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Dynamic and seasonal fluctuations of microarthropod complex in coniferous forest soil

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Investigations of soil biological processes and biota were carried out in 1993–2006 in a relatively natural minimally disturbed ecosystem – pine forest soil of the old Ažvinčiai forest, Aukštaitija National Park. The obtained dynamic data for 14 years allow analysing the influence of climate changes on the density and species diversity of soil microarthropods and determining the trends of changes. In order to find out seasonal fluctuations in the abundance of zoocoenoses and to determine their dependence on climate conditions, the investigation of 1998 was carried out on a monthly basis.

It was determined that coniferous forests (*Pinetum myrtillosa vacciniosum*) of the moderate climate zone, growing in carbonaceous arenosols, are characterized by a rich complex of microarthropods predominated by oribatid mites. The microarthropod density reaches 228.1 thou ind. m^{-2}. Their species composition includes 157 species. The high density of microarthropods persists throughout a year, reaching its maximum (548.6 thou ind. m^{-2}) in late autumn.

Though generally soil moisture in this kind of forests is sufficient and soil temperature is optimal, soil moisture reduction in different years may entail fluctuations of the density of most sensitive (having the shortest life cycle) pedobionts (microorganisms, collembolans, etc.). This may destabilize the settled relationships among the organisms and entail functional changes in the prime biological processes of soil, i.e. mineralization and humification of organic matter.

Key words: temperature, precipitation, microarthropods, coniferous forest

INTRODUCTION

Soil fauna respond to many different environmental variables, and because they can indicate environmental stress through changes in species or community structure, they can also be used as important indicators (Van Straalen, 1998).

Fundamental researches of soil zoocoenoses as bioindicators were known already in the middle of the 20th century (Dunger, 1969; Тишлер, 1971; Гиляров, 1975; Карпачевский, 1976; Гелцер, 1986; Стриганова, 1987). The use of microarthropod complexes in monitoring programmes devoted to the impacts of global climate change in different geographical zones was reported more than once (Kennedy, 1994; Van Straalen, 1998; Hodkinson et al., 1998; Jucevica, Melecis, 2002, 2005; Eitminavičiūtė et al., 2005; Augustaitis et al., 2005). Specific complexes of zoocoenoses develop in each geographical zone. Though many research works in the field of biological soil diagnostics and bioindication methods have been carried out, they are still underestimated (Яковлев, 2000). Quantifying the influences of a specific taxonomic group on soil ecosystems is complicated because of a large number of species and numerous unidentified and multiple interactions among these species (Vetter et al., 2004; Wardle et al., 2004).

Climate changes in different years (especially in those arid) entail structural changes in soil zoocoenoses. The effect of global change on soil structure–biota interactions may be significant through alterations in precipitation, temperature events, or land-use (Young et al., 1998). Many soft-bodied animals such as enchytraeids and collembolans are sensitive to desiccation during dry conditions (Verhoef, Witteveen, 1980). Moisture changes may affect the fungal community and, thereby, have indirect effects on the fungivorous fauna and the position of oribatid mites (Hågvar, 1998). The developmental rate of Gamasina, Oribatida mites and Collembola is often temperature-dependent. Literary sources contain data on the influence of dry conditions on the distribution of Oribatida and Collembola (Lindberg, Bengtsson, 2005). A research carried out in Sweden shows that dry conditions exert different effects on individual species of oribatid mites and collembolans. The restoration of a species population after dry conditions depends on its morphoecology and reproduction types. Euribiont species more easily regenerate after the negative impact of dry conditions. The first to regenerate among Oribatida are parthenogenetically reproducing species. Investigations of the density of Collembola in pine forest soils carried out in Latvia showed that soil moisture fluctuations correlate with collembolan density (Jucevica, Melecis, 2002; 2006). It is assumed that climate warming has a negative effect on collembolans.

In the light of global environmental change, soil organic matter represents a relevant source of and is crucial to soil quality and to the regulation of many soil functions. Mineralization and humification of organics are the most important and most complicated processes taking place in soils where biota – microorganisms and zoocoenoses plays the crucial role. The soil fauna makes a major contribution to the sequestration and decomposition of soil organic matter (Vetter et al., 2004).

Even in the zone of moderate climate, the average air temperature has risen by 1 °C since the 18th century (by 0.4–0.5 °C in the 20th century) in relation with the climate change (Bukantis et al., 1998). Even in a comparatively small territory of this country as it is, the difference between its eastern peripheries with a well-developed continental climate and its western peripheries with marine climate is pronounced (Bukantis, 1994; Bukantis et al., 1998).

The objective of the present work is to reveal seasonal fluctuations of the structure, density and species composition of soil microarthropod community and determine their dependence on climate conditions based on long-term dynamic investigations in a relatively natural forest ecosystem of the eastern part of the country (Aukštaitija NP, Ažvinčiai forest) predominated by continental climate.

MATERIALS AND METHODS

Investigations of the influence of climate change on microarthropod communities in the old Ažvinčiai forest of Aukštaitija National Park (ANP) were carried out in September of 1993–2006 and monthly in 1998. The stationary reference area was chosen in a mature cowberry pine forest (*Peucedano-Pinetum*) with scarce spruce in the Versminis stream basin in the old Ažvinčiai forest. The herbaceous plants were predominated by bilberry (*Vaccinium myrtillus*), forest reedgrass (*Calamagrostis arundinacea*) and moss (*Hylocomium splendens*, *Pleurozium schreberi*). The soil was represented by carbonaceous arenosol. The geographical coordinates of the basin: longitude 26°03'20''–26°04'50'' and latitude 55°26'20''–55°26'53''. The long-term average air temperature is 5.8°C, precipitation 682 mm and the vegetation period lasts 189 days (Augustaitis et al., 2006).

The samples were taken five times repeatedly in September of each year from the 0–5 cm topsoil using a cenometer (5 × 5 × 5 cm). Microarthropods were isolated from the soil samples with a modified Tullgren-Berlese extractor by standard methods (Гиляров, Стриганова, 1987).

The hydrometeorological data (air temperature, t °C, soil surface temperature, t °C, and precipitation, mm) were taken from meteorological observation tables of a hydrometeorological centre (Utena hydrometeorological station). The temperature indices (air, soil surface and substratum) were also measured during sampling.

The concentration of heavy metals in the soil and grasses was determined in 2005 and 2006, in litter in 1994 and 1999–2006.

The following ecological indices were used for data analysis: the number of individual species (S), their density *n* (thou ind. m^{-2}) and occurrence (C_f, %) (Cassagnau, Rouquet, 1962). The dominance of individual species was determined according to H. Engelmann (Engelmann, 1978). The structure of complexes is expressed per cent. The deviations of density from the total average of 14 years are given.

Computer programs Statistica 6.0 and Microsoft Excel were used for statistical data processing.

RESULTS AND DISCUSSION

Soils of relatively natural forest ecosystems abound in invertebrates, yet various types of forests have specific complexes of zoocoenoses. Pine forests are distinguished for the abundance of microarthropods.

A dynamic 14-year-long investigation has shown that the average density of microarthropods in the carbonacous arensol of Ažvinčiai old forest is 228.1 thou. ind. m^{-2} (Table 1). In different years, their density varies depending on climate conditions from 132.1 (dry 1994) to 337.3 thou ind. m^{-2} (2005). Oribatid mites account for 75% of the total of microarthropods (Fig. 1). The average density of oribatid mites during the study period was 102.0 thou ind. m^{-2}. In different years, the density values ranged from 50.5 (in 1994) to 143.3 thou ind. m^{-2} (1993). Other groups of microarthropods are less abundant. The average density of Collembola was 20.5 thou ind. m^{-2}. In different years, their density ranged from 10.2 (in 1996) to 41.4 thou ind. m^{-2} (1998). Collembolans account for 8.9% of the total microarthropods. The average density of gamasid mites equalled to 18.5 thou ind. m^{-2}. In different years its ranged from 6.3 (in 1999) to 13.3 thou ind. m^{-2} (1994) (Table 1). Gamasid mites accounted for 8.1% of the total (Fig. 1).

The density of other mites was low and accounted for about 8.0% of the total microarthropods. Representatives of meso-fauna – earthwarms and insect larvae – occur in these soils as solitary individuals. Oribatida are not only the most abundant but also the species-richest group of microarthropods in the study soil. In 14 years, 93 species of Oribatida, 29 species of Gamasina and 31 species of Collembola were detected (Table 1).

