Biol. Stud. 2025, 19(2), 157–168 • doi: https://doi.org/10.30970/sbi.1902.829
www.http://publications.lnu.edu.ua/journals/index.php/biology

UDC: [504.53:631.468](477.8)

DOMINANCE STRUCTURE OF THE COMMUNITIES OF SOIL AND LITTER MESOFAUNA IN OLD-GROWTH FORESTS OF THE UKRAINIAN ROZTOCHCHIA

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Tsaryk, I., Yavornytskyi, V., & Reshetylo, O. (2025). Dominance structure of the communities of soil and litter mesofauna in old-growth forests of the Ukrainian Roztochchia. *Studia Biologica*, 19(2), 157–168. doi:10.30970/sbi.1902.829

Background. The structure of soil and litter invertebrate mesofauna communities in old-growth forest ecosystems is important for understanding the mechanisms of their stability. Our research is focused on establishing the taxonomic and functional diversity of mesofauna communities in old-growth forests of the Ukrainian Roztochchia. The aim of the study was to determine the taxonomic diversity of soil-litter invertebrates with the subsequent identification of the dominance structure of their communities on a natural old-growth forest site.

Materials and Methods. Mesofauna survey was carried out on a model plot of the natural old-growth oak-beech-pine forest within the Piasetskyi typological forest site on the area of Roztochchia Nature Reserve. The sampling of soil and litter mesofauna was accomplished in 2023 by means of soil layer excavation to the depth of its distribution, manual analysis of soil and litter samples, and Barber pitfall traps. Material analysis was carried out by standard in soil zoology methods.

Results and Discussion. The taxonomic diversity of the community of soil-litter mesofauna of the studied old-growth oak-beech-pine forest includes more than 60 species of invertebrates which belong to 25 families from seven classes of three phyla. In terms of number, the trophic group of predators is dominant in forest litter (49 %), in particular Chilopoda and Staphylinidae; phytophages dominate in the soil (55 %), being represented mostly by Elateridae and Curculionidae larvae. In terms of mass, saprophagae are dominants in litter (77 %) – Lumbricidae, Mollusca, Geotrupidae, and soil (56 %) – Lumbricidae, Diplopoda. This trophic group also dominates in terms of dynamic density (78 %).

Conclusion. The number of the investigated mesofauna is up to 280 ind./m^2 with the mass of up to 13.6 g/m^2. A large proportion of the number (71 %) and the mass (77 %) of the community are concentrated in the litter, the rest are found in 30–40 cm deep soil layer. Insects dominate in the community, accounting for more than 70 % of its taxonomic diversity. Soil and litter mesofauna community of the oak-beech-pine forest has rather high species diversity, and its quantitative indicators as well as structural and functional characteristics are favorable for the long-term existence and maintenance of a sustainable ecosystem of the old-growth forest.

Keywords: invertebrates, old-growth forest, taxonomic diversity, trophic groups, saprophaga, Roztochchia

INTRODUCTION

The research of invertebrate community diversity in old-growth forest ecosystems gives us an understanding of the supporting mechanisms of their stability. Consequently, knowledge about mesofauna community structure is important in this context as its taxonomic and functional diversity secures ecosystem stability (McCann, 2000). Invertebrates are involved in almost all ecosystem processes, but the detailed knowledge and value of their functions, particularly in forest ecosystems, are often overlooked (Hébert, 2023).

Forest soil and litter are inhabited by a diverse community of invertebrates, which directly and indirectly rely on detritus as habitat and food resource (Pollierer *et al*., 2021; Xu *et al*., 2024). It is known that the structure of species-rich communities is usually less changeable over time (McCann *et al*., 1998; Ruppert *et al*., 2023). The reason is a different reaction of each functional species' group on the changes of environmental factors and conditions. Overall, high species diversity stabilizes integral community characteristics, while unbalancing the number of some species in it at the same time (Loreau & de Mazancourt, 2013).

Forest ecosystem functioning is an endless web of interrelations among living organisms and their environment, which is crucial for the ecological balance and its stability. So, investigations focusing on soil-litter biotic and functional diversity play key roles in the knowledge of forest ecosystem essence (Singh *et al*., 2025). The structure of the communities of soil and litter mesofauna depends on both species interrelations and the sensitivity of each of the community species to environmental changes (Warren & Bradford, 2013). The distribution type, number, and species interrelations of various trophic groups in an ecosystem are dependent to a high extent on the influence of different ecological factors, which are determinative for the ecosystem ecological stability. This multidimensional concept describes various aspects of the ecosystem dynamics and its reactions to multiple external and internal disturbances (Leibold *et al*., 2004; Donohue *et al*., 2016; Pollierer *et al*., 2021; Ruppert *et al.*, 2023).

