FORESTRY IDEAS, 2014, vol. 20, No 1 (47): 57–66

THE EFFECTS OF FOREST SITE CONDITIONS AND STANDS' AGE ON LITTER MICROARTHROPOD DENSITY AND COMMUNITY STRUCTURE IN ZHYTOMYR POLISSYA, NORTHERN UKRAINE

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Received: 01 April 2014 Accepted: 13 June 2014

Abstract

The effects of forest site conditions and age of stands on absolute density and community structure of litter microarthropods were studied in pine forest in Zhytomyr Polissya, northern Ukraine. Litter samples from cuts, non-closed, young, middle-aged, and mature stands in a mesofilic pine forest (site condition A2) and mesofilic Pinetum compositum (site condition B2) were collected, microarthropods were extracted, counted and identified to main taxa. Mean absolute density of total microarthropods and their main taxa was higher in B2 site conditions for all ages of stands, except the young. Within each type of forest site conditions, litter microarthropod density fluctuated depending on the age of stands. However, the differences in absolute densities for most microarthropod taxa were statistically significant only between stands of distant age groups: between cuts and middle-aged or mature stands. Decreased absolute density of total litter microarthopods, Acari, and Collembola observed in cut sites and non-closed stands may be the result of forest floor disturbance associated with harvesting and decreased litter input. In microarthropod community structure, relative densities of Mesostigmata and Astigmata increased, whereas Collembola density decreased along forest age gradient. The differences were significant in middle-aged and mature stands relative to cut sites.

Key words: forest site conditions, stands, litter microarthropods, absolute density, community structure.

Introduction

Soil and litter microarthropods play an important role in proper functioning of forest ecosystem. They contribute to regulation of decomposition, nutrient cycling, and energy flow (Curry 1973, Seastedt 1984, Lussenhop 1992, Kandeler et al. 1999, Tripathi et al. 2005). Changes to forest floor microarthropod community structure may lead to changes in these processes. Microarthropods are source of food for predators (Hopkin 1997) and provide an early indication of environmental disturbance (Abbas 2012). The size of microarthropod population and activity of its members can be modified by numerous factors, such as temperature, moisture content (Pflug and Wolters 2001, Palacios-Vargas et al 2007, Xu et al. 2012), altitude (Illig et al. 2010), compaction (Lee et al. 2009; Lindo and Visser 2003, 2004), and

different silvicultural practices (Moore et al. 1984; Lindo and Visser 2003, 2004; Wickings and Grandy 2013) to name a few. Soil fertility determines forest vegetation diversity and thus litter's quality, which in turn attributes to microarthropod community structure (Ferguson and Berube 2004, Ayres et al. 2006, Sylvain and Buddle 2010). Some researches suggest that forest habitat may influence forest floor invertebrate community to ensure rapid decomposition of its litter (Ferguson 2001, Wardle et al. 2004). Wardle et al (2004) showed the relationship of aboveground and belowground components of terrestrial ecosystems and their close interlinkage at community level, reinforced by a greater degree of specificity between plants and soil organisms.

The present study examined litter microarthropod communities, specifically their absolute and relative densities, in pine forests in Zhytomyr Polissya, Ukraine. Different site conditions and different age of stands were examined to test the hypothesis that these factors affect the abundance and composition of litter communities. We predicted that (1) litter in each successional forest age group would be more microarthropod abundant; (2) site conditions would alter the absolute microarthropod density within a particular age group; and (3) community composition would differ along forest age gradient.

Material and Methods

Description of study areas

This study was conducted at the Lugyny State Forest Enterprise of Zhytomyr Polissya zone. The area is located at the latitude of 51°04'52" north and the longitude of 28°24'07" east within the altitude of 156 m above sea level in the Northern part of Ukraine. The climate at this area is mild continental with warm summer and a mean daily temperature in July +20.7 °C and mild winter with a mean temperature in January –2.7 °C. Total annual precipitation in 2011 was 368.6 mm (Meteo 2011). The level of ground water is 2.5–3.5 m.