The long-term dynamics rather vividly demonstrates the richness of soil fauna in the ecosystem under study. The number of individual Oribatida species in soil samples taken once per year ranged from 21 to 38, Gamasina from 10 to 16 and Collembola from 6 to 11. In 1993–2001, the number of detected species of oribatid mites was 74; in 2002–2006 the list of species included additional 9 species but lost 41 previously detected ones. In 14 years, 27 individual species of Oribatida, 4 species of Gamasina and 12 species of Collembola were detected only once.

The species composition of microarthropod groups showed that oribatids *Oppiella nova*, representatives of the family *Suctobelbidae* and *Tectocepheus velatus* comprise the nucleus of this community. Some species of Collembola and gamasid mites are attributed to the category of satellite sparse species (Fig. 2).

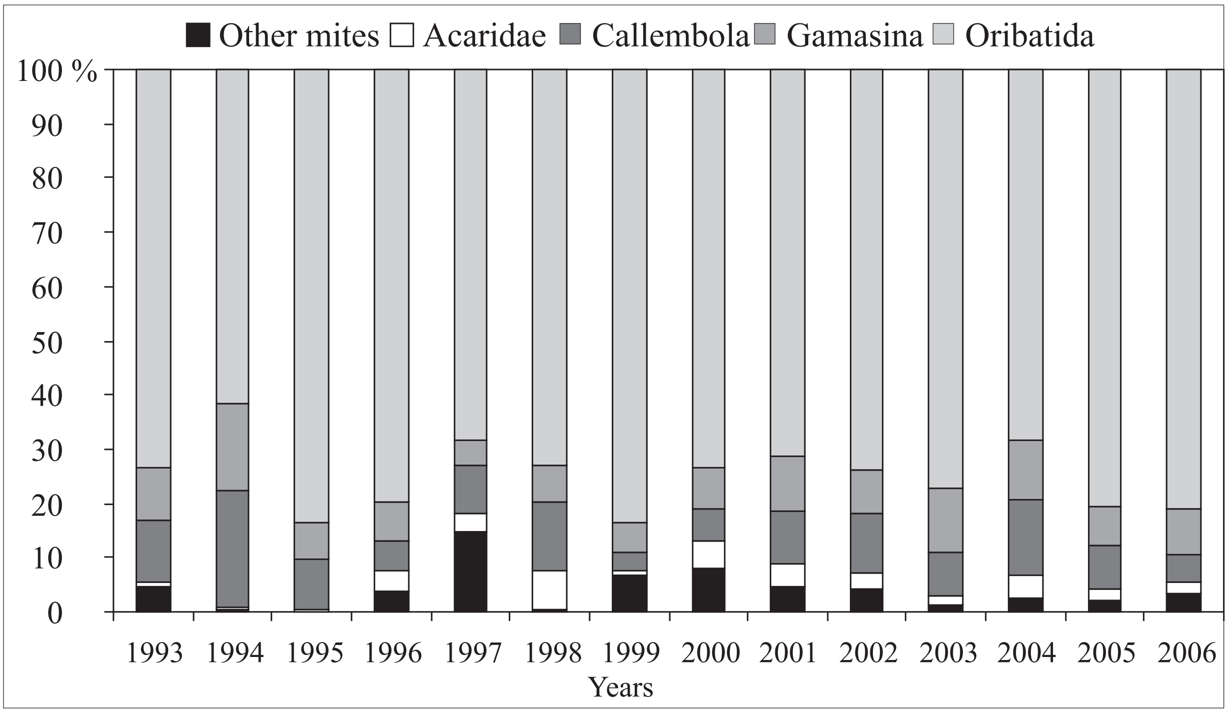

Fig. 1. Structure of microarthropod complex (%) in the soil of old Ažvinčiai forest in Aukštaitija National Park, 1993–2006

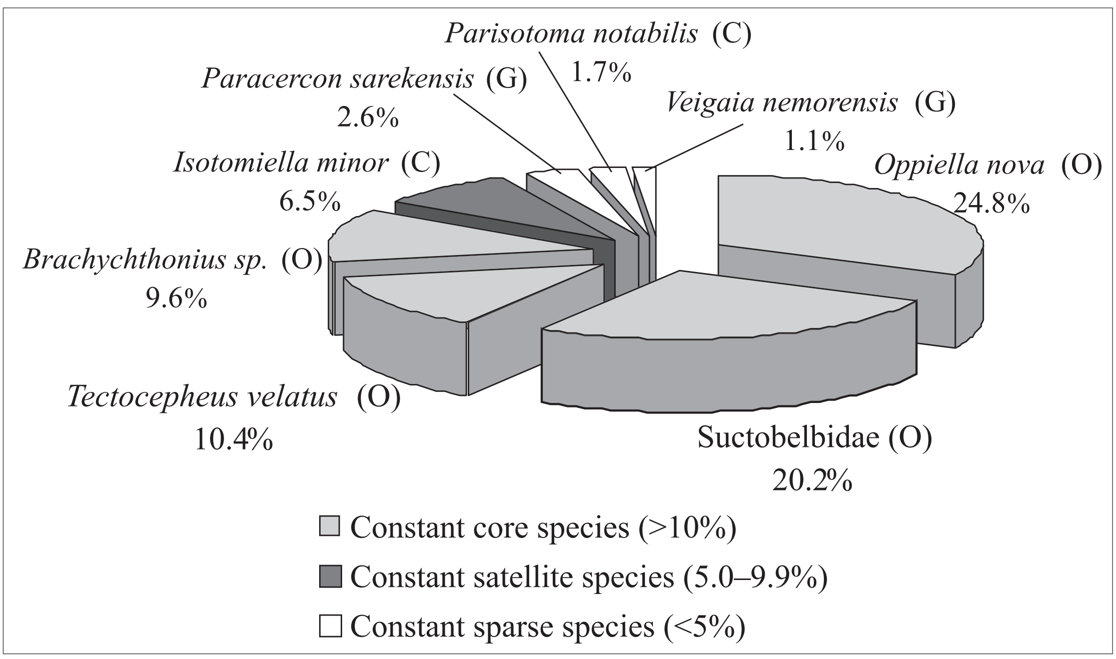

Fig. 2. Species composition of microarthropod complex (regular species with C_f = 100%) in the soil of old Ažvinčiai forest, 1993–2006 (O – Oribatida, C – Collembola, G – Gamasina)

Therefore, the species composition of microarthropods (Oribatida, Gamasina, Collembola) in the slightly disturbed carbonaceous arenosol (humus accounts for 9.1% and pH is 4.0 on the average (Table 2)) of a green moss pine forest in the zone of moderte climate included 157 species (Table 1), *Oppiella nova* being the dominant one (24.8%). Oribatida from the family *Suctobelbidae* accounted for 20.2%. The subdominants included *Tectocepheus velatus* (10.4%), *Brachychthonius* sp. (9.6%), *Isotomiella minor* (6.5%) and *Mesaphorura krausbaueri* (4.4%). Recedent species are represented by *Paracercon sarekensis* (2.6%), *Parisotoma notabilis* (1.7%) and *Steganacarus carinatus* (1.5%). All the other 148 species were sparse (<1.3%) and belonged to the category of subrecedent species. This large number of rare species is characteristic only of the soils of natural, almost intact ecosystems.

