Biosystems Diversity

ISSN 2519-8513 (Print)
ISSN 2520-2529 (Online)
Biosyst. Divers.

Peculiarities of the formation of phytocoenotic ranges of vegetatively propagated herbs and shrubs in forest plant groups of the Ukrainian Polissia

I. Kovalenko, H. Klymenko, N. Kovalenko, R. Yaroshchuk, O. Tykhonova, S. Yaroshchuk, S. Zubko

Sumy National Agrarian University, Sumy, Ukraine

Article info

Received 03.01.2025
Received in revised form 12.02.2025
Accepted 26.02.2025

Sumy National Agrarian University,
G. Kondratiev st., 160,
Sumy, 40021, Ukraine.
Tel.: +38-099-525-61-82.
E-mail:
kovalenko_977@ukr.net

Kovalenko, I., Klymenko, H., Kovalenko, N., Yaroshchuk, R., Tykhonova, O., Yaroshchuk, S., & Zubko, S. (2025). Peculiarities of the formation of phytocoenotic ranges of vegetatively propagated herbs and shrubs in forest plant groups of the Ukrainian Polissia. Biosystems Diversity, 33(1), e2516. doi:10.15421/012516

Forest ecosystems are characterized by a vast biological diversity, comprising millions of plants, animals, fungi, and microorganisms, which interact and form complex food chains and interdependencies. Forest ecosystems contain several strata, from the litter vegetation and shrubs to the tree tops, each supporting an array of life forms and performing specific functions. The upper tier of forest provides the protection from the sun, thus controlling the microclimate at the lower levels, influencing the temperatire and soil humidity. Forests play a crucial role in the global biogeochemical cycles, such as carbon and water cycles. Trees consume carbon dioxide emissions from the atmosphere and produce oxygen through phosynthesis, mitigating the climate change. Water circulates through forest ecosystems, evaporates from the leaf surface, condenses in the clouds, and returns back to Earth as precipitation. Forest ecosystems continuously change subject to both natural and anthropogenic factors. Forests provide a variety of ecosystemic services, ranging from regulation of climate and preservation of soils to filtration of water and support of biodiversity. They also serve as living places for numerous vulnerable and endemic species, thus performing the role of natural reservoirs of genetic resources. Therefore, forest ecosystems are extremely ecologically valuable, and their preservation is crucial to a balanced functioning of the planet. Our studies were conducted in the forest ecosystems of the Desna-Stara Huta National Nature Park, located in the Ukrainian Polissia. The materials and methods of the study included systematic collection of data on the frequency of occurrence of vegetatively propagated herbs and shrubs in forest ecosystems of the Ukrainian Polissia. For the data analysis, we used statistical methods. In the studied group of plants, the largest phytocoenotic ranges, which included 7–9 types of phytocoenoses, were observed for *Vaccinium myrtillus* and *Maianthemum bifolium*. Narrow phytocoenotic ranges, which included only 3-4 phytocoenoses, were noted for *Calluna vulgaris* and *Aegopodium podagraria*. The narrowing of phytocoenotic ranges of the forest herbs and shrubs was found attributable to the populations spreading farther away from their hytocoenotic optima. As the stress factors increased, the species and populations underwent the following transformations: decline in the level of productive process, with decrease in the size of phytomass of individuals – diminution of plant size; their reproductive potential; reduced population density; changes in the age composition of populations, where the share of plants of older ages increased, while the share of pre-generative plants declined; changes in the vital structure of populations that reflected their diversity by vital condition, shifting from prospering to depressing. In total, those processes act as a limiting mechanism of expansion of the plants' phytocoenotic ranges. The comparative analysis of the yielded results revealed that the species individuality of phytocoenotic ranges of forest herbaceous and shrub plants of the Ukrainian Polissia is characterized by two main parameters: the width of phytocoenotic range and the abundance distribution in the phytocoenoses within their phytocoenotic range.

Keywords: geographic range of species; herbaceous plants and shrubs; species abundance; forest ecosystems; protected nature territories; preservation of biodiversity.