Studies were carried out in two forest site conditions, which according to the forest typology adopted in Ukraine, correspond to A2 and B2 types (classification by Pogrebnyak 1955). The classification of sites is based on two main components, soil type and vegetation. A2 type is a mesophilic (slight moist) pine forest, growing on poor sandy sod-podzolic soil. The major tree species is *Pinus sylvestris* L. with limited quantity of Pedunculate oak (*Quercus robur* L.), Silver birch (*Betula pendula* Roth), or Common aspen (*Populus tremula* L.). The understory vegetation is represented mostly by herbaceous species such as mosses, *Pyrola umbellata* L., *Rubus saxatilis* L., *Chamaecytisus ruthenicus* (Fisch. ex Wol.) Klásk. and some shrub species like *Vaccinium vitis-idaea* L. and *Calluna vulgaris* (L.) Hull.

B2 site is a mesophilic Pinetum compositum, growing on relatively poor sandy soil with layers of clay. Forest stands are usually two-storey, with the upper storey formed by pines with limited amount of birch and lower storey represented by oaks and/or aspen. The undergrowth is represented by *Rhamnus frangula* L., *Sorbus aucuparia* L. Herbaceous cover consists of *Fragaria vesca* L., *Convallaria majalis* L., *Pteridium aquilinum* Kuhn, *Vaccinium myrtillus* L., *Vaccinium vitis-idaea* and *Calluna vulgaris*.

The following age groups of forest stands were investigated in each type of site conditions (the abbreviations are given in brackets): cut (Ct); non-closed (NC), young (Yg), middle-aged (MA), and mature (Mt). In A2 forest, in the cut site the harvesting occurred in December 2009 at the age of 55 years; trees were infected by fungal disease (*Heterobasidion annosum* (Fr.) Bref.). The age of non-closed stand was 4 years, young – 23, middle-aged – 43, and mature – 90 years. In B2 forest type, in the cut site the sanitation cutting of 70-year-old trees occurred in 2010; the age of non-closed stand was 4 years, young – 30, middle-aged – 56, and mature – 92 years.

Sampling

Sampling was performed at the beginning of April, August, and November 2011. A sample was a square litter monolith sized 10×10 cm each (100 cm^2) with the thickness of a monolith equaled the thickness of the litter (Table 1). A total of 150 samples were examined: 2 forest types × 5 age groups × 3 seasons × 5 sampling occasions. Microarthropod extraction was conducted using modified Tullgren funnels (diameter 15 cm) containing inserted wire mesh with cells 2×2 mm. An electrical bulb was used as a source of heat. Invertebrates dropped through the exit hole of the funnel into collecting bottles containing 70 % alcohol. Extraction time lasted two days. The total numbers of individuals in major groups were calculated with dissecting microscope at 40x magnification. Acari were identified to suborders Prostigmata, Mesostigmata, Oribatida, and Astigmata.

The analysis of the absolute and relative density of all microarthropods as well as their main groups depending on the age of stands and type of site conditions has been employed. The absolute density was expressed as the number of individuals per square meter (ind·m^{-2}). As the thickness of a litter layer differed in each particular site, to eliminate its effect on the absolute microarthropod density while comparing sites with different litter quantity, the calculated number of animals in each sample was divided by its litter thickness. The relative abundance (percentage of total) of microarthropod suborders was calculated using the formula (1):

$$RA = \frac{Nis}{N} \cdot 100 \text{ , \%} \quad (1),$$

where: *RA* – relative abundance of microarthropod suborders; *Nis* – number of individuals in a suborder; *N* – total number of microarthropods.

Table 1. Mean thickness of litter in sampling areas, cm.

Site condition	Cut	Non-closed	Young	Middle-aged	Mature
A2	1.5	1.0	3.0	3.5	4.0
B2	0.5	0.5	2.0	3.0	3.5

Statistical analysis

Since the distribution of data was not normal even after log-transformation, non-parametric tests, Mann-Whitney (for comparison of two samples) and Kruskal-Wallis (for analysis of variances), were applied for statistical analysis. Hierarchical

cluster analysis was used to group the most similar age groups of stands within a particular type of forest site conditions on the basis of absolute density of litter microarthropods. All calculations were done in XLSTAT-Pro 2013.4.07.

