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Oribatid mite diversity in *Rhododendron ponticum* L. canopy along an altitudinal gradient in Mtirala National Park

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ABSTRACT — Oribatid mite diversity along an altitudinal gradient from 10 m to 850 m a.s.l was investigated on the twigs and leaves of *Rhododendron ponticum* L. in Mtirala National Park. Forest floor sampling (mineral soil and litter) was also performed in the same locations. Altogether, 77 species of oribatid mites were identified. 31 species were found in the canopy and 64 species were found in the mineral soil and litter. Juveniles made-up 7.6% of the canopy fauna. *Ommatocepheus ocellatus* (Michael, 1882), was a new finding for Mtirala National Park. *Steganacarus (Tropacarus) patruelis* Niedbala, 1983 was the most numerous species found on twigs and leaves. Almost the whole canopy fauna (94%) belonged to higher oribatids (Brachypilina) and the lower oribatids were only represented by *S. patruelis* and *Camisia segnis* (Herman, 1804). Canopy fauna was separated from those found on the ground supporting the importance of both habitats in maintaining overall biodiversity. The highest number of individuals and the highest number of species was found on mid-altitudes, decreasing with increasing elevation. There was no difference in species richness between twig and leaf habitats, whereas abundance was much higher on twigs. We showed that rhododendron understory harbored well established and abundant oribatid fauna preserving rare and unique species that enhance regional biodiversity.

KEYWORDS — oribatid mites; Mtirala National Park; canopy; *Rhododendron ponticum*

INTRODUCTION

The role of canopy habitats in maintaining microarthropod diversity is widely recognized (Beaulieu *et al.*, 2006; Behan-Pelletier and Walter, 1998; Fagan and Winchester, 1999, 2005; Lindo and Winchester, 2006; Schowalter, 1989; Thunes *et al.*, 2003; Winchester *et al.*, 2008; Walter, 1995; Walter and O'Dowd, 1995). The range of canopy habitats includes twigs, leaves, suspended soils, mosses, lichens, tree barks etc (André, 1985; Lindo and Winchester, 2006; Proctor *et al.*, 2002). High numbers of oribatid species are restricted to the canopy (Behan-Pelletier and Winchester, 1998) with well established communities.

In spite of the number of studies on forest floor inhabiting microarthropods in natural forests of Georgia (Shtanchaeva and Subias, 2010 and references therein), oribatid mite diversity in canopy habitats of the region is almost unknown. Only two articles are available addressing this issue. Tarba (1992) investigated microarthropods in rock and epiphyte lichens developed on the alder trees in Ritsa reserve (Abkhazian region) and Murvanidze and Mumladze (2014) provided data on

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oribatid mites found on the twigs of conifer and broadleaved trees in Borjom-Kharagauli National Park. Having in mind the diversity of canopy habitats and the experiences from the other areas (Arroyo *et al.*, 2013; Behan-Pelletier and Winchester, 1998; Winchester *et al.*, 1999; Sobeck *et al.*, 2008), one can suppose that significant part of Georgian oribatid fauna is waiting to be explored. The aim of this study was to reveal the diversity of oribatid mites in twigs and leaves of Pontic Rhododendron (*Rhododendron ponticum* L.) in Mtirala National Park (hereafter MNP). MNP is situated in the southwestern part of Georgia (area 15698,8 ha) and represents most humid areas (annual precipitation up to 4000 mm (Zazanashvili *et al.*, 2012)) throughout the Caucasian region. The forests of MNP are predominated with alder (*Alnus barbata* C.A. Mey), chestnut (*Castanea sativa* Mill.) and beach (*Fagus orientalis* L) with *Rhododendron ponticum* L., *Laurocerasus oficinalis* Roem., *Ilex colchica* Pojark., *Hedera colchica* C. Koch, *Buxus colchica* Pojark.etc making large part of the understory (The Management of Mtirala National Park, 2009). This is the only area in the Caucasus where four species of rhododendron trees are found with Pontic Rhododendron represented in all vegetation zones from sea level to subalpine belt (Shetekauri *et al.*, 2013). This plant creates the main part of the understory in mixed, chestnut and beach forests of MNP with tree height of 1-3 m (Shetakauri *et al.*, 2013).

Within the present study we make the inventory of oribatid mites living on understory canopies of Pontic Rhododendron in MNP. We also try to reveal the patterns of the canopy community composition with respect to soil oribatid fauna and altitudinal gradient.

Materials and methods

Sampling

Canopy samples of Pontic Rhododendron were taken in the understory of mixed and chestnut forests of MNP in July 2013. Elevational transect was set from 140 m to 850 m a.s.l., limited by MNP territory. Sampling was performed in every 100 m elevation comprising seven sampling locations (Table 1). At each height mineral soil, litter and canopy sampling was performed in following order:

Mineral soil sampling: litter was removed from forest floor surface and six mineral soil samples of 10 × 10 cm area with the depth of 5-7 cm were taken using trowel. Samples were placed in plastic bags and appropriately labeled. 48 mineral soil samples were collected in total.