Introduction

The spatial distribution of plant species is controlled by numerous factors (Kermavnar et al., 2021; Haq et al., 2024). Under their influence, each plant species forms an area where its individuals and populations live (Ishii et al., 2004). Such a territory, in a broad sence, is defined as a geographic range of the species (Berehovyi & Prakhov, 1969; Didukh, 2007). Within its geographic range, the plant is confined only to certain biotopes (Carvalho et al., 2017). There are no species that occupy their range completely, but on contrary, usually large areas inside the range are completely devoid of individuals of the species (Kuzmishyna, 2017). Complete occupation of a territorial range is impeded by ecological and phytocoenotic obstacles (Corlett, 2016).

The mechanism of ecological limitation is based on the ecological properties of plants (Cosentino et al., 2023) and can be assessed according to their ecological amplitudes, which indicate the range of each ecological factor within which a plant can grow and reproduce (Thuiller et al., 2019). The total sum of ecological amplitudes of the main ecological factors that affect a plant is considered its ecological range (Krasnov et al., 2009; Kovalenko, 2016; Tsymbalista & Herts, 2020). The ecological range is located within the space of a plant's geographic range (Cosentino et al., 2023). The ecological ranges of plants vary by species representativeness. In a part of the plant's ecological range where all the main factors are optimal for the plant, the species acts as a dominant or subdominant, while in another part of its range, where the ecological factors are often beyond the optimum and where the plant has powerful competitors, the species may act as a satellite (asectator) or fall out of the plant group (Lenoir et al., 2017; Rios et al., 2024).

The phytocoenotic factor limiting the growth of a plant species in different types of plant groups is associated with the species composition and the structure of phytocoenoses (Ishii et al., 2004), as well as the presence of rejuvenation niches in them and the level of competition for ecological resources (Vasiliev, 2022). Through those mechanisms, each species within its geographic and ecological ranges forms its phytocoenotic range (Hanz et al., 2023). The phytocoenotic range of a plant is a total sum of types of phytocoenoses where it grows. Within a phytocoenotic range, each plant is represented by local populations with different types of occurrence (Kermavnar et al., 2021), but at the same time is typical for those types of phytocoenoses that comprise its phytocoenotic range (Kovalenko, 2015). We should distinguish between the generalized and local phytocoenotic ranges. The first includes all types of phytocoenoses where the plant occurs within its geographic range, and the second includes phytocoenoses in one natural region.

The degree to which the geographic, ecologic, and phytocoenotic ranges of plants have been studied varies (Carvalho et al., 2017; Kermavnar et al., 2021; Șandru et al., 2023). The geographic ranges of plants have studied quite thoroughly by floral specialists. Those data are available in different general and regional guides to flora. The ecological ranges have been quite accurately determined for most plants and could be scrutinized according to the ecological scales of Ellenberg (1974, 1996), Landolt (1997), Ramenskyi (1956), Diduh (2011), Tsyhanov (1983), and others. By contrast, the phytocoenotic ranges of plants have received little reserach, and no methods of determining them have been developed. Sophisticated studies and guides provide them only in generalized variants, such as pratant (meadow plant), silvant, forest-edge, wetland species, etc. The confinement of species to certain syntaxa – classes, orders, alliances, or associations is known only for a limited number of species. This makes the study of phytocoenotic ranges of plants a relevant scientific objective. The importance of establishing ecological ranges of forest species of plants arises from the necessity to preserve forest phytocoenoses in Ukraine against the background of decline in the forested area worldwide, as determined by the study Global Forest Resources Assessment (2020).

Materials and methods

The objective of the study was to develop a method of studying the phytocoenotic ranges of plants and identifying phytocoenotic ranges of 14 species of herbs and shrubs, characteristic of the forest phytocoenoses of the Ukrainian Polissia, with the accuracy down to the syntaxa of the association level according to Braun-Blanquet.

The objects for the detailed study were 14 species of vegetatively propagated herbs and shrubs, typical of the forest phytocoenoses of the Ukrainian Polissia, namely: *Aegopodium podagraria* L., *Asarum europaeum* L., *Calamagrostis arundinacea* (L.) Roth., *C. epigeios* (L.) Roth., *Calluna vulgaris* (L.) Hull., *Carex pilosa* Scop., *Equisetum sylvaticum* L., *Glechoma hederacea* L., *Maianthemum bifolium* (L.) F. W. Schmidt., *Mercurialis perennis* L., *Orthilia secunda* (L.) House., *Rubus saxatilis* L., *Vaccinium myrtillus* L., *Vaccinium vitis-idaea* L.

