilamellatus* Mihelcic, 1955**	0.52	1.56	32.02	71.6	143.0
***Conchogneta dalecarlica* (Forsslund, 1947)**	0.52	1.56	33.59	71.6	143.0
***Nanhermannia nana* (Nicolet, 1855)**	0.51	1.56	35.15	71.6	143.0
***Eupterotegaeus ornatissimus* (Berlese), 1908**	0.45	1.35	36.5	143.0	143.0
***Ctenobelba pilosella* Jeleva 1962**	0.45	1.35	37.85	143.0	143.0
***Mesoplophora michaeliana* Berlese, 1904**	0.45	1.35	39.21	143.0	143.0
Chamobates caucasicus	0.45	1.35	40.56	143.0	143.0
***Liebstadia similis* (Michael, 1888)**	0.44	1.34	41.9	143.0	143.0
***Oribatella colchica* Krivolutsky, 1974**	0.44	1.34	43.23	143.0	143.0
***Steganacarus* (*Tropacarus*) *carinatus* (C.L. Koch, 1841)**	0.44	1.34	44.57	143.0	143.0
***Acrogalumna longipluma* (Berlese, 1904)**	0.43	1.31	45.88	143.0	143.0
***Liacarus coracinus* (Koch, 1840)**	0.43	1.31	47.19	143.0	143.0
***Euphthiracarus monodactylus* (Willmann, 1919)**	0.41	1.25	48.44	143.0	143.0
***Oxyoppioides decipiens* (Paoli, 1908)**	0.41	1.24	49.67	71.6	71.6
***Parachipteria punctata* (Nicolet, 1855)**	0.40	1.22	50.89	143.0	143.0

Abbreviations used in the table: Av. diss. - Average dissimilarity; Cont. (%) - Contribution %; Cumul. (%) - cumulative %; Mean abund. - Mean abundance.

The results of the study clearly showed that diversity and community structure of oribatid mites differ between the habitats of mountain forest belt in the protected area of the MNP. The cluster analysis, using the incidence data of the species, separated communities of oribatid mites of alder and the mixed broadleaf forests on the territory of the national park. The analysis of the distribution of the abundant species showed a strong impact on the species incidence and insignificance of the species abundance for the discrimination of the mite communities of the surveyed forest habitats.

Table 6. General indicators of the oribatid mite diversity detected on the sampled sites.

Diversity indices	Alder forest			Mixed broadleaf forest		
	KK1	KK2	KK3	KK4	KK5	KK6
Species richness	18	37	22	46	19	24
Shannon's Index of Diversity (H')	2.61	2.92	2.45	2.75	2.40	2.80
Evenness (E_{var})	0.75	0.50	0.53	0.34	0.58	0.69

Several works (Arabuli *et al*. 2007; Murvanidze *et al*. 2011) are available of oribatid mite composition and community structures in the Colchic type of relict ecosystems such as Alder forests (*Alnus barbata*) and broad-leaved mixed forest. In earlier studies, two important sites of the Colchis habitats have been targeted to determine the distribution character of the oribatid mites. The study, which was carried out in Kolkheti National Park (Murvanidze *et al*. 2011) was based on data from 46 mite species sampled in 18 experimental plots and the study in Mtirala National Park (Murvanidze *et al*. 2016) used the data of 112 species obtained from 28 plots. The closest of the national parks to MNP is Mtirala National Park which is also located in the Adjara region at a distance of 55 Km from MNP. Kolkheti National Park is located the in Samegrelo region at a distance of 92 Km (86 km vector distance) from Machakhela National Park.

Comparison of mite communities distribution and abundance data of the recent study with the similar data of the communities of Mtirala and Kolkheti National Parks (Table 7) shows that the abundance per m^2 of oribatid mites is greater in in MNP than in the other communities from compared national parks. The data of Shannon's diversity index and Evenness indicate more even community in MNP than in the other ones. Species richness with 122 oribatid was highest in Mtirala NP which is located at the highest altitudinal point at 1500 m a.s.l. and is also characterized by the highest amount of the annual precipitation of 4000 mm and the level of air humidity (84%). The community of the MNP was represented by a moderate number of mite species (81). The microclimate of the MNP has also an intermediate position among the climatic data of the compared sites. Kolkheti NP holds the smallest amount of oribatid mite species and is also characterized by the smallest amount of annual precipitation and level of humidity.

Forty species occurred in Machakhela as well as in Mtirala NPs. The community of the Kolkheti NP shared 25 species with the community of Mtirala NP and 14 species with the Machakhela NP. Respectively, the similarity in species occurrence between Machakhela and Mtirala NPs is 22.8%; between the communities of Kolkheti and Mtirala NPs is 23% and between the communities of Kolkheti and Machakhela NPs is 18.0% based on the Sørensen–Dice coefficient of the similarity of diversity. This result can be interpreted in two ways: 1) communities of closely allocated NPs have higher similarity in mite diversity to each other and 2) the community of the most humid and species-rich site of Mtirala NP has the highest number of shared species with the communities of the other sites because it holds the highest number of the mite species.

The most abundant species, represented by more than 100 individuals in the samples, shared between the communities of the compared sites were: *Dissorhina ornata*; *Phthiracarus ferrugineus*;

Protoribates capucinus; *Scheloribates latipes*; *Steganacarus spinosus*; *Oppiella subpectinata*; *Oribatula tibialis*, and *Parachipteria georgica*.