Litter sampling: three samples of litter were collected at each site with the area of 20 × 20 cm for each. The depth of the sample was about 5cm. On 140 m and 475 m heights no litter was present under rhododendron twigs; hence, 15 litter samples were collected in total.

Canopy sampling: rhododendron twigs and leaves were clipped using gardening pruner. At each site three rhododendron trees were randomly selected and at each tree samples from 50 cm and 2m from the ground were taken. At each height three twigs of 1m length were removed. Twigs were cleared from leaves and cut into twiglets of 20 cm length. Twigs and leaves were separately placed into plastic bags and appropriately labeled. 192 twig and leaf samples were collected in total.

Laboratory treatment and soil and litter extraction.

Oribatid mites were extracted from mineral soil and litter using modified Berlese-Tullgren extractor. Extraction duration was one week. Collected individuals were stored in 70% alcohol.

Twig washing. Microarthropods from twigs and leaves were removed using twig washing technique (Walter and Kranz, 2009). Twigs and leaves from each sample were placed into separate baskets, filled with water and small amount of detergent was added. After 24 hours twigs and leaves were shaken into the water and removed. Remained water was filtered into two sieves of different mesh sizes (1 mm and 75 μm) and rinsed with 70% alcohol into the Petry dishes.

TABLE 1: Sampling site coordinates and abbreviations used in the manuscripts.

Site 1. 140 m a.s.l. coordinates: 41.69313° 41.82268°			
Mineral Soil	Litter	Twigs	Leaves
1S	1LT	1T 50cm 1T 2m	1L 50cm 1L 2m
Site 2. 310 m a.s.l. coordinates: 41.677200° 41.869717°			
Mineral Soil	Litter	Twigs	Leaves
2S	2LT	2T 50cm 2T 2m	2L 50cm 2L 2m
Site 3. 475 m a.s.l coordinates: 41.67173° 41.87467°			
Mineral Soil	Litter	Twigs	Leaves
3S	3LT	3T 50cm 3T 2m	3L 50cm 3 L 2m
Site 4. 550 m a.s.l. coordinates: 41.65203°41.76229°			
Mineral Soil	Litter	Twigs	Leaves
4S	4LT	4T 50 cm 4T 2m	4L 50 cm 4 L 2m
Site 5. 660 m a.s.l. coordinates: 41.64530° 41.76924°			
Mineral Soil	Litter	Twigs	Leaves
5S	5 LT	5T 50 cm 5T 2m	5L 50 cm 5L 2m
Site 6. 754 m a.s.l. coordinates: 41.64979°41.77804°			
Mineral Soil	Litter	Twigs	Leaves
6S	6 LT	6T 50 cm 6T 2m	6L 50 cm 6L 2m
Site 7. 825 m a.s.l. coordinates: 41.65088° 41.77742°			
Mineral Soil	Litter	Twigs	Leaves
7S	7LT	7T 50 cm 7T 2m	7L 50cm 7L 2m

For identification of oribatid mites temporary cavity slides were prepared using lactic acid. Such slides allow turning the individuals and observing all needed characters. Identification of oribatid mites was performed by means of appropriate keys of Ghilarov and Krivolutsky (1975) and Weigmann (2006). Nomenclature follows that of Schatz *et al.*, (2011). Genus and species names are given according to Weigmann (2006). Feeding biology of oribatid mites was established after Schneider *et al.* (2004) and Fischer *et al.* (2014).

Data analyses

Completeness of the inventory was checked using rarefaction analyses (BioDiversity Pro (http://biodiversity-pro.software.informer.com/2.0/). In order to visualize similarity of studied communities, we have performed hierarchical cluster analyzes (using Jackard's distance measure based on species presence-absence data) using PAST software. The relationship between altitude and species richness and density was tested with first and second order term regression analyses (variables were square root transformed but original values were used in making graphs). Species richness and individual density (estimated as absolute number of individuals) between twigs and leaves were compared by means of two samples T-test.

RESULTS

In total 3827 individuals were identified from the ground and canopy habitats belonging to 77 species and 38 families of oribatid mites (Table 2). 2946 individuals of 31 species were found in the canopy and 881 individuals of 64 species were found in soil and litter. *Ommatocepheus ocellatus* (Michael, 1882) was new finding for MNP. Juveniles made 7.6% of canopy fauna. 12 species - *Cymbaeremaeus cymba* Nicolet, 1855, *Camisia segnis* (Herman, 1804), *Cepheus dentatus* (Michael, 1888), *O. ocellatus* , *Caleremaeus monilipes* (Michael, 1882), *Liacarus brevilamellatus* Mihelčič, 1955, *L. coracinus* (Koch, 1881), *Micreremus brevipes* (Michael, 1888), *Oribatella berlesei* (Michael, 1898), *Poroliodes farinosus* (Koch, 1839), *Trichoribates trimaculatus*