The research was conducted in 2016–2022 in the territory of the Desna-Stara Huta National Nature Park and the neighboring forests. The methods of studying the phytocoenotic ranges of forest herbs of the Ukrainian Polissia were based on 124 complete geobotanic releves. In each plant association, at least 7–10 releves were recorded, according to which we assessed the occurrence of species of the herbaceous-shrub stratum. The releves were conducted on 10x10 plots, the frequency of occurrence of the studied vegetatively propagated plants was determined as a percentage. The forest phytocoenoses of the Polissia are arranged the following order:

1. *Eriophoro vaginati-Pinetum sylvestris* Hueck 1925
   Sphagnion medii Kästner et Flössner 1933
   Sphagnetalia medii Kästner et Flössner 1933
   Oxycocco-Sphagnetea Br.-Bl. et Tx. ex Westhoff, Dijk et Paschier 1933
2. *Salicetum triandrae* Malcuit ex Noirfalise in Lebrun et al. 1955
   Salicion triandrae T. Müller et Görs 1958
   Salicetalia purpureae Moor 1958
   Salicetea purpureae Moor 1958
3. *Carici elongatae-Alnetum* W. Koch. 1926 ex Tx. 1931
   Alnion glutinosae Malcuit 1929
   Alnetalia glutinosae Tx. 1937
   Alnetea glutinosae Br.-Bl. et Tx. ex Westhoff et al. 1946
4. *Betulo-Salicetum repentis* Oberdorfer 1964
   Salicion cinereae T. Müller et Görs ex Passarge 1961
   Salicetalia auritae Doing 1962
   Franguletea Doing ex Westhoff in Westhoff et Den Held 1969
5. *Mercurialo perrenis-Quercetum roboris typicum* Bulokhov et Solomeshch 2003
   Aceri campestris-Quercion roboris Bulokhov et Solomeshch in Bulokhov et Semenishchenkov 2015
   Carpinetalia betuli P. Fukarek 1968
   Carpino-Fagetea sylvaticae Jakucs ex Passarge 1968
6. *Corylo avellanae-Pinetum sylvestris* Bulokhov et Solomeshch 2003
   Querco roboris-Tilion cordatae Solomeshch et Laivins 1993 ex Bulokhov et Solomeshch 2003
   Fagetalia sylvaticae Pawlowski 1928
   Querco-Fagetea Br.-Bl. et Vlieger 1937
7. *Fraxino-Alnetum* W. Matuszkiewicz 1952 = *Ficario-Ulmetum minoris* Knapp 1942
   Alnion incanae Pawłowski et al. 1928
   Alno-Fraxinetalia excelsioris Passarge 1968
   Carpino-Fagetea sylvaticae Jakucs ex Passarge 1968
8. *Lathyro nigri-Quercetum roboris* Bulokhov et Solomeshch 2003
   Quercion petraeae Zolyomi et Lakucs ex Jakucs 1960
   Quercetalia pubescenti-petraeae Klika 1933
   Quercetea pubescenti-Petreae Jakucs (1960) 1961
9. *Querco-Pinetum typicum* J. Matuszkiewicz 1982 = *Querco robori-Pinetum* Matuszkiewicz 1981
   Pino-Quercion Medwecka-Kornaš et al. in Szafer 1959
   Convallario majalis-Quercion roboris Shevchyk et Solomakha in Shevchyk, Solomakha et Voityuk 1996
   Quercetea robori-Petraeae Br.-Bl. et Tx. ex Oberd. 1957
10. *Peucedano-Pinetum* W. Matuszkiewicz (1962) 1973
   Dicrano-Pinion sylvestris (Libbert 1933) Matuszkiewicz 1962
   Pinetalia sylvestris Oberd. 1957
   Vaccinio-Piceetea Br.-Bl. in Br.-Bl. et al. 1939
11. *Querco-Piceetum* (W. Matuszkiewicz 1952) W. Matuszkiewicz et Polak 1955
   Piceion excelsae Pawłowski et al. 1928
   Piceetalia excelsae Pawłowski et al. 1928
   Vaccinio-Piceetea Br.-Bl. in Br.-Bl. et al. 1939

The syntaxonomic status of phytocoenoses where the releves were conducted was assessed using the general methods taking into account the literature data (Onyshchenko, 2006; Onyshchenko, 2009; Panchenko, 2013; Prodromus..., 2019). The yielded data were analyzed using the correlation and dispersion analyses in the Statistica software.