Table 7. Comparison of the distribution and abundance data of the mite communities distributed in the National Parks of West Georgia

Features	Mtirala National Park	Machakhela National Park	Kolkheti National Park
Total species richness	122	81	46
Shannon's index (H')	4.43	3.34	3.02
Evenness (E_{var})	0.69	0.35	0.45
Average abundance	4.33	28.86	37.56
Standard Deviation (of abundance)	4.14	56.30	55.20
Total sample size	122	81	46
Confidence coefficient	1.96	1.96	1.96
Margin of error (of abundance)	0.74	12.26	15.95
Upper bound of 95% conf. interval (of abundance)	5.06	41.12	53.51
Lower bound of 95% conf. interval (of abundance)	3.59	16.60	21.61
Minimum (abundance)	1	4	1
Maximum (abundance)	20	338	230
Range (of abundance)	19	334	229
Total of average abundance per m^2 (total number × 100)	3345	8685	9600
General data on the locality and climate*			
Features	**Mtirala National Park**	**Machakhela National Park**	**Kolkheti National Park**
Latitude	41.8779°	41.8417°	41.6966°
Longitude	41.6617°	41.4641°	42.1106°
Highest altitudinal point (m a.s.l.)	1500	900	10
Area (ha)	15698	7333.18	44980
Relative humidity (%)	84	74	72
Total annual precipitation (mm)	4000	2600	2000
Average annual temp. (°C)	15	14.8	22.1

Abbreviations used in the table: conf. - Confidence; a.s.l. - altitude above sea level; temp. - temperature.

* climate data is taken from the updated and the most authentic literature sources (Tabidze and Tskhovrebashvili 2000; Government of Georgia 2008).

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تنوع و ساختار اجتماعی کنه‌های اوریباتید (Acari: Oribatida) در رویشگاه‌های غالب پارک ملی ماچاخلا (گرجستان، قفقاز)

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چکیده

تنوع و پراکنش کنه‌های اوریباتید در جنگل‌های بارانی بی‌نظیر کلشی پارک ملی ماچاخلا بررسی شد که میراث جهانی یونسکو است. جوامع کنه‌های اوریباتید در شش محل در پارک ملی ماچاخلا (غرب گرجستان) در انواع زیستگاه‌های بسیار معمول جنگل‌های کلخی مورد بررسی قرار گرفتند: جنگل توسکا (*Alnus barbata*) و جنگل مخلوط با شاه‌بلوط (*Castanea sativa*)، راش (*Fagus orientalis*) و ممرز (*Carpinus* sp.). در مجموع ۸۱ گونه کنه اوریباتید شناسایی شد و فهرست کامل گونه‌ها ارایه شده است. زیرجنس *Ctenobelba* (*Caucasiobelba*) Subías & Shtanchaeva, 2010، با گونه *C.* (*C.*) *urhani* Baran, 2015، برای نخستین بار از گرجستان گزارش می‌شود. هشت گونه دیگر از کنه‌های پتیکتیموس (*Oribotritia krivolutskyi*، *Acrotritia duplicata*، *Phthiracarus incertus*، *P. perstomaticus*، *P. scitus*، *Steganacarus incomptus*، *Austrophthiracarus pavidus*، *Atropacarus perversus*) در فهرست به تازگی منتشر شده گرجستان لحاظ نشده‌اند، بنابراین تعداد کنه‌های اوریباتید ثبت‌شده در قلمرو کشور به ۵۷۲ مورد افزایش می‌یابد. نتایج مطالعه این پژوهش به وضوح تفاوت‌های موجود در جامعه کنه‌های اوریباتید جنگل‌های کلخی را در منطقه حفاظت‌شده پارک ملی ماچاخلا نشان داد. تجزیه و تحلیل خوشه‌ای جوامع کنه‌های توسکا و جنگل‌های پهن برگ مخلوط کلخیس را جدا کرد. غنای گونه‌ای، شاخص شانون و یکنواختی بین دو زیستگاه جنگلی تفاوت معنی‌داری داشتند. نتایج ANOVA یک طرفه نشان داد که فراوانی گونه‌ها بین دو نوع رویشگاه تفاوتی نداشت. نتایج تجزیه و تحلیل SIMPER نه گونه از کنه‌های اوریباتید را مسئول تفاوت در تنوع جامعه کنه‌ها در زیستگاه‌های جنگلی مورد مطالعه دانست. این گونه‌ها به دستهٔ گونه‌های فراوان تعلق ندارند، با این حال آنها به شدت با هر زیستگاه جنگلی هدف مرتبط هستند. نتایج این مطالعه با نتایج بررسی‌های پیشین در مورد توزیع و تنوع جوامع کنه‌های اوریباتید در پارک‌های ملی Mtirala و Kolkheti مقایسه شدند. پارک ملی Mtirala بیشترین غنای گونه‌ای را داشت و بیشترین همپوشانی گونه‌ها را با پارک‌های ملی ماچاخلا و کلختی داشت. پارک‌های ملی ماچاخلا و کلختی دارای همپوشانی کمتری از گونه‌ها بودند. همچنین نتایج نشان داد که مکان‌های مقایسه شده از قلمرو پارک ملی با مرطوب‌ترین اقلیم کوچک، میزان بیشتری از غنای گونه‌ای را دارند. دقت مقایسه نتایج ممکن است به دلیل نمونه‌برداری غیر یکنواخت کم باشد، با این حال، مبنای منطقی را برای این فرض فراهم می‌کند که رطوبت عامل مهم تعیین‌کننده ویژگی پراکنش کنه‌ها در زیستگاه‌های جنگلی کلخیس است، زیرا در منطقه جغرافیایی بزرگ‌تر است.

واژگان کلیدی: فهرست، جنگل کلخیز، مطالعه مقایسه‌ای، *Ctenobelba*، پراکنش، کنه‌های اوریباتید، گزارش جدید.

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