Table 1. **Species compostion and microarthropod density (thou ind. m^{-2}) in the soil of Aukštaitija National Park (Ažvinčiai old forest), 1993–2006**

No	Microarthropod group	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Σ
	Oribatida															
1.	*Achipteria nitens* (Nicolet, 1855)						0.1	0.6								0.7
2.	*Adoristes ovatus* (C. L. Koch, 1840)		1.1	0.4	0.4	1.1	1.1	1.6	2.8	0.1	1.0	0.2	0.6	0.1	0.4	10.9
3.	*Adoristes poppei* (Oudemans, 1906)	3.0		0.4	0.7	0.5	0.1	0.4	0.4	1.4	0.7	0.9	3.2	1.7	0.4	13.8
4.	*Atopochthonius artiodactylus* (Grandjean, 1948)							0.1	0.3				0.8			1.2
5.	*Autogneta longilamellata* (Michael, 1885)											0.1		0.2		0.3
6.	*Autogneta traegardhi* (Forsslund, 1947)								0.4							0.4
7.	*Autogneta* sp.									0.1						0.1
8.	*Belba* sp.	0.1														0.1
9.	*Brachychthonius* sp.	13.6	6.4	15.4	12.0	20.1	31.6	19.5	9.2	6.4	5.0	4.8	2.0	5.1	13.9	165.0
10.	*Camisia biurus* (C. L. Koch, 1839)					0.1		0.1	0.4							0.6
11.	*Camisia segnis* (Hermann, 1804)	0.2									0.2					0.4
12.	*Camisia spinifer* (C. L. Koch, 1836)						0.1									0.1
13.	*Camisia* sp.			0.1												0.1
14.	*Carabodes areolatus* (Berlese, 1916)	0.3														0.3
15.	*Carabodes coriaceus* (C. L. Koch, 1835)								0.1							0.1
16.	*Carabodes femoralis* (Nicolet, 1855)										0.2	0.3				0.5
17.	*Carabodes forsslundi* (Sellnick, 1953)				0.1	0.2	0.3	0.6			0.1	0.2	0.1	0.3	0.2	2.1
18.	*Carabodes labyrinthicus* (Michael, 1879)	0.9								0.2	0.4	0.9	0.4	1.1	0.2	4.1
19.	*Carabodes marginatus* (Michael, 1884)									0.2						0.2
20.	*Carabodes minusculus* (Berlese, 1923)									0.1			0.2			0.3
21.	*Carabodes* sp.	0.3	0.1	0.1	0.6					0.2						1.3
22.	*Cepheus cepheiformis* (Nicolet, 1855)													0.1		0.1
23.	*Ceratoppia bipilis* (Hermann, 1904)			0.1										0.1		0.2
24.	*Ceratozetella minima* (Sellnick, 1929)										1.0	0.3	0.2			1.5
25.	*Ceratozetella thienemanni* (Willmann, 1943)					0.8	0.3	0.2	2.4		0.5		0.4	0.9		5.5
26.	*Ceratozetes minutissimus* (Willmann, 1951)	1.6								0.4						2.0
27.	*Chamobates cuspidatus* (Michael, 1884)										0.2					0.2
28.	*Chamobates borealis* (Trägardh, 1902)					0.1	0.3	0.1								0.5
29.	*Chamobates* sp.	0.8	0.3		1.3									0.5		2.9
30.	*Conchogneta delacarlica* (Forsslund, 1947)									0.1						0.1
31.	*Ctenoppiella tuberculata* (Bulanova-Zachvatkina, 1964)					7.2	2.5	2.7	0.6							13.0
32.	*Cultroribula bicultrata* (Berlese, 1905)							0.3			0.1					0.4
33.	*Damaeus onustus* (C. L. Koch, 1841)												0.2	0.1		0.3
34.	*Damaeus* sp.				0.1	0.2						0.1		0.2		0.6
35.	*Damaeus* sp. a													1.0		1.0

Table 1 (continued)

No	Microarthropod group	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Σ
36.	*Dissorhina ornata* (Oudemans, 1900)	3.6						0.1		0.8	0.1	1.5	1.6	0.3		8.0
37.	*Eobrachychthonius* sp.						2.1	2.2								4.3
38.	*Eremaeus oblongus* (C. L. Koch, 1836)					1.3			0.1	0.1			0.3	0.1		1.9
39.	*Eupelops occultus* (C. L. Koch, 1836)										0.3	0.5	0.1	0.3	0.1	1.3
40.	*Eupelops subuliger* (Berlese, 1916)						0.1									0.1
41.	*Eupelops torulosus* (C. L. Koch, 1840)							0.2	0.3	0.1	0.3	0.3	0.2	0.5		1.9
42.	*Eupelops* sp.	0.6	0.2	0.2	0.6	0.2				0.2					0.3	2.3
43.	*Furcoribula furcillata* (Nordenskiöld, 1901)	0.4					0.1									0.5
44.	*Galumna europaeus* (Berlese, 1914)					0.2	0.2		0.1						0.1	0.6
45.	*Galumna lanceata* (Oudemans, 1900)							0,1							0.1	0.2
46.	*Galumna* sp.	0.3		0.1	0.5						0.3	0.4	0.2			1.8
47.	*Heminothrus longisetosus* (Willmann, 1925)	1.5			0.7	0.5	0.4	0.5	1.1	3.3	1.9	3.3	0.4	1.2	1.0	15.8
48.	*Heminothrus peltifer* (C. L. Koch, 1839)	0.7	0.9	0.2	0.2	0.2	1.0	0.5	0.3	0.6	0.2	1.0	0.2	0.2		6.2
49.	*Heminothrus* sp.		1.0	1.5												2.5
50.	*Lauroppia fallax* (Paoli, 1908)										2.4	1.2	1.2	0.8		5.6
51.	*Liebstadia similis* (Michael, 1888)								0.1							0.1
52.	*Malaconothrus globiger* (Trägardh, 1910)												0,1			0.1
53.	*Malaconothrus* sp.	0.2	0.2		0.3	0.1										0.8
54.	*Metabelba pulverulenta* (C. L. Koch, 1839)					1.2		0.1	0.2							1.5
55.	*Metabelba* sp.	0.9		0.4							0.3	0.2	0.1	0.5		2.4
56.	*Microppia minus* (Paoli, 1908)	0.3	0.1	0.1		0.3	0.1							1.4		2.3
57.	*Microtritia minima* (Berlese, 1904)	0.1								0.1	0.1	0.4	0.1			0.8
58.	*Minunthozetes* sp.			5.1						0.1						5.2
59.	*Nanhermannia elegantula* (Berlese, 1913)	2.4				0.7				0.1	2.0	1.9	0.7	0.5	1.3	9.6
60.	*Nanhermannia nanus* (Nicolet, 1855)				0.5	0.1	0.6	1.8	3.0	0.1						6.1
61.	*Nanhermania* sp.		0.7	2.2		0.1										3.0
62.	*Nothrus anauniensis* (Canestrini & Fanzago, 1876)						1.8	1.9	3.0							6.7
63.	*Nothrus silvestris* (Nicolet, 1855)	2.9	0.8	1.6	0.5	0.7				1.4	1.5	1.6	1.4	2.3	2.7	17.4
64.	*Oppia* sp.		0.8	5.2	3.3		0.2	0.3	0.3						0.1	10.2
65.	*Oppiella nova* (Oudemans, 1902)	31.3	10.7	30.6	50.2	53.5	45.8	27.3	22.6	14.0	16.7	16.8	29.2	41.5	34.5	424.7
66.	*Oppiella* sp.						0.1									0.1
67.	*Oppiella rossica* (Bulanova-Zachvatkina, 1964)										0.3				0.1	0.4
68.	*Oribatula tibialis* (Nicolet, 1855)	0.9			0.3	0.3	0.4	0.2	0.2		0.5	0.5	0.1	1.0	0.3	4.7
69.	*Palaeacarus hystricinus* (Trägardh, 1932)			0.4		0.3		0.1								0.8
70.	*Parachipteria punctata* (Nicolet, 1855)	1.1	1.0	2.1	0.5	3.4	1.7	1.4	2.7	1.4	1.8	1.2	1.7	1.4		21.4
71.	*Parachipteria willmanni* (van der Hammen, 1952)						0.3			0.3	2.4	3.7	0.5	2.0		9.2

Table 1 (continued)