Species/Sites	1T	1L	1S	2T	2L	2S	2LT	3T	3L	3S	4T	4L	4S	4LT	5T	5L	5S	5LT	6T	6L	6S	6LT	7T	7L	7S	7LT
Adults																										
Hypochthoniella minutissima (Berlese, 1904)	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0
Hypochthonius rufulus C.L. Koch, 1835	0	0	0	0	0	3	12	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3	1
Mesoplophora michaeliana Berlese, 1904	0	0	1	0	0	2	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Acrotritia ardua (C.L. Koch, 1841)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Hoplophthiracarus illinoisensis (Ewing, 1909)	0	0	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Phthiracarus (Phthiracarus) ferrugineus (C.L. Koch, 1841)	0	0	4	0	0	2	19	0	0	0	0	0	1	1	0	0	0	3	0	0	0	0	0	0	0	0
P. (P.) laevigatus (C.L. Koch, 1941)	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	1	0	0	0	0	2	0	0	1	17
Steganacarus (Steganacarus) spinosus (Sellnick, 1920)	0	0	52	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	10	0	0	0	1	5
S. (Tropacarus) patruelis Niedbala, 1983	204	6	0	171	92	0	0	156	7	0	313	56	0	1	444	30	0	2	150	5	0	1	138	2	2	1
Camisia horrida (Hermann, 1804)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C. segnis (Hermann, 1804)	0	0	0	47	21	0	0	26	16	0	18	7	0	0	5	1	0	0	1	0	0	0	2	0	0	0
Platynothrus peltifer (C.L. Koch, 1839)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0
Hermannia gibba (C.L. Koch, 1839)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Nanhermannia nana (Nicolet, 1855)	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Nothrus silvestris Nicolet, 1855	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hermanniella granulata (Nicolet, 1855)	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0
H. punctulata Berlese, 1908	0	0	7	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poroliodes farinosus (C.L. Koch, 1839)	27	0	0	30	0	0	0	2	0	0	16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Metabelba monilipeda Bulanova-Zachvatkina, 1965	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
M. papillipes (Nicolet, 1855)	0	0	0	0	0	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Cepheus dentatus (Michael, 1888)	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eupterotegaeus ornatissimus (Berlese, 1908)	0	0	0	0	0	0	0	0	0	1	2	0	0	1	6	0	1	0	0	0	0	0	0	0	0	3
Hypocepheus mirabilis Krivolutsy, 1971	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ommatocepheus ocellatus (Michael, 1882)	0	0	0	1	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Oribatodes heterosetosus Sitnikova, 1975	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amerus polonicus Kulczynski, 1902	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amerobelba decedens Berlese, 1908	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	2	3
Caleremaeus monilipes (Michael, 1882)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Damaeolus ornatissimus Csiszar, 1962	0	0	1	0	0	1	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eremobelba geographica Berlese, 1908	0	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cultroribula bicultrata (Berlese, 1905)	0	0	0	0	0	3	0	0	0	1	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0
Ceratoppia quadridentata (Haller, 1882)	1	0	0	0	4	0	0	0	0	0	0	0	0	0	3	59	1	0	0	8	0	0	0	0	1	0
Gustavia microcephala (Nicolet, 1855)	0	0	0	0	0	2	11	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Adoristes ovatus (C.L. Koch, 1939)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0
Liacarus brevilamellatus Mihelcic, 1955	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
L. coracinus (C.L. Koch, 1841)	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L. lencoranicus Krivolutsky, 1967	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
L. xylariae (Schrank, 1803)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Xenillus tegeocranus (Hermann, 1804)	1	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
Carabodes kintrishiana Murvanidze, 2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
C. procerus Weigmann & Murvanidze, 2003	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C. rugosior Berlese, 1916	0	0	1	0	0	0	13	0	0	0	0	0	0	1	3	0	0	1	0	0	0	0	0	0	3	0
C. tenuis Forsslund, 1953	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conchogneta dalecarlica (Forsslund, 1947)	0	0	0	0	0	4	5	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Dissorhina ornata (Oudemans, 1900)	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0