Results

The phytocoenoses for the study were chosen in such a way that each association represented an individual class of vegetation. The studied phytocoenoses comprised an ecological-phytocoenotic sequence, presented schematically (Fig. 1). From the 1st to 11th association, soil humidity decreases, and the intra-coenosis competition for light and other ecological resources increases.

1. Oligotrophic swamped pine forest with herbaceous cover comprised of species of *Sphagnum*.
2. Swamped forest group in meadow-soddy soil, with tree stand made up of species of *Salix*.
3. Forest phytocoenosis in meadow-wetland soil with an *Alnus glutinosa* tree stand.
4. Forest in peat soil, formed by species of the genera *Betula* and *Salix*.
5. Forest in moderately humid soddy soil with *Quercus* and *Acer* tree stand.
6. Pine forest in moderately wet soil with participation of deciduous trees.
7. Forest phytocoenosis of nemoral type, formed of species of the genera *Fraxinus* and *Alnus*.
8. Thermophyle forest phytocoenosis in fertile soil, formed by a *Quercus* tree stand.
9. Acidophilic oak-pine phytocoenosis in poor soddy podzolized soil.
10. Pine phytocoenosis in light loamy soil.
11. Forest phytocoenosis, formed by *Picea* and *Quercus* in podzolized soil.

Fig. 1. The ecological-phytocoenotic sequence of phytocoenoses where the studied species were recorded

The measurement of phytocoenotic range in the studied plants of the herbaceous-shrub stratum varied within the amplitude from 3 to 7 types of phytocoenoses. The occurrence frequency of plant species in them had significant fluctuations, equaling several percents to hun-

dred. The determined sizes of the phytocoenotic ranges of all 14 species of herbs and shrubs were statistically significant. The correlation coefficients, as determined by the method of dispersion analysis, were significant at the level of $P < 0.05$ (Table 1).

The phytocoenotic range of *Aegopodium podagraria* in the forest phytocoenoses of the Ukrainian Polissia included 4 classes of vegetation and respectively 4 associations (Fig. 2). The central part of phytoconotic range of this species comprised the vegetation classes *Carpino-Fagetea sylvaticae* and *Querco-Fagetea* and respectively the associations *Mercurialo perrenis-Quercetum roboris typicum* and *Corylo avellanae-Pinetum sylvestris*, i.e. oak and pine forests of the region. Furthermore, the phytocoenotic range of *Aegopodium podagraria* included the associations of another two classes of vegetation: *Carpino-Fagetea sylvaticae* and *Vaccinio-Piceetea*. The expansion of the phytocoenotic range of *Aegopodium podagraria* has been hindered by its high demand for fertility and humus content in soil.

Table 1

The assessment of statistical significance of the phytocoenotic ranges of 14 species of forest herbs and shrubs in the Ukrainian Polissia

Plant	Coefficient of correlation, r	Fisher's criterion	P
1. Aegopodium podagraria L.	0.426 ± 0.031	75.33	0.000006
2. Asarun europaeum L.	0.629 ± 0.004	63.11	0.000013
3. Calamagrostis arundinacea (L.) Roth.	0.462 ± 0.009	34.32	0.000120
4. Calamagrostis epigeios (L.) Roth.	0.851 ± 0.044	63.67	0.000012
5. Calluna vulgaris (L.) Hull.	0.504 ± 0.007	80.81	0.000050
6. Carex pilosa Scop.	0.253 ± 0.005	157.19	0.000001
7. Equisetum sylvaticum L.	0.950 ± 0.110	50.45	0.000029
8. Glechoma hederacea L.	0.852 ± 0.099	19.49	0.000840
9. Maianthemum bifolium (L.) F. W. Schmidt	0.881 ± 0.006	29.23	0.000820
10. Mercurialis perennis L.	0.907 ± 0.013	125.74	0.000001
11. Orthilia secunda (L.) House.	0.392 ± 0.007	96.50	0.000003
12. Rubus saxatilis L.	0.961 ± 0.020	68.44	0.000009
13. Vaccinium myrtillus L.	0.769 ± 0.040	24.07	0.000410
14. Vaccinium vitis-idaea L.	0.882 ± 0.016	28.44	0.000230