No	Microarthropod group	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Σ
72.	*Parachipteria* sp.														1.8	1.8
73.	*Phthiracarus borealis* (Trägardh, 1910)							0.1								0.1
74.	*Phthiracarus globosus* (C. L. Koch, 1841)						0.4				0.7	0.2	0.5	0.2	0.1	2.1
75.	*Phthiracarus ligneus* (Willmann, 1931)						0.1									0.1
76.	*Phthiracarus nitens* (Nicolet, 1855)							0.2								0.2
77.	*Phthiracarus piger* (Scopoli, 1763)					0.1		0.5	1.3							1.9
78.	*Phthiracarus* sp.	0.9	1.5	2.0	0.9		0.3	0.1				0.1				5.8
79.	*Protoribates* sp.		0.5													0.5
80.	*Quadroppia quadricarinata* (Michael, 1885)	2.9	1.7	0.6	0.5	0.5	0.1	1.3	1.9	0.9	0.6	0.8	0.4	1.6		13.8
81.	*Rhysotritia ardua* (C. L. Koch, 1841)							0.1								0.1
82.	*Scheloribates confundatus* (Sellnick, 1928)	3.9														3.9
83.	*Scheloribates laevigatus* (C. L. Koch, 1836)	0.2			1.3	2.0		0.3	0.3	0.5	0.2	0.2				5.0
84.	*Scheloribates latipes* (C. L. Koch, 1844)	0.3				0.2	0.8	0.5	2.6	0.4	2.1	0.8	1.6	0.1	1.9	11.3
85.	*Scheloribates pallidulus* (C. L. Koch, 1841)						0.7	1.7								2.4
86.	*Scheloribates* sp.		0.8	1.6	1.0											3.4
87.	*Steganacarus carinatus* (C. L. Koch, 1841)	2.8		2.4	2.8	2.0	2.2	3.3	3.9	1.1	2.2	2.2	1.6	1.0	1.1	28.6
88.	*Steganacarus striculus* (C. L. Koch, 1835)					0.7	0.1			0.5	1.3	2.9	2.6	1.7	1.2	11.0
89.	*Steganacarus* sp.				0.3											0.3
90.	*Suctobelba* sp.	33.1	4.8	3.9	2.2	0.4	4.2	1.6	2.0	7.2	2.8	3.0	1.8	1.6	3.1	71.7
91.	*Suctobelbella* sp.	25.6	10.8	28.5	14.8	20.5	22.9	22.4	14.3	11.8	14.4	11.0	19.4	45.5	12.6	274.5
92.	*Tectocepheus velatus* (Michael, 1880)	5.6	6.1	16.8	5.8	11.5	14.7	7.5	17.0	22.2	8.6	6.4	7.3	22.5	26.3	178.3
93.	*Xenillus tegeocranus* (Hermann, 1804)											0.1				0.1
	Σ	143.3	50.5	122.0	102.4	131.3	137.8	102.5	93.9	76.4	73.4	70.0	81.4	139.6	103.8	1428.3
	Number of species	**34**	**21**	**26**	**28**	**34**	**35**	**38**	**30**	**29**	**36**	**36**	**35**	**36**	**24**	
	Gamasina															
1.	*Amblyseius* sp.	0.1													0.1	0.2
2.	*Asca aphidioides* (Linnaeus, 1758)	0.4			0.3	0.1	0.5	0.2	0.5	0.5	0.7	1.6	0.1	0.1	0.2	5.2
3.	*Asca bicornis* (Canestrini & Fanzago, 1887)		0.3	0.1												0.4
4.	*Dendrolaelaps* sp.	0.8		0.1									0.3	0.6		1.8
5.	*Dinychus* sp.	0.1						0.1			0.1	0.1		0.4	0.1	0.9
6.	*Eviphis ostrinus* (C. L. Koch, 1836)	0.6	0.2				0.1	0.1							0.2	1.2
7.	*Geolaelaps aculeifer* (Canestrini, 1883)	0.4	0.7	1.0	1.1	0.9	2.4	0.7	1.0	0.4		0.2	0.4	1.0	1.0	11.2
8.	*Cosmolaelaps vacua* (Michael, 1891)														1.0	1.0
9.	*Leioseius bicolor* (Berlese, 1918)					0.1										0.1
10.	*Ololaelaps placentulus* (Berlese, 1887)	0.1		0.2	0.2			0.1			0.1	0.2	0.2		1.0	2.1
11.	*Parasitus* sp.						0.2									0.2

Table 1 (continued)

No	Microarthropod group	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Σ
12.	*Parazercon sarekensis* (Willmann, 1939)	2.1	7.4	4.0	2.7	3.0	2.8	1.7	1.4	4.0	3.2	1.9	3.0	3.7	4.1	45.0
13.	*Pergamasus brevicornis* (Berlese, 1903)		0.1							0.1			0.2	0.1		0.5
14.	*Pergamasus crassipes* (Berlese, 1906)	0.1		0.1												0.2
15.	*Pergamasus septentrionalis* (Oudemans, 1902)	0.3	0.2						0.1							0.6
16.	*Pergamasus* sp.	1.1	0.2	0.2	0.4		0.1	0.1	0.3	0.5	0.3	0.5	0.5	0.4	0.2	4.8
17.	*Prozercon kochi* (Sellnick, 1943)	0.4	1.6	0.9	0.8	1.4	1.4	0.1	0.9	0.7	0.5	0.7	2.3	1.1	1.2	14.0
18.	*Rhodacarellus silesiacus* (Willmann, 1935)								0.1							0.1
19.	*Rhodacarus* sp.		0.4	0.3	0.2		0.2					1.6	0.8	0.1		3.6
20.	*Trachytes aegrota* (C. L. Koch, 1841)	0.1		0.4	0.2		0.5	0.4	0.3	1.7	0.7	0.6	0.5	0.3		5.7
21.	*Trachytes pauperior* (Berlese, 1914)		0.3	0.1	0.2	0.5	0.5	0.9	0.9	0.6	0.3		0.3	0.5	0.2	5.3
22.	*Urodiaspis tecta* (Kramer, 1876)				0.1		0.1	0.1		0.1	0.1		0.1	0.1		0.7
23.	*Uropoda minima* (Kramer, 1882)	0.3	0.6	0.1	0.2	0.3		0.2	0.2	0.1	0.6	0.2		0.1	0.1	3.0
24.	*Veigaia cerva* (Kramer, 1876)		0.1							0.1						0.2
25.	*Veigaia exigua* (Berlese, 1916)			0.2			0.4								0.4	1.0
26.	*Veigaia kochi* (Trägardh, 1901)			0.3	0.1	0.2	0.3	0.2	0.2	0.3	0.2		0.3	0.2		2.3
27.	*Veigaia nemorensis* (C. L. Koch, 1839)	2.4	1.2	1.0	0.2	1.1	2.9	1.0	0.6	0.4	0.1	0.9	3.0	3.6	1.5	19.9
28.	*Zercon triangularis* (C. L. Koch, 1836)	0.1			0.1		0.5									0.7
29.	*Zercon* sp.			0.1		0.6		0.4	0.8	0.3	0.3	0.2	0.2		0.1	3.0
	Σ	9.4	13.3	9.1	6.8	8.2	12.9	6.3	7.3	9.8	7.2	8.7	12.2	12.3	11.4	134.9
	Number of species	**16**	**13**	**16**	**14**	**10**	**15**	**15**	**13**	**14**	**13**	**12**	**15**	**15**	**15**	
	Collembola															
1.	*Anurophorus laricis* (Nicolet, 1842)	0.3	3.0		0.5	3.1		0.2	0.2	0.3		0.1	0.3	0.7	0.2	8.9
2.	*Bourletiella arvalis* (Fitch 1863)								0.1							0.1
3.	*Bourletiella hortensis* (Fitch, 1863)	0.1	0.1				0.1									0.3
4.	*Bourletiella lutea* (Lubbock, 1868)											0.1				0.1
5.	*Brachystomella parvula* (Schaeffer, 1896)					7.6					0.1			0.1		7.8
6.	*Desoria violacea* (Tullberg, 1876)	0.1										0.2	0.9	0.2		1.4
7.	*Entomobrya muscorum* (Nicolet, 1842)												0.3			0.3
8.	*Friesea mirabilis* (Tullberg, 1871)	0.4														0.4
9.	*Hypogastrura assimilis* (Krausbauer, 1898)			0.3										0.2	0.6	1.1
10.	*Hypogastrura* sp.				0.1			0.1	0.1	2.6	3.7	0.5				7.1
11.	*Isotomodes productus* (Axelson, 1906)												0.5			0.5
12.	*Isotoma* sp. juv.									0.5						0.5
13.	*Isotomiella minor* (Schaeffer, 1896)	7.7	8.0	13.1	2.7	6.9	12.0	2.7	8.6	12.4	7.0	8.2	8.7	11.4	2.3	111.7
14.	*Isotoma viridis* (Bourlet, 1839)			0.1						0.1						0.2
15.	*Isotomurus* sp. juv.					0.2			0.3	0.7		0.1			0.6	1.9

Table 1 (continued)