Species/Sites	1T	1L	1S	2T	2L	2S	2LT	3T	3L	3S	4T	4L	4S	4LT	5T	5L	5S	5LT	6T	6L	6S	6LT	7T	7L	7S	7LT
Oppia nitens C.L. Koch, 1836	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Oppiella (Lauroppia) fallax (Paoli, 1908)	0	0	2	0	5	6	0	0	0	1	0	0	3	0	0	0	2	3	0	0	0	0	0	0	1	0
O. (Oppiella) nova (Oudemans, 1902)	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
O. (Rhinoppia) similifallax (Subias & Minguez, 1986)	0	0	0	0	0	2	0	0	0	4	0	0	0	2	0	0	0	0	0	0	8	1	0	0	0	0
O. (R.) subpectinata (Oudemans, 1900)	0	0	3	0	0	7	5	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Suctobelbella subtrigona (Oudemans, 1916)	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tectocepheus velatus velatus (Michael, 1880)	0	0	26	0	0	0	8	0	0	4	0	0	1	1	0	0	0	5	0	0	0	0	0	0	0	0
Cymbaeremaeus cymba (Nicolet, 1855)	0	0	0	1	0	0	0	1	1	0	20	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micreremus brevipes (Michael, 1988)	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eupelops acromios (Hermann, 1804)	31	7	0	25	42	0	0	52	11	0	45	10	0	0	31	16	0	0	12	24	0	0	7	2	0	1
Achipteria longisetosa Weigmann & Murvanidze, 2003	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parachipteria georgica Murvanidze & Weigmann, 2003	0	0	0	0	0	7	227	0	0	0	0	0	0	2	0	0	0	0	0	0	3	0	0	0	2	1
P. fanzagoi (Jacot, 1929)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	11	0	0	0	0	0	0	1	0
Oribatella berlesei (Michael, 1898)	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. colchica Krivolutsky, 1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
O. nigra Kulijev, 1967	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Protoribates capucinus Berlese, 1908	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oribatula (Oribatula) tibialis (Nicolet, 1855)	0	0	0	0	1	1	5	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
O. (Zygoribatula) cognata (Oudemans, 1902)	0	0	0	0	0	2	2	0	0	2	13	0	0	0	13	0	0	0	34	1	0	0	6	0	0	0
O. (Z.) exilis (Nicolet, 1855)	1	0	0	0	1	0	0	7	6	0	2	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phauloppia lucorum (C.L. Koch, 1841)	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scheloribates latipes (C.L. Koch, 1844)	0	0	2	0	0	2	6	3	0	2	0	0	0	2	0	0	1	1	0	0	0	0	0	0	0	0
Ceratozetes gracilis (Michael, 1884)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichoribates trimaculatus (C. L. Koch, 1835)	0	0	0	21	84	0	0	1	1	0	8	0	0	0	1	3	0	0	1	0	0	0	19	0	0	0
Chamobates kieviensis Shaldybina, 1980	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C. voigtsi (Oudemans, 1902)	0	0	25	0	0	0	0	0	0	9	0	0	0	13	0	1	0	6	0	0	0	0	0	0	0	0
Globozetes microtus Shaldybina, 1969	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feiderzetes latus (Schweizer, 1956)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Minunthozetes pseudofusiger (Schweizer, 1922)	1	0	0	1	0	0	2	6	0	6	1	0	0	0	0	0	0	3	0	0	0	1	0	0	0	0
Punctoribates punctum (C.L. Koch, 1839)	0	0	0	0	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Acrogalumna longipluma adjarica Murvanidze & Weigmann, 2003	0	0	0	0	0	0	0	0	0	5	0	0	2	0	0	0	0	0	0	0	29	4	0	0	1	0
Pergalumna minor (Willmann, 1928)	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juveniles																										
Hypochthonius rufulus C.L. Koch, 1835	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	8	6
Steganacarus (Tropacarus) patruelis Niedbala, 1983	0	0	0	3	1	0	0	87	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Camisia segnis (Hermann, 1804)	0	0	0	1	1	0	0	0	0	0	15	1	0	0	17	0	0	0	12	0	0	0	2	0	0	1
Hermannia gibba (C.L. Koch, 1839)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Nothrus silvestris Nicolet, 1855	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Hermanniella punctulata Berlese, 1908	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poroliodes farinosus (C.L. Koch, 1839)	16	0	0	18	1	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratoppia quadridentata (Haller, 1882)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Cymbaeremaeus cymba (Nicolet, 1855)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eupelops acromios (Hermann, 1804)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	18	0	0	0	1	0	0
Trichoribates trimaculatus (C. L. Koch, 1835)	0	0	0	2	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acrogalumna longipluma adjarica Murvanidze & Weigmann, 2003	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	3	0	0	0	0

TABLE 2: List and numbers of individuals of oribatid mites on Rhododendron ponticum canopy and forest floor in Mtirala National Park (abbreviations and description of sampling locations are given in Table 1).

(Koch, 1835) and *Oribatula (Zygoribatula) exilis* (Nicolet, 1855) were found only in the canopy and 45 species were found only on forest floor. 18 species were common to the ground and the canopy (Table 2). Cluster analyses showed complete separation of canopy mites from those registered on soil and litter habitats. Within groups no well-developed sub-clusters were noticeable (Figure 1). All species found in canopy except *Camisia segnis* and *Platynothrus peltifer* (C.L. Koch, 1839) were sexually reproducing. 13 parthenogenic species were found on the ground.

Sample based rarefaction curves made only for canopy species (for each altitude) indicated that faunal completeness has been achieved for all elevational zones except 311 m and 550 m altitude (Figure 2).

The most dominant species (*i.e.*, species with more than 100 individuals) found in the canopy were *C. segnis, Eupelops acromios* (Hermann, 1804), *Steganacarus (Tropacarus) patruelis* Niedbala, 1983 and *T. trimaculatus* with *S. patruelis* showing the highest numbers of individuals. All dominant species except *S. patruelis* reached highest abundance at mid-altitude (311 m a.s.l) and declined along increasing the altitude. Abundance of *S. patruelis* peaks at 660 m a.s.l. and declined consequently (Figure 3).