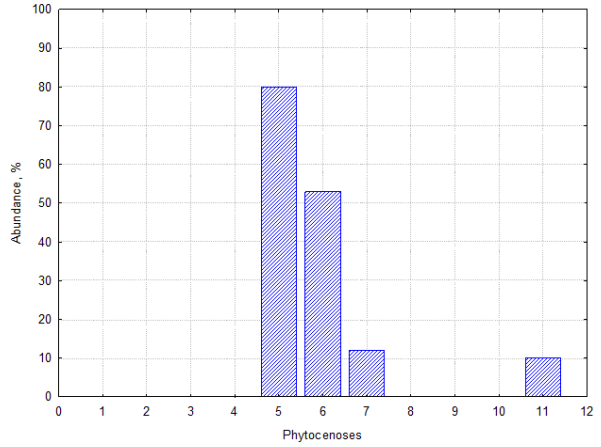

Fig. 2. Phytocoenotic range of *Aegopodium podagraria* in forest phytotocoenoses of the Ukrainian Polissia: numeration of phytocoenoses: 1. Oligotrophic swamped pine forest with herbaceous cover comprised of species of *Sphagnum*. 2. Swamped forest group in meadow-soddy soil, with tree stand made up of species of *Salix*. 3. Forest phytocoenosis in meadow-wetland soil with an *Alnus glutinosa* tree stand. 4. Forest in peat soil, formed by species of the genera *Betula* and *Salix*. 5. Forest in moderately humid soddy soil with *Quercus* and *Acer* tree stand. 6. Pine forest in moderately wet soil with participation of deciduous trees. 7. Forest phytocoenosis of nemoral type, formed of species of the genera *Fraxinus* and *Alnus*. 8. Thermophyle forest phytocoenosis in fertile soil, comprising a *Quercus* tree stand. 9. Acidophilic oak-pine phytocoenosis in poor soddy podzolized soil. 10. Pine phytocoenosis in light loamy soil. 11. Forest phytocoenosis, formed by *Picea* and *Quercus* in podzolized soil

The phytocoenotic range of *Asarum europaeum* included the associations of five classes of vegetation (Fig. 3). The highest occurrence frequency of this species was seen in the classes *Carpino-Fagetea sylvaticae*, *Querco-Fagetea*, and *Quercetea pubescenti-Petreae*. Those are leaved, mostly oak forests in moderately wet fertile soil. The phytocoenotic range of this species also included the two associations *Fraxino-Alnetum* and *Querco-Piceetum*, respectively, from classes *Carpino-Fagetea sylvaticae* and *Vaccinio-Piceetea*. Those are ecologically and phytocoenotically close to nemoral deciduous and coniferous-deciduous forests in loam soil. The formation of the broad phytocoenotic range of *Asarum europaeum* is due to its high shade tolerance.

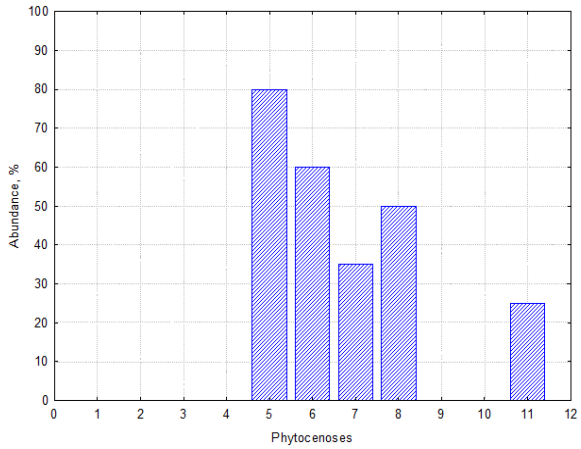

Fig. 3. The phytocoenotic range of *Asarum europaeum* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