Results

In stands of all studied age groups, except the young, the mean absolute density of total microarthropods was significantly higher in B2 sites than in A2 (Mann-Whitney test, $P<0.05$) (Figure. 1,

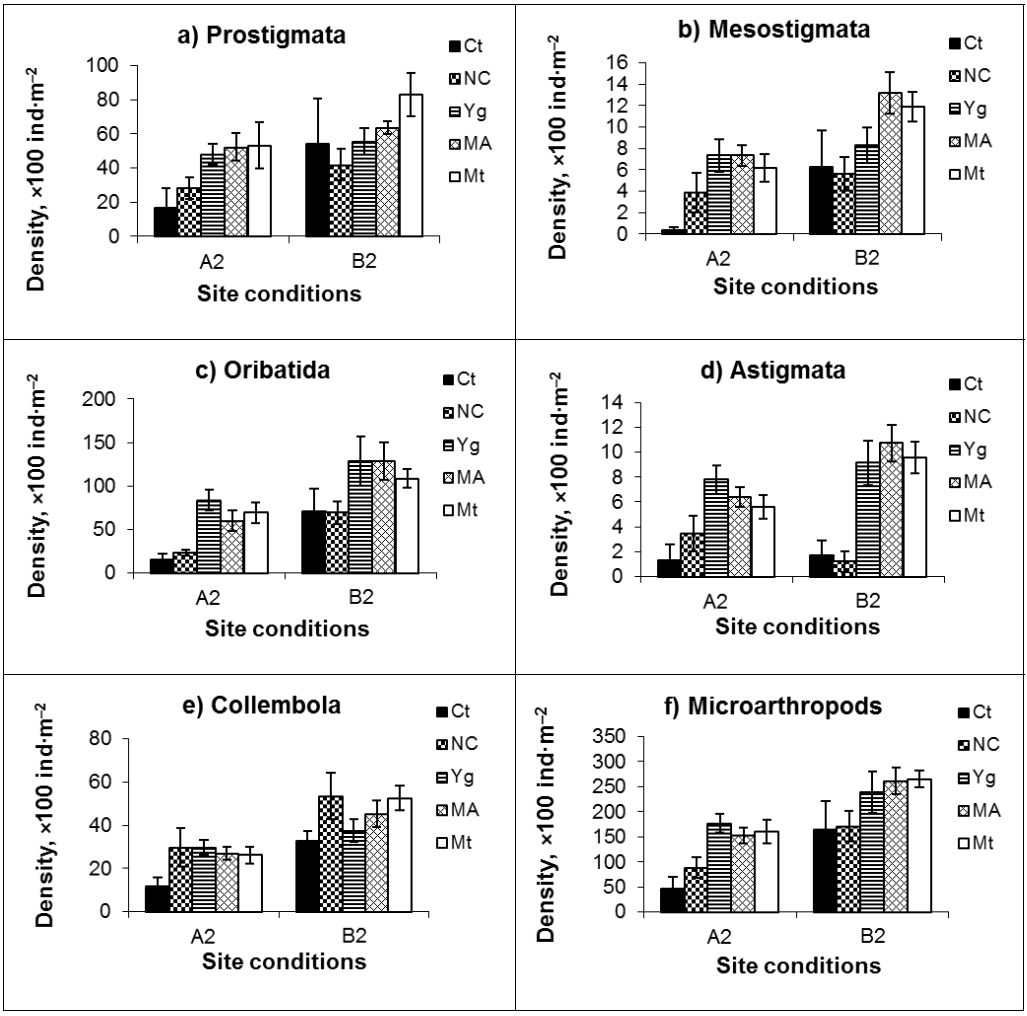

Fig. 1. Absolute density of (a) Prostigmata, (b) Mesostigmata, (c) Oribatida, (d) Astigmata, (e) Collembola, and (f) Total microarthropods in litters of cut, non-closed, young, middle-aged and mature stands in A2 and B2 forest site conditions.