Linear relationship between altitude and absolute individual density or species richness of canopy oribatids was not significant ($p>0.05$). Instead, the density response with altitude followed the distribution of a positive bell shape ($R^2 = 0.610$, $P<0.05$; t Stat = 0.86; df = 6) (Figure 4a) as well as that between altitude and species richness ($R^2 = 0.739$, $P< 0.05$; t Stat = 5.58; df = 6). The number of species was highest at mid-altitudes and declined to the lower and higher elevations (Figure 4b).

Twigs harbored significantly higher individual density than leaves ($p<0.05$; t Stat = 4.25; df = 5). However the number of species was similar in both habitats ($p>0.05$; t Stat = 3.40; df = 6).

Discussion

Rhododendron ponticum forms the main part of the understory vegetation in MNP (Shetekauri *et al.*, 2013). In this study, an analysis of the forest floor and rhododendron canopy habitats revealed 77 species of oribatid mites on thoses habitats, with *O. ocellatus* being a new finding for MNP. Both twigs and leaves were well colonized by oribatid communities. As one of the source of colonization of arboreal habitats by oribatid mites, passive dispersal or phoresy is suggested (Behan-Pelletier and Winchester, 1998). In particular, Norton (1980) wrote that phoresy is the main mode of dispersal for some oribatid families (Mesoplophoridae, Oppiidae, Oribatulidae and Scheloribatidae). None of these families predominated in the canopy fauna reported here. Another hypothesis for canopy colonization is that of random movement from forest floor vegetation to canopy habitats, suggested by Behan-Pelletier and Winchester (1998). Behan-Pelletier *et al.* (2007) consider the litter oribatid mite fauna to be the source of canopy diversity. We have found well-established oribatid fauna close to the forest floor (50 cm) and on 2m distance from the ground. Beaulieu *et al.* (2010) also suggest that the "canopy starts at 50 cm". The high number of juveniles on twigs and leaves on both heights suggests that oribatid mites form resident communities in the canopy. However, not all forest floor species can colonize above ground habitats. Lindo *et al.* (2008) show low levels of colonization from the forest floor to lower heights. Limited habitat availability, differences in organic matter and greater abiotic extremity existing in canopy can all act as limiting factors for the colonization of arboreal habitats (Lindo *et al.*, 2008; Lindo and Winchetster 2009; Nadkarni and Longino 1990). Indeed, several studies indicate that arboreal fauna clearly differs from the terrestrial one (Beaulieu *et al.*, 2010; Behan-Pelletier and Winchester, 1998; Behan-Pelletier *et al.*, 2007; Behan-Pelletier and Walter, 2000; Maraun *et al.*, 2009; Murvanidze and Mumladze, 2014). Behan-Pelletier *et al.* (2007) even show zero similarity between ground and canopy lichen inhabiting oribatids which is regarded as surprising for temperate forests. This trend is supported by our research as well. 18 oribatid mite species were presented in both terrestrial and arboreal habitats, comprising 23 % of total fauna. There are evidences that usually about 40 % of oribatid fauna is common for ground and canopy in tropical rain forests (Behan-Pelletier *et al.*, 1993; Wunderle 1992). The clear differences existing between forest floor and arboreal oribatid fauna is visualized by the cluster analysis (Figure 1). Considering that forest ecosystems of MNP belong to the temperate rain forests with annual precipitation of - up to 4000 mm (Zazanashvili *et al.*, 2012), it is even more interesting that, despite frequent and heavy rains, the oribatid fauna is not washed from the canopy and is sheltered in the forest understory represented by the rhododendron trees.

Most of the canopy fauna (94 %) belongs to higher oribatids (Brachypilina). Only *S. patruelis* and *C. segnis* are representing lower oribatids. Behan-Pelletier and Walter (2000) also reported over 90 % of brachypilin mite species in the canopy, whereas 74 % of brachypilins were found on the ground (in our case, proportion of higher oribatids on the ground is about 82 %). However, Lindo and Winchester (2006) report higher numbers of lower oribatids in the canopy of red cedar trees.

The canopy community was characterized by the presence of species typical to that habitat - *C. segnis, C. cymba, P. farinosus, O. ocellatus, E. acromios, T. trimaculatus* and *M. brevipes*. Behan-Pelletier *et al.* (2007) even regard whole genus *Camisia* as arboreal, while Aoki (1971) con-