An even broader phytocoenotic range was noted for *Calamagrostis arundinacea*: it included phytocoenoses of six classes of vegetation (Fig. 4). In ecological-phytocoenotic order, those were associations from the class *Franguletea* to the class *Vaccinio-Piceetea* (except the class of plant group *Carpino-Fagetea sylvaticae*, the examination of which found no individuals of *Calamagrostis arundinacea*). The highest abundance of this species (85–100%) was seen in the association *Lathyro nigri-Quercetum roboris* of the class *Quercetea pubescenti-Petreae* and in the association *Peucedano-Pinetum* of the class *Vaccinio-Piceetea*. Those are oak and pine forests in fertile soils. In the other four forest associations of the Ukrainian Polissia, *Calamagrostis arundinacea* had the occurrence of 5–25% with high constancy. The broad phytocoenotic amplitude was determined by the ecological-biological properties of *Calamagrostis arundinacea*.

A similar, quite broad phytocoenotic range was observed in another species of this genus – *Calamagrostis epigeios* (Fig. 5). It included six syntaxons from the fourth, class *Franguletea*, to the tenth, class *Vaccinio-Piceetea*, except the association of class *Carpino-Fagetea sylvaticae*. The highest frequency occurence (70%) in *Calamagrostis epigeios* was observed in the association *Querco-Piceetum*, and in the other associations it was at the level of 5–25%. In all cases, this species – due to its preference for abundant sunlight – was confined to the areas of forest with low crown density of the tree stand. The persistence of *Calamagrostis epigeios* in various types of forest

phytocoenoses was to a high degree provided by a combination of effective generative reproduction (one plant can produce up to 6 thou fruits – caryopses) and long vegetative creeping roots.

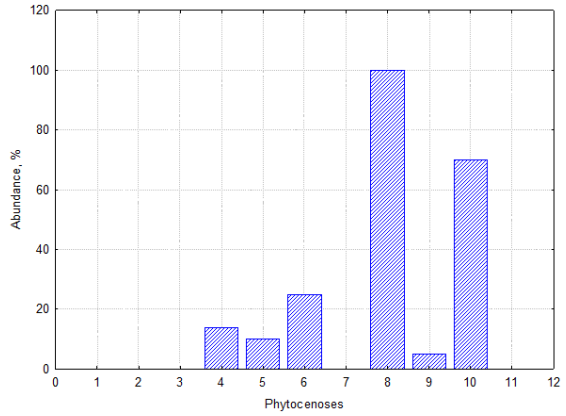

Fig. 4. The phytocoenotic range of *Calamagrostis arundinacea* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

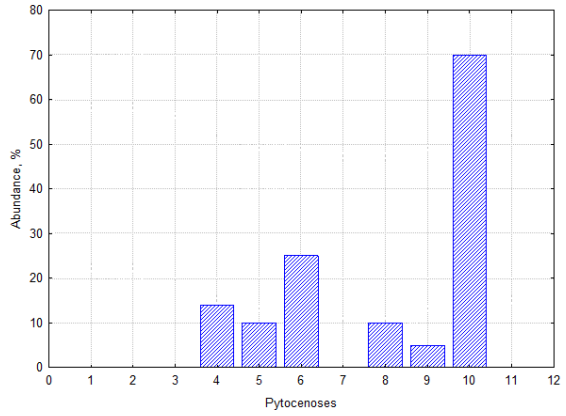

Fig. 5. The phytocoenotic range of *Calamagrostis epigeios* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

In the conditions of the forest groups in the Desna-Stara Huta National Park, the phytocoenotic range of *Calluna vulgaris* is narrow, including only three associations of the vegetation classes *Quercetea robori-Petraeae*, *Vaccinio-Piceetea*, and *Vaccinio-Piceetea* (Fig. 6). At the same time, in the Ukrainian Polissia in general, the phytocoenotic range of this species was broader and included 11 associations. In the area of the studies, *Calluna vulgaris* has tended to live in pine forests and lingonberry patches and spruce forests, in acidic oligotrophic soils, which determined the narrowness of its phytocoenotic range.