No	Microarthropod group	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Σ
16.	Lepidocyrtus sp. 1	0.6	0.4	0.2			0.3	0.1	0.2		0.2			0.2		2.2
17.	Lepidocyrtus sp. 2						0.2									0.2
18.	Lepidocyrtus sp. juv.	0.1		0.2		0.1										0.4
19.	*Mesaphorura gr. krausbaueri* (Boerner, 1901)	1.4	8.6	5.3	5.7		24.0	1.9	2.6	1.8	6.9		3.4	8.2	7.0	76.8
20.	*Neanura muscorum* (Templeton, 1835)	0.4		0.1			0.5			0.3			0.1			1.4
21.	Orchesella sp. juv.							0.1		0.3						0.4
22.	*Parisotoma notabilis* (Schaeffer, 1896)	4.4	1.4	2.5	0.6	0.9	2.5	0.6	1.4	1.6	0.4	1.0	6.5	5.3	0.7	29.8
23.	*Pogonognathellus longicornis* (Müller, 1776)							0.1								0.1
24.	*Proisotoma minima* (Absolon, 1901)			2.8					0.1		0.7			0.1		3.7
25.	*Protaphorura gr. armata* (Tullberg, 1869)		6.8					0.7				1.9	8.0	0.9	0.1	18.4
26.	*Pseudachorutes subcrassus* (Tullberg, 1871)				0.6	1.2					0.4			0.1		2.3
27.	Pseudochorutes sp.						1.8									1.8
28.	*Pseudosinella alba* (Packard 1873)			0.1												0.1
29.	*Sminthurides assimilis* (Krausbauer, 1898)												0.1			0.1
30.	*Sphaeridia pumilis* (Krausbauer, 1828)			0.2					0.2	0.6			0.1		0.4	1.5
	Σ	15.5	28.3	24.9	10.2	20.0	41.4	6.5	13.8	21.2	19.4	12.1	28.9	27.4	11.9	281.5
	Number of species	**10**	**7**	**11**	**6**	**7**	**8**	**9**	**10**	**11**	**8**	**8**	**11**	**11**	**8**	
	Total density	167.9	92.1	156.0	119.4	159.5	192.1	115.3	115.0	107.4	100.0	90.8	122.5	179.3	127.1	
	Number of species	**60**	**41**	**53**	**48**	**51**	**58**	**62**	**53**	**54**	**57**	**56**	**61**	**62**	**47**	

The obtained long-term results show that in the last five years (2002–2006), the average density of microarthropods (219.8 thou ind. m^{-2}) in the soil of the old Ažvinčiai forest was lower than in the nine previous years (232.7 thou ind. m^{-2}). The calculated 14-year total average density of microarthropods (including individual groups), equalled to 100%, showed deviations of individual groups from the average value throughout the study period (Fig. 3). The highest positive deviations from the average values were observed in 1997, 1998 and 2005 and the lowest in 1994, 2002 and 2003. Significant deviations from the average value were characteristic of the density of collembolans. In 1997, 1998, 2004 and 2005, their density was markedly higher and in 1999 and 2000 markedly lower.

The annual values of precipitation below the climatic norm of Lithuania were registered in the ANP in 1996, 1999, 2002 and 2006. Dry conditions developed in 1994, 2002 and 2006 (Galvonaitė ir kt., 2007). The droughts of 1996 and 1999 preconditioned the fall of the groundwater level (Augustaitis et al., 2006).

Apparently, precipitation is a climate element subject to highest annual fluctuations. In some years, depending on atmospheric circulation, precipitation may 1.5–2 times exceed or be under the long-term average. Precipitation and air temperature during the vegetation period had a marked effect only on the density of soil microarthropods. However, different groups of microarthropods are unevenly sensitive to these factors. At high values of precipitation, the total density of Collembola and gamasid mites increased and reduced the relative density of Oribatida, e. g. in 1994 and 2004 (Fig. 4).

N. Lindberg and J. Bengtson (2005) tried to elucidate the influence of dry conditions on the distribution and regeneration of Oribatida and Collembola. They reported that Collembola species regenerated more rapidly than did Oribatida species. This is related to the specific features of species reproduction and their morphoecology.

For a more accurate evaluation of the specific structural and density aspects of microarthropod communities related with climate factors, investigations in 1998 were carried out on a monthly basis. This year was distinguished for high values of precipitation, in the summer months in particular (Fig. 5). In 1998, the density of oribatid mites was 207.4 thou ind. m^{-2} and accounted for 75.2% of the total microarthropods. The density of other groups was not high: Collembola 23.8 thou ind. m^{-2} (8.6%), Gamasina 19.6 thou ind. m^{-2} (7.1%), Acaridae 14.6 thou ind. m^{-2} (5.2%), Tarsonemidae 8.5 thou ind. m^{-2} (3.0%), and other mites 1.8 thou ind. m^{-2} (0.6%) (Table 3). The highest density of oribatid mites (80%) was determined in winter months: February, November and December (Fig. 5). The density of oribatid mites had been permanently increasing since January, reaching its maximum in November (439.5 thou ind. m^{-2}) (Table 3). The

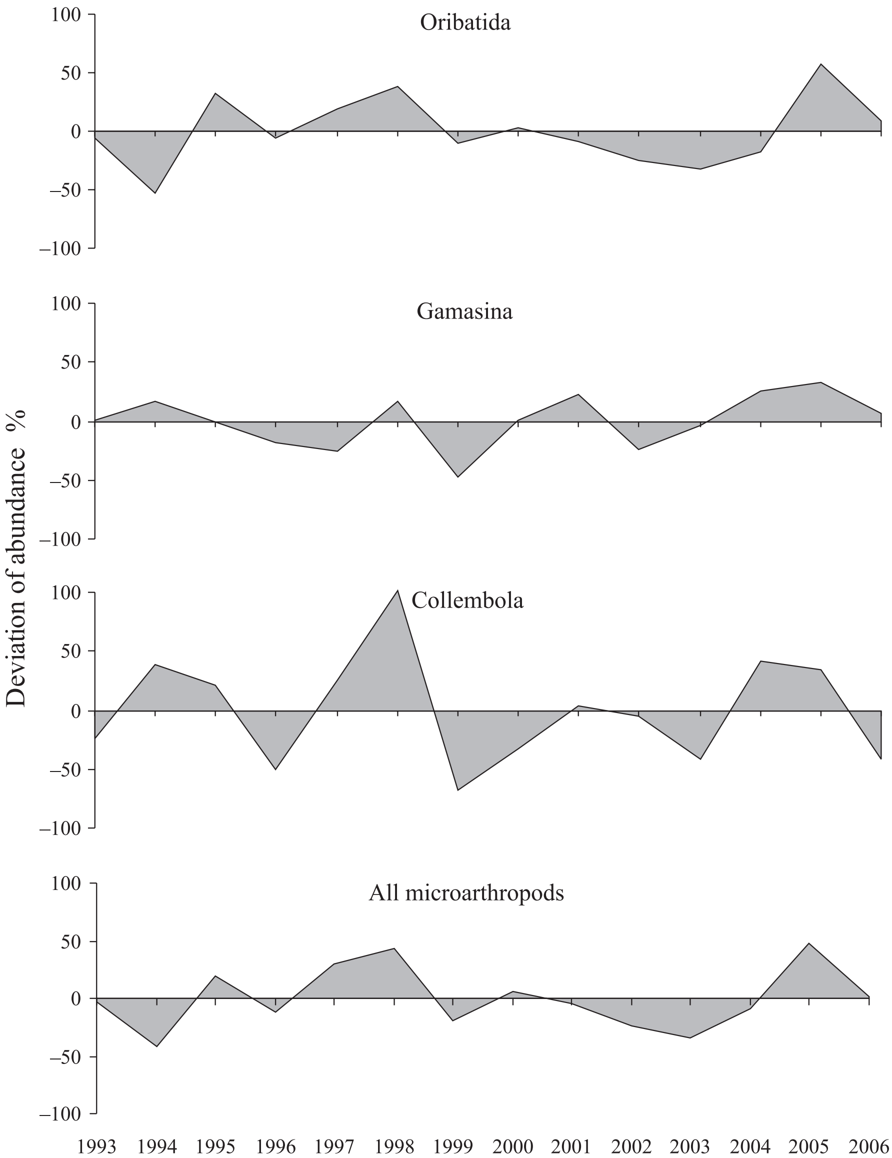

Fig. 3. Percental deviation of microarthropod density from the total 14-year average in the soil of Aukštaitija National Park (Ažvinčiai) (1993–2006)