Old-growth forests in the Ukrainian Roztochchia remain untouched within nature protected areas of Yavoriv National Nature Park and Roztochchia Nature Reserve. In particular, the studied ecosystem of natural old-growth forest is located within the Piasetskyi typological forest site of Roztochchia Nature Reserve (Horoshko & Khomiuk, 2005).

Our study is focused on exploring the taxonomic and functional diversity of soil and litter mesofauna communities in old-growth forests, where the preconditions for formation of heterogeneous litter composition are usually more favorable for invertebrates.

This, in turn, provides them with better trophic base and creates more microhabitat options. It is worth mentioning, that the research of soil invertebrate trophic groups is the actual aspect of terrestrial ecosystem dynamics investigations (Cameron *et al*., 2018; Tsaryk & Yavornytskyi, 2020; Hébert, 2023; Singh *et al.*, 2025).

It is known, that soil mesofauna is sensitive to the environmental changes and plays one of the key functional roles, particularly, in the destruction of some litter components of forest ecosystems (Bonada *et al*., 2006; Pollierer *et al*., 2021; Singh *et al.*, 2025). An important transformative role in this case belongs to the trophic group of saprophaga which is mostly the destructor of phytodetritus: it plays a key role in litter decomposition process in two ways – directly via fragmentation and consumption, and indirectly via changes in soil structure (Xu *et al.*, 2024). This animal ecological group serves as a natural mechanism of support and improvement of soil characteristics. The tempo of forest litter destruction depends on abiotic factors (temperature, substrate chemical composition etc.) and the destructors' activity (Vasconcelos & Laurance, 2005). Besides, it is important to mention that the taxonomic diversity of saprophagae, their number, mass, and spatial distribution deflect the soil condition and the intensity of biological processes taking place in it (Andrusevich *et al*., 2018; Hébert, 2023; Ruppert *et al*., 2023; Xu *et al.*, 2024). Our recent investigations also show that the more natural (climax stage) forest ecosystem vegetation is the more significant saprophaga domination becomes (Tsaryk *et al*., 2023).

Considering the above, the aim of the study was to determine the taxonomic diversity of soil-litter invertebrates with the subsequent identification of the dominance structure of their communities on a natural old-growth forest site by the indicators of taxonomic diversity, number, mass and dynamic density.

MATERIALS AND METHODS

The Ukrainian Roztochchia stretches out north-westwards by a narrow ridge (15–20 km wide) from Lviv to the Polish state border for about 60 km (**Fig. 1**). The terrain determines the domination of winds from the west bringing moisture and precipitation mostly from the Baltics. The average air temperatures here in January and July are -3 °C and +17.5 °C, accordingly; annual precipitation reaches 700 mm with the summer maximum (Khomiuk, 2005).

Mesofauna survey was carried out on a model plot (30 x 40 m) of the natural old-growth forest within the Piasetskyi typological forest site (50 x 1050 m, 295-340 m a.s.l.) on the area of Roztochchia Nature Reserve (Horoshko & Khomiuk, 2005). Forest vegetation conditions of the site are of conifer-deciduous type with the domination of Scots pine (*Pinus sylvestris*) on the model plot. The trees are 6-30 m high with the diameter from 6 to over 70 cm. Their age is 50-150 years old; closeness of tree crowns is 0.7 (Bashta *et al*., 2023).

Grass vegetation of the model plot covers up to 40 % of the research area and represents a natural type of the current tree stand development with the domination of *Anemonoides nemorosa*, *Maianthemum bifolium*, and *Carex brizoides.* Mesotrophs and mesophytes are the dominant ecological groups of vegetation in the plant cover of the model plot. A rather poor grass cover on sod-podzolic soils of light granulometric composition with the domination of middle and small sand fractions is typical for the ecosystem of the studied old-growth oak-beech-pine forest (*Querceto-Fageto-Pinetum majanthemoso-caricosum* (*brizoidis*)) (Bashta *et al*., 2023).

The studied model plot was set up in quarter 22 of allotment 5 of the Stavchanske Nature Protection Department of Roztochchia Nature Reserve (**Fig. 1**).