Note: Values are means ± SE. Ct – cut, NC – non-closed, Yg – young, MA – middle-aged, Mt – mature stand.

Table 2). The absolute density of mite taxa and collembolans was also higher in the litter of B2 site type (Figure 1). Significant differences for mite density were observed in cut, middle-aged, and mature stands and for collembolan density – in non-closed, middle-aged, and mature stands (Table 2).

Within each type of site conditions, litter microarthropod density fluctuated depending on the stand age. In A2 site condition, the lowest densities of all studied microarthropod groups were observed in cut forest (Figure 1). There were no significant differences observed between cut and non-closed stands as well as young and older stands (Table 3). The numbers of mites, Collembola and all microarthropods were significantly higher in young and older stands compared to cuts.

Within B2 site conditions, the dynamic trends in microarthropod densities in most cases were similar to those in A2. The lowest mean absolute densities of mite taxa were observed in non-closed stands followed by cut site (Figure 1). The minimal absolute density of collembolans was observed in the litter of cut forest, whereas the maximal – in non-closed stands; however, it was not statistically significant (Table 3). The differences in microarthropod densities in stands of adjacent age groups were not significant for all taxa except Astigmata, which density in the young stand was significantly higher than in the cut and non-closed stand (Table 3). Differences in absolute densities for most microarthropod taxa were statistically significant only between stands of distant age groups: between cut and middle-aged or mature stands (Table. 3).

Table 2. The results of comparison of absolute litter microarthropod densities between A2 and B2 forest site conditions (Mann-Whitney test, α=0.05)

Microarthropods	Age groups of stands				
	Cut	Non-closed	Young	Middle-aged	Mature
Prostigmata					
U	58.00	91.00	99.00	88.50	56.00
P	0.024	0.383	0.59	0.33	0.02
Mesostigmata					
U	68.00	89.00	104.50	49.50	47.00
P	0.024	0.307	0.755	0.01	0.007
Oribatida					
U	31.50	43.50	95.50	47.00	57.00
P	0.001	0.004	0.494	0.007	0.023
Astigmata					
U	106.00	140.50	104.50	64.50	55.00
P	0.633	0.143	0.740	0.049	0.018
Collembola					
U	92.50	58.50	94.00	54.50	42.00
P	0.417	0.026	0.455	0.017	0.004
All microarthropods					
U	24.50	60.50	98.00	41.00	40.00
P	0.0003	0.033	0.0561	0.003	0.003

Note: U – sum of ranks, P – probability.

Table 3. The results of comparison of absolute litter microarthropod densities in stands of different ages for A2 and B2 forest site conditions (Kruskal-Wallis test, multiple pairwise comparison, α=0.05, Bonferroni corrected significance level: 0.005)

Microarthropods	Age groups of stands					*P*
	Cut	Non-closed	Young	Middle-aged	Mature	
A2						
Prostigmata	A	AB	B	B	B	<0.0001
Mesostigmata	A	AB	BC	C	BC	<0.005
Oribatida	A	AB	C	BC	BC	<0.001
Astigmata	A	AB	C	BC	BC	<0.005
Collembola	A	AB	B	B	B	<0.005
All microarthropods	A	AB	B	B	B	<0.0001
B2						
Prostigmata	A	AB	AB	B	B	≤0.001
Mesostigmata	A	AB	AB	B	B	<0.0001
Oribatida	A	AB	AB	B	B	<0.005
Astigmata	A	A	B	B	B	≤0.001
Collembola	A	AB	AB	AB	B	<0.005
All microarthropods	A	AB	AB	B	B	≤ 0.001

Note: Within each row, different letters are significantly different.