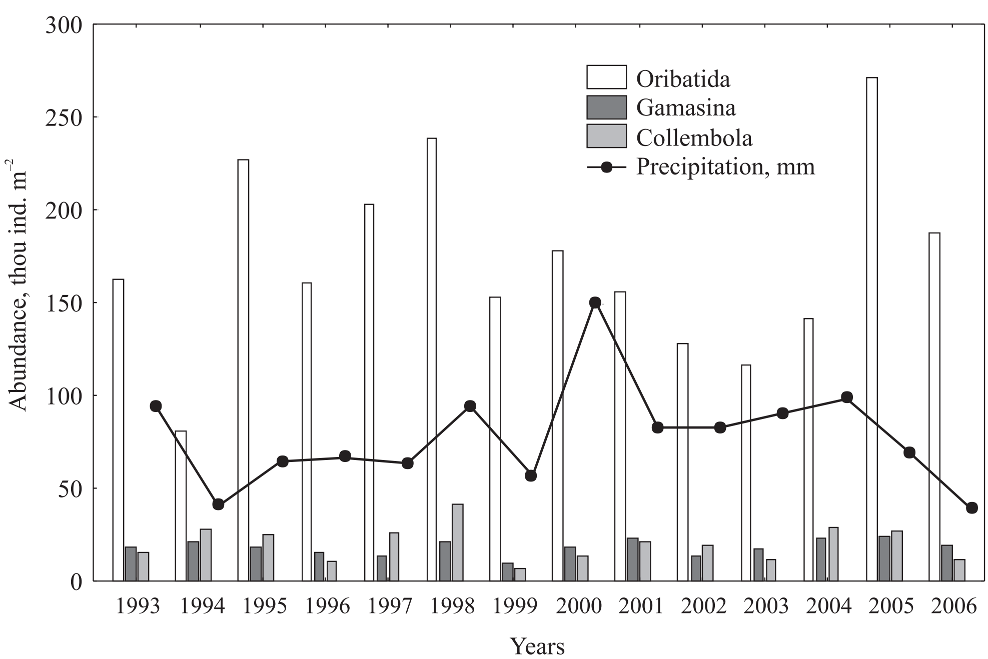

Fig. 4. Density of oribatid and gamasid mites and Collembola (thou ind. m^{-2}) and precipitation (mm), 1993–2006

Table 2. **Average meteorological data for summer time (months 5–8) of 1993–2006 (Utena hydrometeorological station) and physical soil parameters during sampling time***

Year	Temperature, °C		Precipitation, mm	Humidity, %*	Humus, %*	pH*
	Air	Topsoil				
1993	14.9	18.5	94.2	22.9		3.54
1994	15.3	22.0	40.9	27.1		3.21
1995	17.8	22.5	64.4	13.1		3.33
1996	15.1	20.0	66.7	20.5		3.63
1997	17.0	22.0	63.6	23.3		3.28
1998	16.7	20.5	94.2	21.9		3.49
1999	19.5	22.5	56.7	36.6		3.33
2000	15.4	19.0	150.6	24.9		4.13
2001	17.8	22.0	82.6	41.3		
2002	18.3	23.0	82.6			
2003	17.2	22.0	90.1			
2004	15.3	19.0	98.4	40.9		5.80
2005	16.8	22.5	69.0	13.2	10.2	5.87
2006	18.2	24.0	39.1	21.6	8.0	4.44

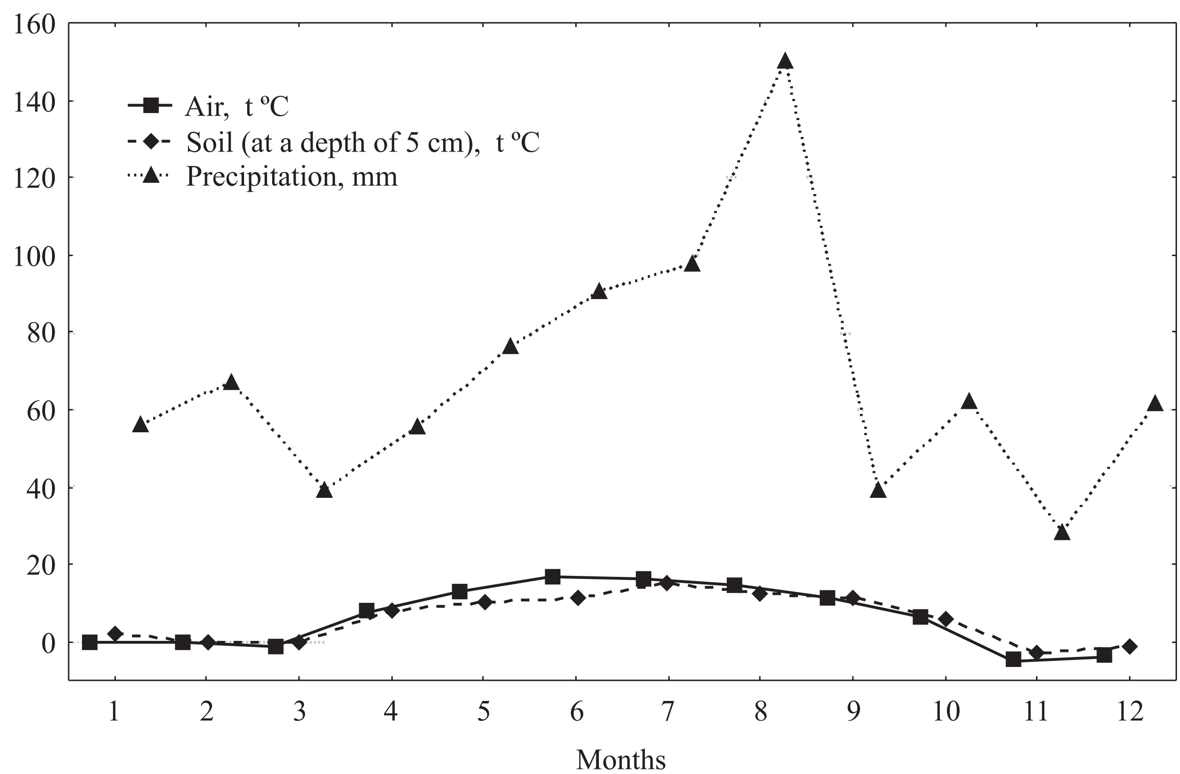

Fig. 5. Climate conditions in old Ažvinčiai forest, 1998 (data of Utena hydrometeorological station)

lowest values of their density were obtained in July. It is possible to assume that in climatically favourable years – sufficient soil humidity and temperature – the annual density of microarthropods in an almost intact forest soil of the climate zone under consideration reaches its maximum in late autumn (November). In this case, it was 548.6 thou ind. m^{-2} (oribatids accounted for 80%). Their high density also persisted in winter (Fig. 6). The greatest number (even 39) of species was identified in December (Table 3).

The density of oribatid mites of the preimaginal stage of development increased in the forest soil in June–October. In winter and spring, oribatid mites occurred mainly in the grown-up stage (Fig. 7). In comparison with the density of preimaginal stages, the average density of grown-ups accounted for about 73%. The density of individuals in the preimaginal stage accounted only for 27%. In summer (months 6–8), the individuals of preimaginal stage accounted for 35.5 and in autumn (months 9th–10th) even for 42.8%.

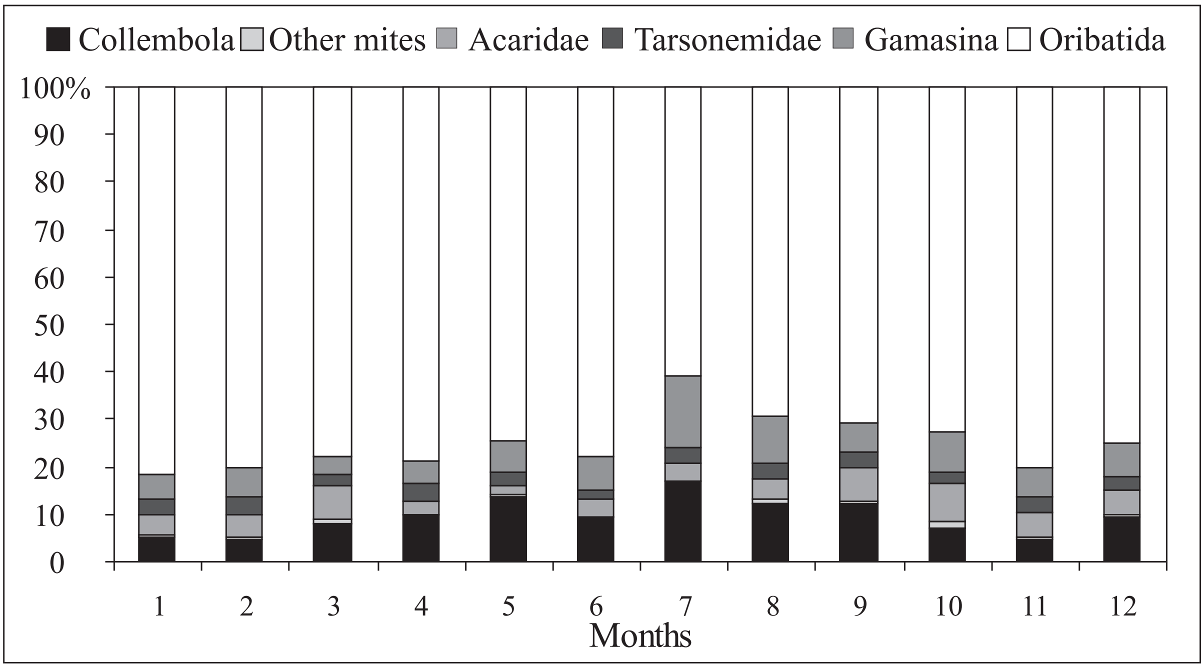

Fig. 6. Microarthropod complex structure (%) in the soil of old Ažvinčiai forest of Aukštaitija National Park, 1998