Fig. 1. The localization of the studied model plot within the Piasetskyi typological forest site (49.930931, 23.762090) (Yavoriv District of Lviv Region, Ukraine)

The sampling of soil and litter mesofauna was accomplished in 2023 by means of Barber pitfall traps and soil-litter layer collection. Particularly, the sampling of litter mesofauna was done by using two approaches. In the first case, standard glass containers (0.5 L jars) (Barber pitfall traps) were dug into the soil at the surface level and filled up with 4 % formaldehyde solution to one third. Ten pitfall traps were positioned along the line across the model plot every 5 m (Dunger & Fiedler, 1989). The second approach involved manual sampling of forest litter on randomly selected 25×25 cm squares within the model plot (5 sample reiterations) with the following analysis of mesofauna composition using a column of laboratory sieves with wire mesh screens of graded mesh size decreasing downwards from 10 to 2 mm (González *et al*., 2021). The sampling of soil mesofauna was done by means of manual soil layer excavation to the depth of its distribution (approx. 30–40 cm) on randomly selected 25×25 cm squares within the model plot (5 sample reiterations). The subsequent mesofauna analysis of collected soil samples was performed manually using stationary table magnifying glass (5×) (Moretti *et al*., 2017).

The taxonomic composition of invertebrate communities was determined to species or higher categories depending on the community component (Burakowski *et al*., 1973, 1974; Harde & Severa, 1988**;** Rizun, 2003; Sverlova & Hural, 2005; Radchenko & Elmes, 2010). The ordering of animals into trophic groups was carried out according to Görres & Amador (2021). The dominance structure of invertebrate taxa was established after Stöcker & Bergmann (1977).

For presenting quantitative values and data visualization, standard descriptive statistic functions for Microsoft Excel LTSC 2021 were used.

RESULTS AND DISCUSSION

Our study revealed that the taxonomic diversity of the community of soil-litter mesofauna of the studied old-growth oak-beech-pine forest includes more than 60 species of invertebrates which belong to 25 families from seven classes of three phyla: ANNELIDA – Oligochaeta (Lumbricidae), ARTHROPODA – Malacostraca (Isopoda), Chilopoda (Lithobiidae, Geophilidae), Diplopoda (Glomeridae, Polydesmidae, Julidae), Insecta (Trichoptera, Blattidae, Dermaptera, Carabidae, Scarabaeidae, Staphylinidae, Silphidae, Elateridae, Chrysomelidae, Curculionidae, Tenthredinidae, Geotrupidae, Noctuidae, Vespidae, Formicidae, Panorpidae, Diptera, Rhagionidae), Arachnida (Araneae), MOLLUSCA – Gastropoda.

The trophic group of predators dominates in forest litter in terms of numbers (49 %) according to the data obtained by means of soil layer excavation and manual analysis of soil and litter samples. Quantitative domination of predators in forest litter is ensured mainly by the representatives of Chilopoda (Lithobiidae, Geophilidae) and Staphylinidae. On the contrary, phytophages dominate in the soil in terms of numbers (55 %), which is due to the large number of Curculionidae, Elateridae and Scarabaeidae larvae in it, particularly *Limonius parvulus*, *Ectinus aterrimus*, *Dalopius marginatus* (**Table 1**, **Fig. 2**).

Table 1. **Indicators of number (N, ind. per 1 sq. m) and mass (m, mg per 1 sq. m) of the communities of soil-litter mesofauna in old-growth oak-beech-pine forest of Roztochchia Nature Reserve**