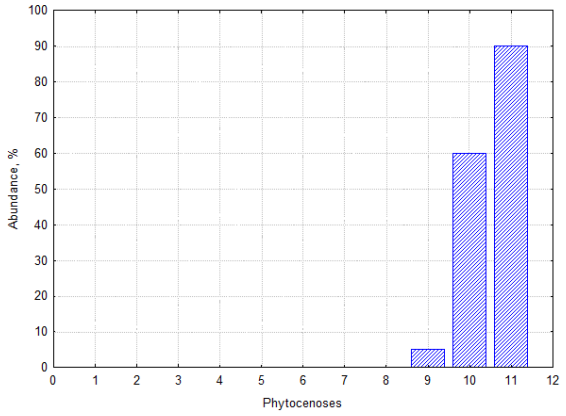

Fig. 6. The phytocoenotic range of *Calluna vulgaris* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

In the forests in the north of Sumy Oblast, the phytocoenotic range of *Carex pilosa* included six associations of six vegetation classes (Fig. 7), the central associations being *Mercurialo perrenis-Quercetum roboris typicum* and *Corylo avellanae-Pinetum sylvestris*. Those are pine and pine-deciduous forests in moderately humid soil. The range of *Carex pilosa* also included 4 associations of oak forests with participation of *Fraxinus* and *Alnus*. Those associations belonged to the vegetation classes *Carpino-Fagetea sylvaticae*, *Quercetea pubescenti-Petreae*, *Vaccinio-Piceetea*, and *Vaccinio-Piceetea*. *Carex pilosa* owes its broad range to its shade tolerance and its ability to grow in poor soils of different types.

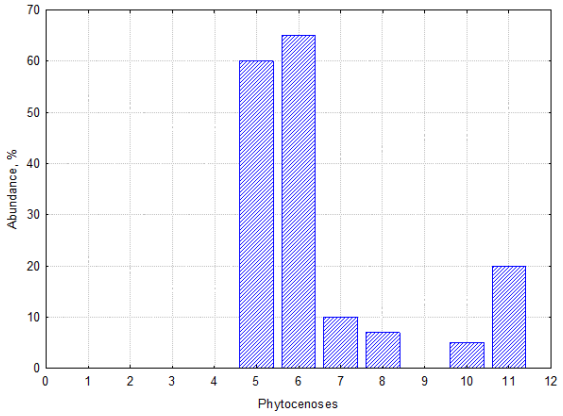

Fig. 7. The phytocoenotic range of *Carex pilosa* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

Among the studied species of herbaceous and shrub forest plants, we should note *Equisetum sylvaticum*, whose phytocoenotic range was the broadest (Fig. 8), including seven association of seven types of vegetation. The occurrence frequency of this species in different associations ranged 3% to 25%, but with high constancy. The central associations in the phytocoenotic range of *Equisetum sylvaticum* were *Fraxino-Alnetum*, *Lathyro nigri-Quercetum roboris*, *Mercurialo perrenis-Quercetum roboris typicum*, and *Querco-Piceetum*. Those are nemoral forests with the forest-forming trees of *Quercus*, *Fraxinus*, *Acer*, and *Alnus* genera. In the Ukrainian Polissia, *Equisetum sylvaticum* actively propagates by spores, and also vegetatively by the roots. The plant is low-demanding, grows in acidic, poor soils. Its growth in various types of phytocoenoses is also due to its low demand for light.

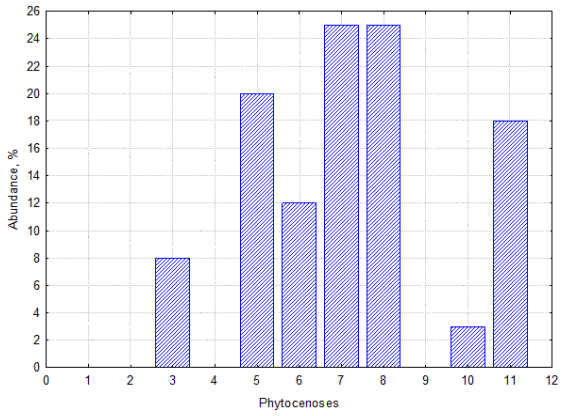

Fig. 8. The phytocoenotic range of *Equisetum sylvaticum* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