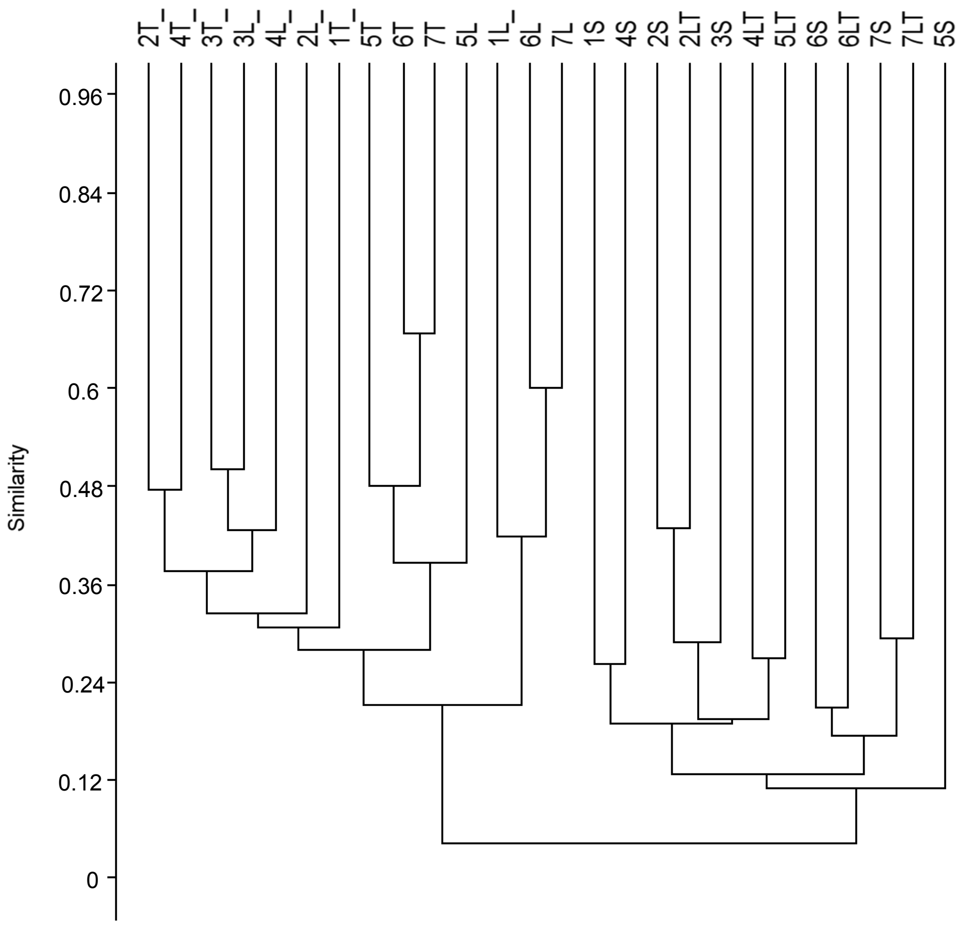

FIGURE 1: Cluster of faunal similarities of oribatid species from rododendron canopy and forest floor. Explanations of abbreviations are given in table 1.

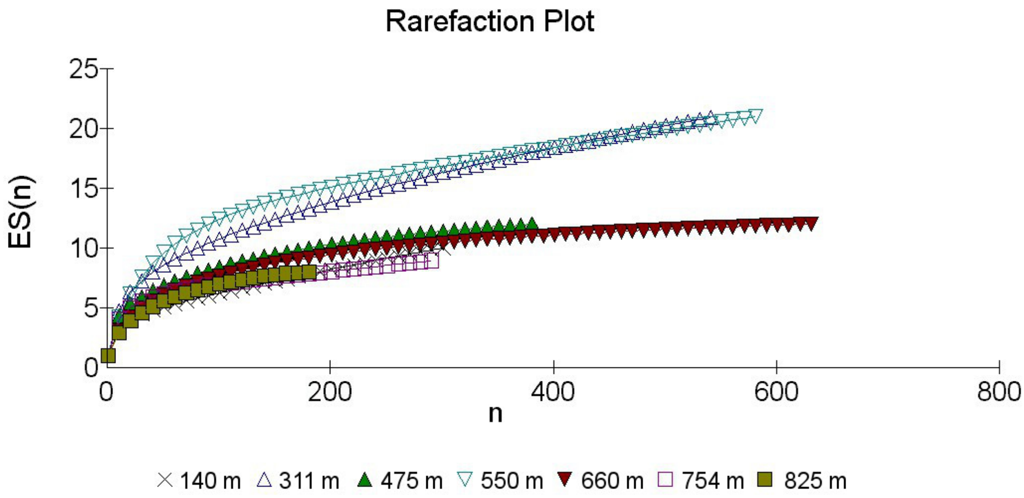

FIGURE 2: Oribatid mite species richness based on species accumulation curves and rarefaction methods for samples taken from rhododendron canopy microhabitats at seven elevations of MNP.