Taxon	Litter				Soil				Total			
	N	%	m	%	N	%	m	%	N	%	m	%
Lumbricidae	28	14.4	3600	34.3	8	10	1020	33.3	36	13	4620	34
Araneae	8	4.1	28	0.3	8	10	304	9.9	16	5.8	332	2.4
Isopoda	12	6.1	180	1.7					12	4.3	180	1.3
Diplopoda	8	4.1	488	4.6	4	5	700	22.8	12	4.3	1188	8.8
Chilopoda	64	32.7	740	7	12	15	32	1.1	76	27.5	772	5.7
Blattoptera	4	2	72	0.7					4	1.5	72	0.5
Dermaptera	8	4.1	448	4.3					8	2.9	448	3.3
Staphylinidae	20	10.2	372	3.5					20	7.2	372	2.7
Adephaga (lar.)	4	2	40	0.4					4	1.5	40	0.3
Elateridae (im.)	4	2	240	2.3					4	1.5	240	1.8
Elateridae (lar.)					24	30	224	7.3	24	8.7	224	1.7
Curculionidae (im.)	8	4.1	88	0.8					8	2.9	88	0.7
Curculionidae (lar.)					12	15	132	4.3	12	4.3	132	1
Diptera (im. & lar.)	8	4.1	84	0.8					8	2.9	84	0.6
Rhagionidae (lar.)					4	5	53	1.7	4	1.5	53	0.4
Tenthredinidae (lar.)	12	6.1	924	8.8					12	4.3	924	6.8
Geotrupidae	4	2	1480	14.1					4	1.5	1480	10.9
Scarabaeidae (lar.)					8	10	600	19.6	8	2.9	600	4.4
Mollusca	4	2	1720	16.4					4	1.5	1720	12.7
Total	196	100	10504	100	80	100	3065	100	276	100	13569	100

In terms of mass, saprophagae are total dominants in both litter and soil with their portions of 77 % and 56 %, accordingly. Lumbricidae, in particular *Dendrobaena octaedra*, and Diplopoda representatives (*Polydesmus complanatus*, *Julus* sp.) dominate in soil, while slugs (*Arion subfuscus*) and earth boring beetles (*Geotrupes* sp.) dominate in forest litter (**Table 1**, **Fig. 3**).

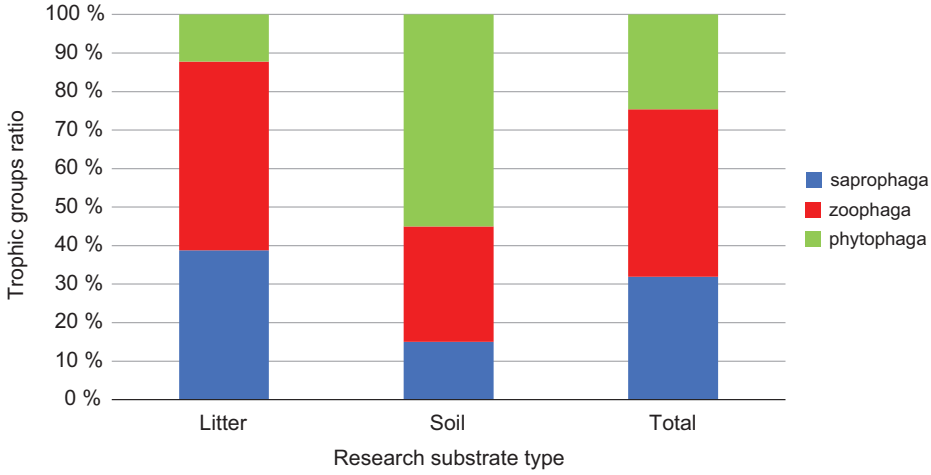

Fig. 2. The number ratio of trophic groups of soil-litter invertebrate mesofauna of the old-growth forest research model plot in Roztochchia Nature Reserve

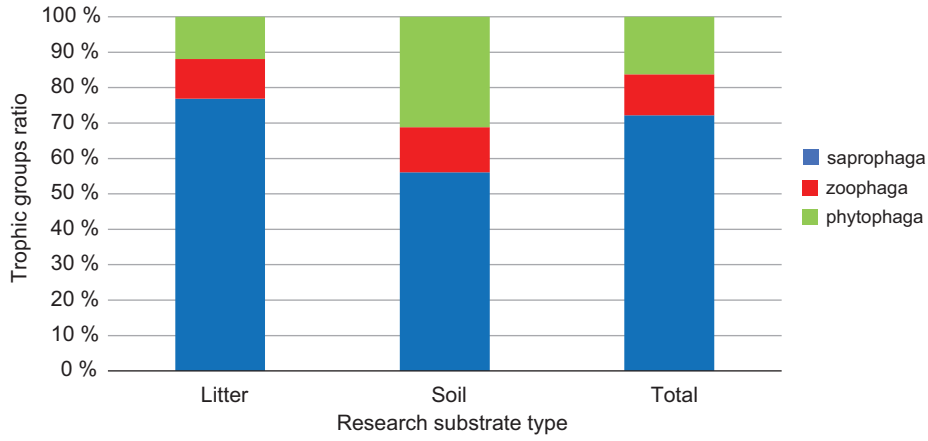

Fig. 3. The mass ratio of trophic groups of soil-litter invertebrate mesofauna of the old-growth forest research model plot in Roztochchia Nature Reserve