Hierarchical cluster analysis (Figure 2) showed that patterns of absolute microarthropod density in A2 site conditions were similar between the middle-aged and mature stands whereas microarthropod densities in young stands were more similar to those in the non-closed stands. In B2 site conditions, absolute densities of microarthropods were similar in young and middle-aged stands followed by non-closed stand and

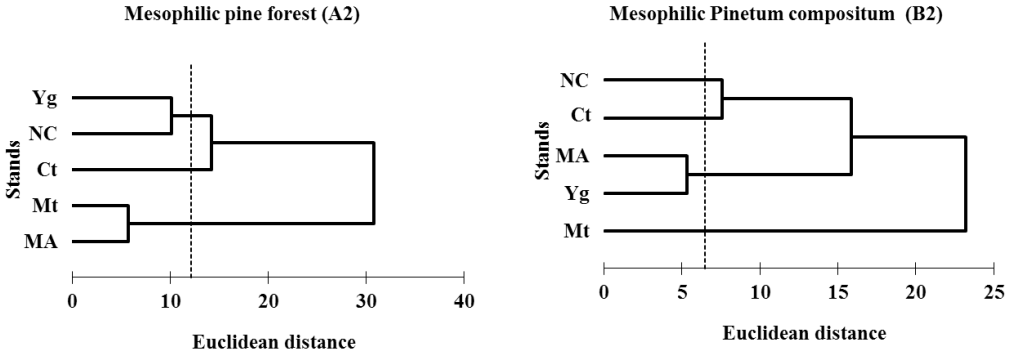

Fig. 2. Agglomerative hierarchical cluster analysis of forest age groups based on absolute abundance of forest litter microarthropods for A2 and B2 site conditions.

Note: Groups connected at lower distance index are more similar, than those with higher distance indices.

Table 4. Relative densities of main suborders of litter microarthropods in stands of different ages for A2 and B2 forest site conditions.

Microarthropods	Cut	Non-closed	Young	Middle-aged	Mature
A2					
Prostigmata	25.14 (5.74)^{a}	30.42 (3.47)^{a}	28.92 (3.00)^{a}	35.50 (5.03)^{a}	31.01 (4.96)^{a}
Mesostigmata	1.56 (1.29)^{a}	4.23 (1.49)^{ab}	4.03 (0.49)^{b}	5.30 (0.87)^{b}	3.60 (0.39)^{b}
Oribatida	40.16 (4.84)^{a}	33.37 (2.88)^{a}	44.76 (3.98)^{a}	36.69 (4.51)^{a}	43.38 (4.22)^{a}
Astigmata	0.35 (0.35)^{a}	2.63 (0.99)^{ab}	4.68 (0.74)^{b}	4.52 (0.57)^{b}	3.45 (0.26)^{b}
Collembola	32.79 (4.83)^{ab}	29.35 (1.58)^{b}	17.62 (1.58)^{a}	17.99 (1.19)^{ab}	18.55 (2.35)^{a}
B2					
Prostigmata	24.83 (4.44)^{a}	22.54 (4.25)^{a}	27.31 (3.28)^{a}	28.42 (3.31)^{a}	30.00 (3.55)^{a}
Mesostigmata	2.70 (0.95)^{a}	2.41 (0.80)^{a}	3.49 (0.52)^{ab}	5.23 (0.54)^{b}	4.37 (0.44)^{ab}
Oribatida	38.76 (3.68)^{a}	42.28 (3.80)^{a}	47.45 (4.00)^{a}	45.18 (3.56)^{a}	41.76 (3.92)^{a}
Astigmata	0.50 (0.39)^{a}	0.53 (0.40)^{a}	3.61 (0.47)^{b}	4.11 (0.42)^{b}	3.62 (0.44)^{b}
Collembola	33.21 (4.59)^{b}	32.24 (3.34)^{b}	18.14 (1.70)^{a}	17.06 (1.19)^{a}	20.25 (2.27)^{ab}

Note: Values are means, with SE given in parenthesis. Within each row, values followed by a different letter are significantly different, based on Kruskal-Wallis test (multiple pairwise comparison, α=0.05, Bonferroni corrected significance level: 0.005).

cuts. The mature stand was dissimilar to any other age group in B2 site conditions.