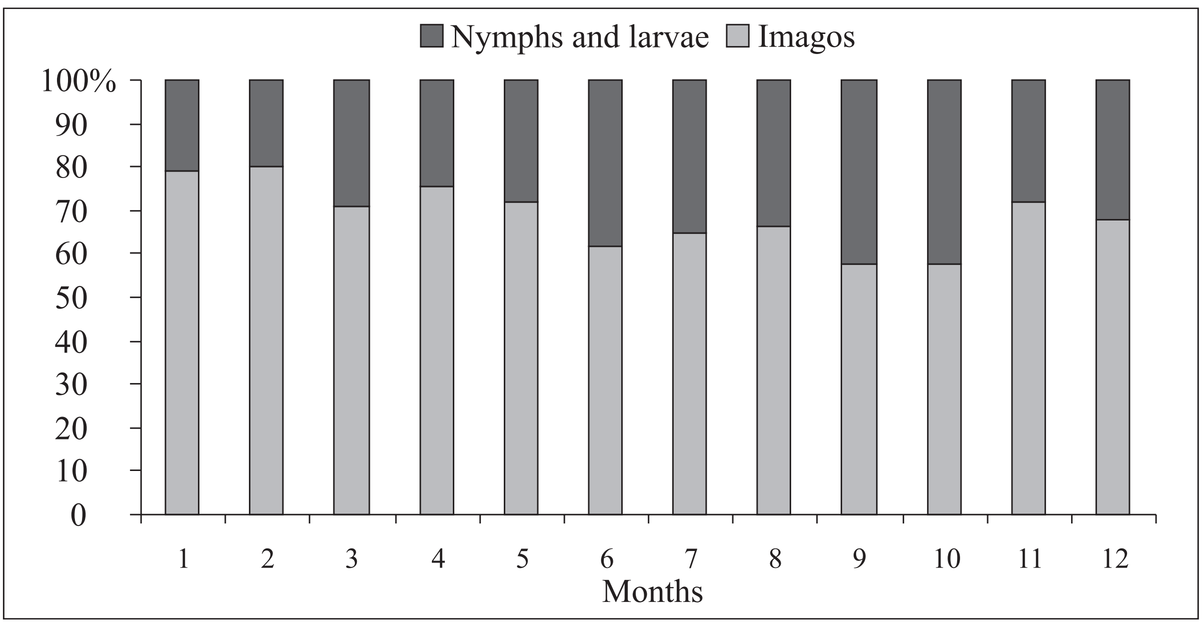

Fig. 7. Seasonal distribution of imagos, and nymphs and larvae (%) in old Ažvinčiai forest, 1998

Meteorological data show that different climate conditions (air and soil temperatures) of some years produce an insignificant effect on the density of microarthropods in soils with a sufficient moisture and optimal temperature. The impact of climate change becomes evident when analysing different groups of microarthropods. Under conditions of high soil moisture in autumn (in 1998 in particular), the processes of litter mineralization intensify and the density of microorganisms increases. Microorganisms represent one of the crucial trophic links in microarthropods. Thus, meteorological conditions, though indirectly (through nutrition links), affect the density and species composition of microarthropods. The density of microorganisms is subject to marked fluctuations during a year. Micromycetes are very important for many oribatid species. Different groups of microorganisms reacted differently to seasonal climate changes: the greatest density of bacteria ammonificators was recorded during the plant vegetation period, whereas the density of bacteria assimilating inorganic nitrogen, oligonitrophilous bacteria and bacteria transforming humic compounds increased towards the end of the vegetation period (months 7–11). Micromycetes

Table 3. Seasonal density dynamics of microarthropods (thou ind. m^{-2}) and species composition in old Ažvinčiai forest, 1998

Group	month 1		month 2		month 3		month 4		month 5		month 6		month 7		month 8		month 9		month 10		month 11		month 12		Average value	
	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S	T. ind. / m^{-2}	S
Oribatida	210.6	32	174.4	32	151.1	35	186.1	36	132.8	33	144.0	33	126.2	31	179.0	33	238.1	32	230.5	28	439.5	35	276.7	39	**207.4**	**33.3**
Gamasina	13.4	9	13.6	13	7.6	8	11.7	11	11.7	10	12.9	11	31.1	10	25.3	12	21.7	15	26.3	14	35.1	12	24.8	13	**19.6**	**11.5**
Tarsonemidae	8.6		7.9		4.2		8.7		4.6		4.3		7.5		8.1		10.8		8.2		16.3		13.3		**8.5**	
Acaridae	10.7	5	10.5	3	13.9	5	6.4	5	3.7	5	6.2	4	7.2	5	11.0	5	23.5	5	24.8	3	28.7	5	28.2	4	**14.6**	**4.5**
Other mites	0.9		0.6		2.2		0		0.7		0.3		0.7		2.1		1.3		5.1		3.6		4.1		**1.8**	
Collembola	13.9	5	10.4	9	15.6	8	23.8	10	24.1	13	17.3	10	35.0	10	32.0	8	41.4	8	22.0	11	25.4	10	24.6	9	**23.8**	**9.3**
Σ	**258.1**	**51**	**217.4**	**57**	**194.6**	**56**	**236.7**	**62**	**177.6**	**61**	**185.0**	**58**	**207.7**	**56**	**258**	**58**	**337**	**60**	**317**	**56**	**548.6**	**62**	**371.7**	**65**	**275.7**	**58.5**

were distinguished for density values which were rather high throughout a year (Eitminavičiūtė et al., 2006a). Apparently this factor predetermined the density of Oribatida in the study soil.

It should be pointed out that it is impossible to determine the alternation of microarthropod species within a year. It has been reported that the alternation of oribatid mites under the conditions of decaying organics is slower than that of Collembola and micromycetes because many of their species undergo a long and complicated developmental cycle. This allows adapting to different nutrients and offers a possibility to stick to the living environment. A species is able to change the nutrition medium (Шварц, 2005).

According to our data, *Oppiella nova* becomes eudominant among other species of oribatid mites in a cold season (months 2, 3 and 4), what is a rare phenomenon in forest soils (Table 4).

The obtained results show that the microarthropod density being 228.1 thou ind. m^{-2} on the average, mineralization of waste plants and litter in the study forest type takes place the whole year round. The content of litter in this kind of forests (mainly spruce and pine needles) amounts to 2.2 t · ha^{-1} per season mainly (Augustaitis et al., 2006).

Analysis of the intensity of organic matter decomposition in different seasons of 1998 has shown that 66.8% of cellulose disintegrates during the four months of vegetation. The intensity of cellulose disintegration directly depends on soil temperature (Eitminavičiūtė et al., 1998). In July when soil temperature reached 16.2 °C, cellulose disintegrated even by 31%. In January–March when soil temperature fluctuated within –0.16 to +0.5 °C, the content of cellulose reduced only by 0.5–0.9%. Cellulose disintegration considerably intensified in May when soil temperature reached 11.4 °C. In the cold season (months 9–1), the content of cellulose reduced by 30.6%, although soil temperature was +6.5 °C. Intensification of cellulose destruction was observed in October. The density of microarthropods at that time increased noticeably. Schimel and Gulledge (1998) have suggested that the increased frequency of episodic drying and rewetting of soil associated with climate change could alter the populations of cellulytic and lignolytic fungi. They also suggested that the corresponding decrease in litter decomposition may be greater than that predicted by the mere changes in soil and litter moisture (Swift et al., 1998).