Analysis of the indicators of taxonomic diversity and dynamic density of soil-litter mesofauna in old-growth oak-beech-pine forest shows that the community dominants are earth boring beetles (*Geotrupes* sp.) and ground beetles (*Carabus violaceus, Pterostichus oblongopunctatus*, *P. niger*, *Cychrus caraboides*). Part of the other invertebrate taxa representatives is significantly smaller – the level of recedents and subrecedents, – e.g., rove beetles (*Staphylinus caesareus*, *Ocypus olens* etc.) and ants (*Myrmica rubra*, *M. scabrinodis, Lasius brunneus*) (**Table 2**).

Table 2. **Indicators of taxonomic diversity (S) and dynamic density (N_d, ind. per 100 trap-days) of the communities of soil-litter mesofauna in old-growth oak-beech-pine forest of Roztochchia Nature Reserve**

Taxon	S	N_d	%
Lumbricidae	1	0.9	0.7
Isopoda	1	0.6	0.5
Araneae	3	0.4	0.3
Chilopoda	2	2.2	1.7
Diplopoda	4	0.8	0.6
Dermaptera	1	0.4	0.3
Carabidae	10	21	16.7
Staphylinidae	4	0.7	0.5
Adephaga (lar.)	1	1.3	1
Formicidae	2	1.1	0.9
Chrysomelidae (im. & lar.)	1	0.9	0.7
Silphidae	1	0.4	0.3
Elateridae	1	0.1	0.1
Geotrupidae	3	92.7	73.6
Diptera (lar.)	2	0.1	0.1
Trichoptera (lar.)	1	0.1	0.1
Vespidae	1	0.4	0.3
Panorpidae (lar.)	1	0.6	0.5
Noctuidae (lar.)	1	0.2	0.2
Mollusca	1	1.1	0.9
Total	42	126	100

Data analysis on the dominance structure of trophic groups of this community shows cumulative domination of saprophaga by the dynamic density indicator – its part constitues almost 78 %. Predators' part in the community is over 21 %, and only about 1 % is accounted for phytophaga trophic group, which is presented mostly by the single Coleoptera and Lepidoptera larvae (**Fig. 4**).

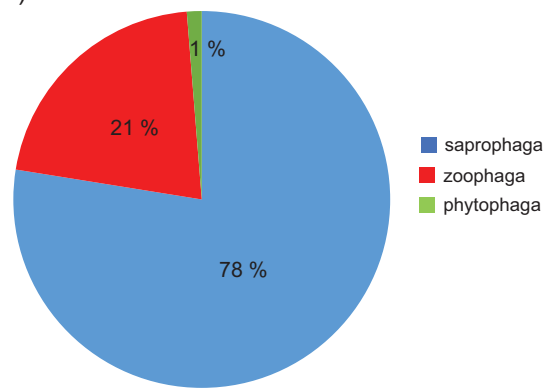

Fig. 4. The dynamic density of trophic groups of soil-litter invertebrate mesofauna of the old-growth forest research model plot in Roztochchia Nature Reserve

CONCLUSION

According to the research results the communities of soil-litter invertebrate mesofauna of old-growth oak-beech-pine forest consist of over 60 species. The number of mesofauna reaches 280 ind. per sq. m with mass up to 13.6 g per sq. m. A large proportion of the number (71 %) and the mass (77 %) of mesofauna community are concentrated in the forest litter; the rest are found in 30 cm deep soil layer.

Insects are absolute dominants in the community as they account for over 70% of its taxonomic diversity; their parts in total number and mass are 44 and 34%, accordingly. The parts of other taxa representatives are significantly smaller: Lumbricidae (13 and 34 %), Chilopoda (28 and 6 %), Diplopoda (4 and 9 %), Mollusca (2 and 13 %). Insect dominants in terms of number are Elateridae (10 %), Staphylinidae and Curculionidae (7 % each).

Predators dominate in the trophic structure of soil-litter mesofauna community in terms of taxonomic diversity (52 %) and number (44 %). Saprophagae prevail absolutely by the mass (72 %) and the dynamic density (78 %). The trophic group of phytophaga shows the lowest figures by all of the research characteristics: taxonomic diversity – 12 %, number – 25 %, mass – 16 % and dynamic density – only 1 %.