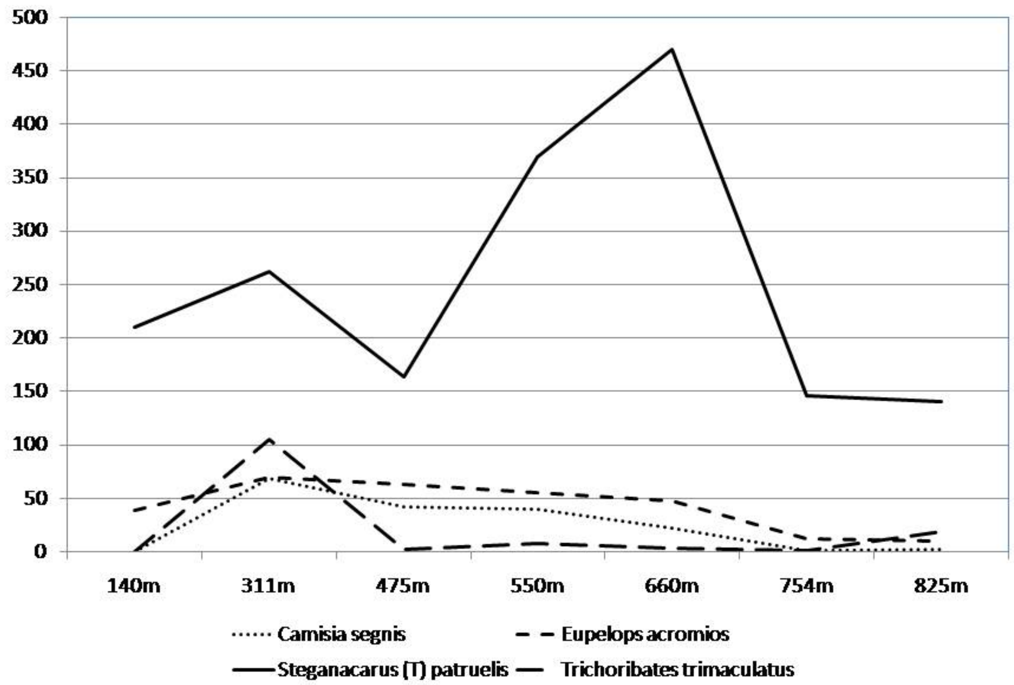

FIGURE 3: Abundance graph of four dominant canopy species along the altitudinal gradient in MNP.

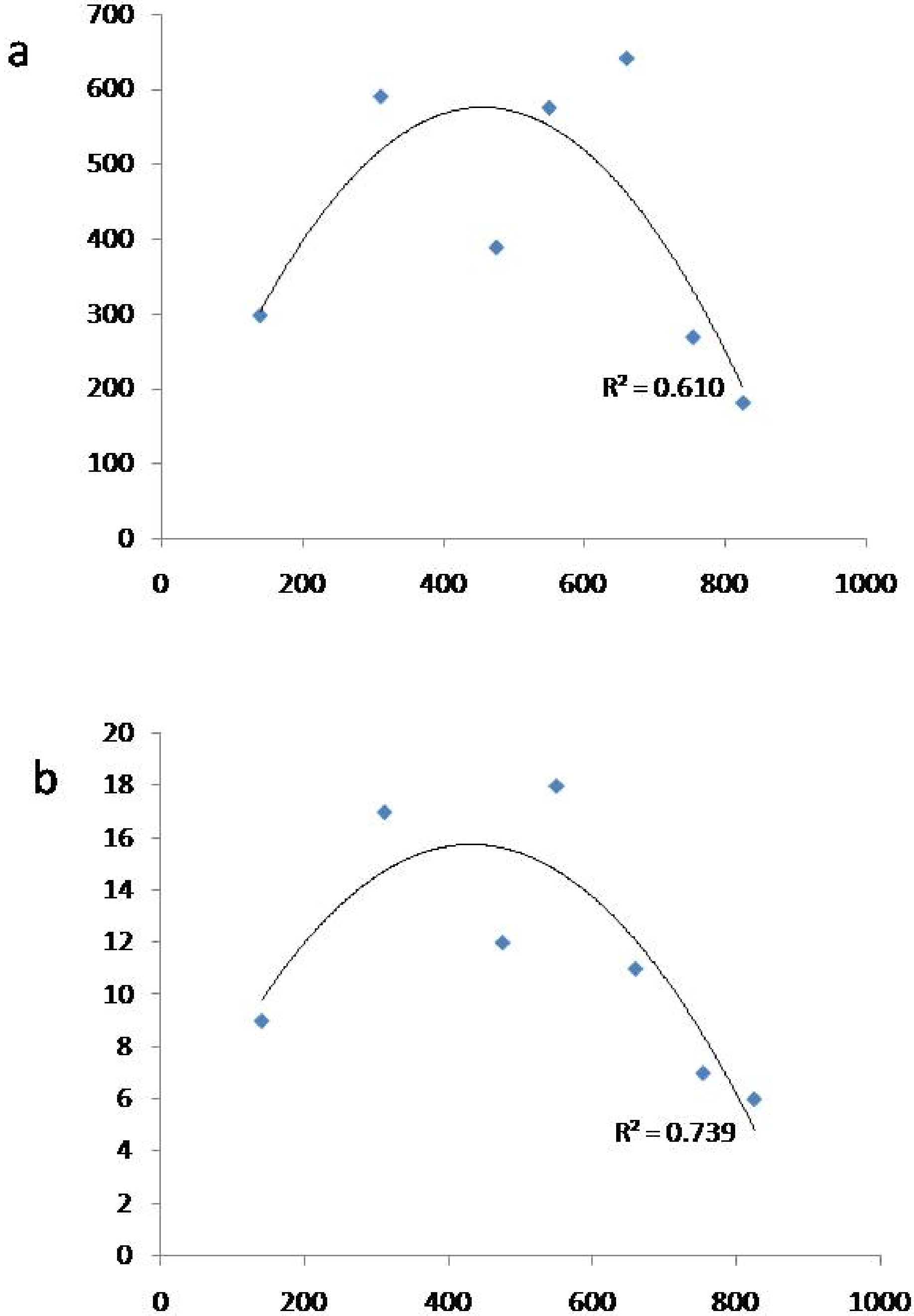

FIGURE 4: Changes of oribatid mite (a) abundance and (b) species number along altitudinal gradient in MNP.