Apparently all the mentioned processes are interrelated. During the vegetation period when the greatest amount of cellulose is disintegrated, bacteria ammonificators become most active. Undoubtedly, micromycetes and microarthropods are also active. Fresh organic matter is made available to bacteria through collembolan activity (Lussenhop, 1992). Collembola stimulate microflora by selective grazing (Vetter et al., 2004). The traditional approach in ecosystem ecology has primarily focused on dominant species as biotic controllers of ecosystem processes (Loreau et al., 2001).

The impact of climatic factors on the species composition of microarthropods is weaker and statistically insignificant, though positive. Soil pollution is important and must be taken into account in evaluations of microarthropod species composition. Various atmospheric chemical elements get into soil with litter (Table 5). The concentration of heavy metals in litter did not exceed the MPV in herbaceous plants growing in a clean

Table 4. **Species composition of oribatid mite community in old Ažvinčiai forest, 1998**

Species \ Month	01	02	03	04	05	06	07	08	09	10	11	12
Eudominants 40–100												
Oppiella nova (Oudemans, 1902)		52.8	52.5	50.9							44.4	
Number of species		**1**	**1**	**1**							**1**	
Dominants 12.9–39.9												
Oppiella nova (Oudemans, 1902)	33.0				30.3	18.5	22.2	34.0	33.2	29.3		27.0
Brachychthonius sp.	20.3	14.7			26.1	19.2	23.5	13.7	22.9	15.6	22.1	19.2
Suctobelbella sp.	13.7					30.9	20.5	19.2	16.6	20.9	13.3	26.0
Tectocepheus velatus (Michael, 1880)					13.2							
Number of species	**3**	**1**			**3**	**3**	**3**	**3**	**3**	**3**	**2**	**3**
Subdominants 12.8–4.0												
Tectocepheus velatus (Michael, 1880)	7.6	6.5	9.0	8.6		9.9	12.7	10.7	10.7	11.0	4.7	9.0
Suctobelbella sp.		6.1	11.3	11.2	11.4							
Ctenoppiella tuberculata (Bulanova-Zachvatkina 1964)	5.5					6.0				5.0		
Steganacarus carinatus (C. L. Koch, 1841)							4.9					
Brachychthonius sp.			7.4	11.9								
Number of species	**2**	**2**	**3**	**3**	**1**	**2**	**2**	**1**	**1**	**2**	**1**	**1**
Recedents 3.9–1.3												
Steganacarus carinatus (C. L. Koch, 1841)	2.4	2.8	2.5		2.0	3.5		2.6	1.6	2.0	2.5	1.7
Ctenoppiella tuberculata (Bulanova-Zachvatkina, 1964)		3.3	3.5	2.3	3.4		2.4	2.4	1.8		2.5	3.3
Eobrachychthonius sp.	3.7	1.4		1.4					1.5	3.2		
Oppia sp.		1.4										
Suctobelba sp.	1.8		2.1	1.5	1.3				3.0	2.5	1.5	1.7
Oppiella sp.	1.5	2.9					1.3					
Scheloribates pallidulus (C. L. Koch, 1841)	1.3					1.7						
Nanhermannia coronata Berlese, 1913	1.3											
Scheloribates latipes (C. L. Koch, 1844)		1.6		1.3	2.1							
Nothrus anauniensis Canestrini & Fanzago, 1876				1.4				1.5	1.3			1.5
Adoristes poppei (Oudemans, 1906)							2.4	2.2				
Quadroppia quadricarinata (Michael, 1885)				1.3								
Parachipteria punctata (Nicolet, 1855)						1.4						
Heminothrus longisetosus Willmann, 1925										1.7		
Number of species	**6**	**6**	**3**	**6**	**4**	**3**	**3**	**4**	**5**	**4**	**3**	**4**
Subrecedents <1.3												
Number of species	**22**	**23**	**30**	**26**	**24**	**23**	**23**	**31**	**26**	**24**	**32**	**36**
Σ	**33**	**33**	**37**	**36**	**32**	**31**	**31**	**39**	**35**	**33**	**39**	**44**

Table 5. **Concentration of heavy metals (mg· kg^{-1}) in Ažvinčiai forest litter, grass and soil**

Years	Heavy metals, mg · kg^{-1}						
	Cu	Pb	Cd	Cr	Zn	Na	Mn
	Litter						
1994	1.9	1.2	0.2	0.7			113.7
1999	2.9	2.8	0.1	2.0	40.4	69.6	702.8
2000	1.2	0.6	0.1	0.9	27.9	51.3	415.6
2001	3.5	1.6	0.1	2.7	64.1	52.5	790.0
2002	4.0	5.7	0.2	2.3	39.3	76.3	585.0
2003	2.9	5.9	0.2	1.7	44.0	75.4	552.0
2004	3.1	3.9	0.4	0.8	47.8	41.6	568.0
2005	2.8	4.2	0.3	0.9	53.0	65.0	710.8
2006	2.2	0.9	0.2	0.4	49.3	21.3	586.0
Average	**2.7**	**3.0**	**0.2**	**1.4**	**45.7**	**56.6**	**558.2**
	Grass						
2006	216.0	4.1	0.29	2.0	95.0		
	Soil						
2005	3.1	12.9	0.1	17.3	24.0		3.4
2006	13.3	23.7	0.25	9.6	25.7		2.9

environment, but the concentration of copper in plants of the forest floor in 2006 was high (216.0 mg · kg^{-1}). In 2006, the concentration of this element in the soil was four times as high as in 2005, possibly because of the droughts of recent years: The dry conditions might have influenced the density of microarthropods (Fig. 3).

The density of micromycetes showed a trend of reduction (Eitminavičiūtė ir kt., 2006). This might be related to soil leaching (Table 2).

The obtained results indicate that slow climate changes in the geographic zone of moderate climate so far have not produced any stronger influence on the species composition of soil biota in forest ecosystems. The influence may be more pronounced in critical ecosystems impoverished by anthropogenic activity, for example, in soils of intensively cultivated fields. Yet stress environments and especially stress fluctuations may entail adaptations and the natural selection of organisms of a rich genetic diversity and a short life cycle, microorganisms in the first place. This may destabilize the relationships among the organisms and cause functional transformations in the crucial biological processes of soil, i. e. in the mineralization and humification of organic matterial.

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DINAMINIAI IR SEZONINIAI MIKROARTROPODŲ KOMPLEKSO POKYČIAI SPYGLIUOČIŲ MIŠKO DIRVOŽEMYJE

Santrauka

Dirvožemio biologinių procesų ir biotos tyrimai vykdyti sąlyginai natūralioje, minimaliai pažeistoje ekosistemoje Aukštaitijos nacionaliniame parke pušyno dirvožemyje (Ažvinčių sengirėje) 1993–2006 m. Sukaupti dinaminiai 14 metų duomenys leidžia analizuoti šio laikotarpio klimato kaitos poveikį dirvožemio mikroartropodų gausumui, rūšinei įvairovei ir nustatyti tų pokyčių trendus. Siekiant išaiškinti sezoninius zoocenozių gausumo svyravimus ir nustatyti jų priklausymą nuo klimato sąlygų, 1998 m. tyrimai atlikti kas mėnesį.

Buvo nustatyta, kad vidutinio klimato zonoje mišriuose miškuose (*Pinetum myrtillosa vacciniosum*), augančiuose ant karbonatingų smėlžemių, yra susiformavęs gausus mikroartropodų kompleksas, kuriame vyrauja oribatidai. Mikroartropodų gausumas siekia vidutiniškai 228,1 tūkst. ind. m^{-2}. Rūšių įvairovę sudaro 157 rūšys. Oribatidai sudaro vidutiniškai 75% visų tirtų mikroartropodų grupių. Didelis mikroartropodų gausumas išsilaiko visus metus, ir maksimumą (548,6 tūkst. ind. m^{-2}) pasiekia vėlai rudenį.

Nors šio tipo miškų dirvožemyje yra pakankamai drėgmės ir optimali dirvožemio temperatūra, tačiau atskirų metų drėgmės kiekio mažėjimas dirvožemyje gali sukelti pačių jautriausių, trumpą gyvenimo ciklą turinčių, pedobiontų gausumo (mikroorganizmai, kolembolos ir kt.) fliuktuacijas. Tai gali destabilizuoti nusistovėjusius tarp organizmų tarpusavio santykius ir sukelti funkcinius pakitimus pagrindiniuose dirvožemio biologiniuose procesuose, t. y. organinių medžiagų mineralizacijoje ir humifikacijoje.

Raktažodžiai: temperatūra, drėgmė, mikroartropodai, spygliuočių miškas