Thus, soil and litter mesofauna community of the oak-beech-pine forest has rather high species diversity, and its quantitative indicators as well as structural and functional characteristics are favorable for the long-term existence and maintenance of a sustainable ecosystem of the old-growth forest.

ACKNOWLEDGMENTS AND FUNDING SOURCES

The conducted research was financially supported as part of a fundamental research project of the Institute of Ecology of the Carpathians of the National Academy of Sciences of Ukraine “Structural and functional organization of old-growth natural forest ecosystems as the model for re-naturalization of the transformed forests of western regions of Ukraine” (State registration number of the project: 110/13/18-22/f).

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: the authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Animal Rights: this article does not contain any studies with animal subjects performed by any of the authors.

AUTHOR CONTRIBUTIONS

Conceptualization, [I.T.; V.Y.; O.R.]; methodology, [I.T.; V.Y.]; validation, [I.T.; O.R.]; formal analysis, [I.T.; V.Y.; O.R.].; investigation, [I.T.; V.Y.]; resources, [I.T.; V.Y.; O.R.]; data curation, [I.T.; O.R.]; writing – original draft preparation, [I.T.; V.Y.; O.R.]; writing – review and editing, [I.T.; O.R.]; visualization, [O.R.] supervision, [O.R.]; project administration, [I.T.; O.R.]; funding acquisition, [I.T.; V.Y.; O.R.].

All authors have read and agreed to the published version of the manuscript.

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СТРУКТУРА ДОМІНУВАННЯ УГРУПОВАНЬ ҐРУНТОВО-ПІДСТИЛКОВОЇ МЕЗОФАУНИ СТАРОВІКОВИХ ЛІСІВ УКРАЇНСЬКОГО РОЗТОЧЧЯ

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Вступ. З'ясування структури угруповань ґрунтово-підстилкових безхребетних мезофауни в екосистемах старовікових лісів є важливим для розуміння механізмів підтримання їхньої стабільності. Наші дослідження зосереджені на встановленні таксономічного та функціонального різноманіття угруповань мезофауни старовікових лісів Українського Розточчя. Метою дослідження було з'ясувати таксономічне різноманіття ґрунтово-підстилкових безхребетних з подальшим встановленням структури домінування їхніх угруповань на ділянці природного старовікового лісу.

Матеріали та методи. Дослідження мезофауни здійснене на пробній площі природного старовікового дубово-буково-соснового лісу в межах лісотипологічного профілю Пясецького на території природного заповідника "Розточчя". Збір ґрунтово-підстилкової мезофауни проведено у 2023 р. методом пошарового викопування на глибину її поширення, ручного розбору ґрунтово-підстилкових проб і відловом пастками Барбера. Обробку і опрацювання матеріалу виконували відповідно до загальноприйнятих методик у ґрунтовій зоології.

Результати. Таксономічне різноманіття угруповання безхребетних ґрунтово-підстилкової мезофауни досліджуваного старовікового дубово-букового сосняка становить понад 60 видів, які належать до 25 родин зі семи класів трьох типів. За чисельністю у підстилці переважає трофічна група хижаків (49 %), зокрема Chilopoda і Staphylinidae; у ґрунті ж домінують фітофаги (55 %) – личинки Elateridae та Curculionidae. За показником маси сапротрофи є домінантами як у підстилці (77 %) – Lumbricidae, Mollusca, Geotrupidae, так і у ґрунті (56 %) – Lumbricidae, Diplopoda. Вони також домінують за показником динамічної щільності (78 %).

Висновки. Чисельність досліджуваної мезофауни становить до 280 ос./м^2 з масою до 13,6 г/м^2. 71 % чисельності та 77 % маси угруповання зосереджені у підстилці, решта – у товщі ґрунту до 30–40 см завглибшки. Домінантами в угрупованні є комахи – на них припадає понад 70 % таксономічного різноманіття. Угруповання безхребетних ґрунтово-підстилкової мезофауни дубово-букового сосняка має достатньо високу видову різноманітність, а його кількісні показники та структурно-функціональна організація сприяють тривалому існуванню і підтриманню стабільної екосистеми старовікового лісу.

Ключові слова: безхребетні, старовіковий ліс, таксономічне різноманіття, трофічні групи, сапротрофи, Розточчя

Received / Одержано 11 April, 2025 | Revision / Доопрацьовано 25 May, 2025 | Accepted / Прийнято 03 June, 2025 | Published / Опубліковано 25 June, 2025