tributes *Camisa* spp. to "wanderers" between the floor and canopy. We have encountered two species of this genus - *C. horrida* (Hermann, 1804) and *C. segnis*. *C. horrida* was found only in the litter. *C. segnis* was restricted mainly to the canopy habitats and just one juvenile individual was found in the litter. As for other "canopy" species, *O. ocellatus* represents a very interesting finding for the Georgian oribatid fauna. Up to now it was found only from the Abkhazian part of Georgia in lichens developed on rocky outcrops and barks of the trees (Tarba, 1992). We found it as numerous on twigs and leaves of rhododendron trees on elevation of 550 m a.s.l with fewer individuals present in other locations and no individual found on the forest floor.

The abundance graph of the four dominant canopy species (*S. patruelis, C. segnis, E. acromios* and *T. trimaculatus*) resembles the bell-shaped curve of the whole canopy fauna with the highest number of individuals at mid-altitudes and decreasing at lowest and highest altitudes (Figure 3). That influences the abundance distribution of whole fauna peaking at mid-altitudes (Figure 4a). The distribution of species numbers along the altitudes show similar bell-shaped pattern with highest number of species at mid-altitudes (Figure 4b). This finding contradicts recent elevational studies of soil oribatid fauna from nearby region (Mumladze *et al.*, 2015) where oribatid mite species richness decreases with increasing elevation. In this study, resource limitation was proposed to be of prime importance as well as elsewhere (Maraun *et al.*, 2009; Illig *et al.*, 2010). In the current study, a limitation of feeding resources in the canopy is accompanied by harsh environmental conditions leaving oribatid fauna more exposed to the abiotic severity than those found in soil which may explain the pattern observed. Rarefaction curves indicate that species richness of oribatid mites are almost similar at high elevations and encountering of new species by additional sampling is less likely, whereas additional sampling is needed for mid-elevations. It is highly possible that increasing sampling effort may result in a more pronounced bell-shaped pattern. Winchester *et al.* (2008) also investigated canopy species distribution along elevational gradient from 710 to 1190 m a.s.l. in conifer montane forests. But unlike our investigation, they found the highest number of species at the lowest (710 m) altitude.

The pattern of oribatid species richness and abundance distribution is less likely to change along the seasons. Winchester *et al.* (2009) suggest that species of canopy oribatids form seasonally stable populations with overlapping generations. That is additionally supported by the high numbers of juveniles of typical arboricolar species (*C. segnis, P. farinosus, T. trimaculatus*) and evergreen rhododendron trees that maintain leaves during the whole year. Bark structure (rough or smooth) is also known to affect the canopy fauna (Beaulieu *et al.*, 2006; Prinzing, 1997; Sobek *et al.*, 2008). Rough bark structure provides more shelter and feeding source for canopy arthropods compared with smooth one (Murvanidze and Mumladze, 2014; Prinzing, 1997; Sobek *et al.*, 2008). Bark of the twigs of *Rh. ponticum* has slight cracks that can serve as a refuge for oribatids. Walter and O'Dowd (1995) show that trees with hairy leaves harbor three times as many species and five times many individuals than trees with smooth leaves. The reduction of mite population from smooth and leathery leaves during rainy seasons is also shown by Walter (1995). Supporting this, we found both twig and leave habitats to differ significantly by abundance with twigs being more highly populated; however, no such difference is shown for species richness.

Rhododendron canopy is relatively free from fungi and lichens. Availability of the fresh feeding material should favor fauna having specific feeding requirements. Gut content analyses of a few species indicate that the canopy oribatid fauna utilizes resources that are broadly similar to those exploited by species in forest floor litter (Andre and Voegtlin, 1981; Walter and Behan-Pelletier, 1999). The arboreal fauna found in this study is composed mainly by primary and secondary decomposers, *M. brevipes* and *Phauloppia rauschensis* (Sellnick, 1908) are typical grazers and feed on lichens. In spite of the evidences on canopy oribatids feeding on phytopathogenic fungi on the leaves (Norton *et al.*, 1998) we did not find any fungal feeder species. Predator/scavengers are also absent from the canopy except for *Oppiella fallax* that is represented by five individuals in just one location.

In summary, we show that rhododendron understory harbor well-established and abundant oribatid fauna. Investigation of the canopy habitats in natural forests of Caucasus promises to add information to the knowledge on the ecology of separate species and to enhance regional biodiversity.

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