The relative density of prostigmatid and oribatid mites in litter samples form A2 sites fluctuated insignificantly in stands of different ages (Table 4). Mesostigmatid and astigmatid mite densities in samples from young and older stands were significantly higher than those from cut site (Table 4). Collembola content was the highest in litter from cut forest and decreased with forest age reaching its minimum in young stand. In older forests, it remained almost the same. Significant differences in collembolan relative densities were noted in litters of young and mature stands compared to non-closed one (Table 4). Similar trend was observed in B2 site conditions. Significant differences were also noted for mesostigmatids, astigmatids, and collembolans in cut or non-closed stands versus any other age group (Table 4).

Discussion

The main hypothesis tested in this study was whether the type of forest site conditions influences the density and structure of litter microarthropod community. We sampled litter in forests areas, which, according to Pohrebnyak classification currently used for forest typology in Ukraine, belong to types A2 and B2. Although both of them have similar soil moisture conditions (both are mesophilic soils), they differ on soil fertility, which is higher in B2 conditions. Soil fertility determines forest

vegetation diversity and thus litter's quality, which in turn attributes to the microarthropod community structure (Ferguson and Berube 2004, Ayres et al. 2006). According to Sylvain and Buddle (2010), more diverse aboveground plant assemblages support more diverse mite assemblage. In our studies, absolute density of all litter microarthropods and their main taxa was higher in forest areas of B2 conditions (Figure 1) in stands of all age groups and this supports our prediction. However, significant difference was observed mostly in cut, middle-aged, and mature stands (Table 2).

The lowest absolute abundance of microarthropods was observed in litter from cut forest sites. The reduction in microarthropod numbers in cut forests compared to young and older age groups probably occurred due to forest floor disturbance following forest harvesting. Harvesting is always associated with soil compaction, which increases soil bulk density and decreases soil porosity, aeration, and infiltration capacity (Greacen and Sands 1980; Huang et al. 1996, Kozlowski 1999). Lindo and Visner (2003) observed a significant negative relationship between microarthropod abundance and soil bulk density associated with harvesting. Tan and Chang (2007) studied the effect of soil compaction and forest litter amendment on microbial properties and processes in this boreal forest soil under controlled conditions and concluded that forest management practices that alter soil porosity (through compaction) and organic matter distribution in the soil profile can dramatically change soil C and N dynamics that may result in the eventual change in soil C and N concentrations or availability. Compaction can shift soil conditions towards anaerobic state that is associated with reduced aerobic microbial activities, increased denitrification rates, and reduced uptake of nutrients resulting in decrease of woody plants growth and yields of harvestable plant products (Greacen and Sands 1980, Kozlowski 1999). Litter quantity is another important factor influencing the abundance of forest floor microarthopods. The decrease in litter input leads to the reduction of organic matter available for decomposition. In present study, the drop in absolute microarthropod density and changes in litter microarthropod community structure in cut sites and non-closed stands relative to older-aged stands may probably be explained by some of above mentioned factors.

Community structure studies showed an increase in relative content of mesostigmatid and astigmatid mites and decrease in Collembola content in litters of middle-aged and mature stands relative to cuts in both studied site conditions. Fluctuations of relative densities of oribatid and prostigmatid mites along the forest age gradient were not significant. In contrast, Lindo and Visner (2004) reported a reduced relative abundance of prostigmatid and oribatid mites and increased relative abundance of mesostigmatid mites in forest floor cores from clear-cut and corridor treatments as a result of physical disturbance of the forest floor. In our studies, there were no differences in litter community compositions between cut site and non-closed stands as well as between young and older age stands.

Conclusions

Mean absolute density of total litter microarthropods and their main suborders

in sites with mesofilic Pinetum compositum (B2) was higher than in mesofilic pine forest (A2). Within each type of site conditions, litter microarthropod density fluctuated depending on the forest age; however, the differences in absolute densities for most microarthropod taxa were statistically significant only between stands of distant age groups: between cut and middle-aged or mature stands. Decreased absolute density of total litter microarthopods, Acari suborders and Collembola in cut sites and non-closed stands may be the result of forest floor compaction associated with harvesting.

Litter microarthropod community structure differed along forest age gradient. The relative densities of mesostigmatid and astigmatid mites increased, whereas Collembola content decreased. The differences were significant in middle-aged and mature stands relative to cut sites.

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