The phytocoenotic range of *Glechoma hederacea* included 11 associations (Fig. 9). The highest occurrence frequency of this species, measuring 88%, was seen in the associations *Corylo avellanae-Pinetum sylvestris* of the class *Querco-Fagetea*. With high, 40–50%, frequency, *Glechoma hederacea* occurred in the associations *Mercurialo perrenis-Quercetum roboris typicum* and *Lathyro nigri-Querce-*

tum roboris of the classes *Carpino-Fagetea sylvaticae* and *Quercetea pubescenti-Petreae*, respectively. In the rest four associations, which make up the phytocoenotic range of *Glechoma hederacea*, its occurrence frequency was at the level of 5–15%. The phytocoenotic range of *Glechoma hederacea* corresponded to its biological and ecological properties. It prefers quite rich soils of deciduous forests of the region, with oack, ash, and alder. The width of the phytocoenotic range of *Glechoma hederacea* has allowed it to form a broad geographic range, which includes almost the whole of Europe and most of Asia. The wide distribution of this herbaceous perennial is due to its low ecological demand.

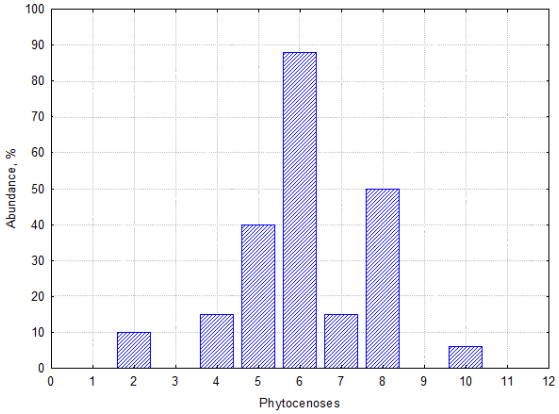

Fig. 9. The phytocoenotic range of *Glechoma hederacea* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

The phytocoenotic range of *Maianthemum bifolium* contained associations of seven of the total of 11 vegetation classes, which in the conditions of the Ukrainian Polissia can be considered broad (Fig. 10). At the same time, only in two of them,did its occurrence frequency equal 5–10%. In the rest of the associations, it was at the level of 45–100%. The center of the phytocoenotic range of *Maianthemum bifolium* was the two associations with 100% abundance of this species. Those were the associations *Corylo avellanae-Pinetum sylvestris* of the class *Querco-Fagetea* and the association *Querco-Piceetum* of the class *Vaccinio-Piceetea*. Those were pine and spruce forests with highly dense tree stands, in soils of average fertility. The resilience of the populations of *Maianthemum bifolium* is due to its shade tolerance. Low occurence and abundance of *Maianthemum bifolium* were noted in alder and oak forests in fertile soil, where its presence has been diminished by stronger competitors of the herbaceous and shrub strata.

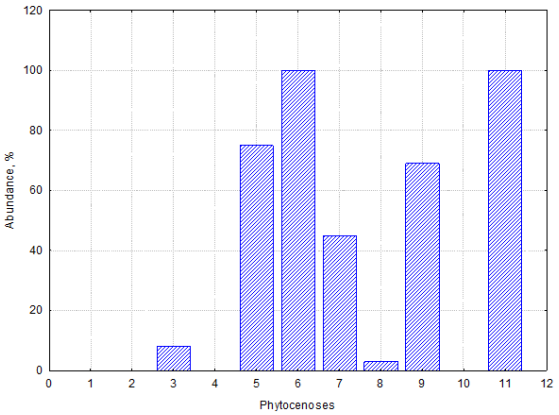

Fig. 10. The phytocoenotic range of *Maianthemum bifolium* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

The phytocoenotic range of *Mercurialis perennis* included the associations of five vegetation classes (Fig. 11). The central association was *Lathyro nigri-Quercetum roboris* of the class *Quercetea pubescenti-Petreae*, where the occurrence frequency of this species was 80%. In other associations of the phytocoenotic range, the plant's occurrence frequency was no higher than 25%. The main types of phytocoenoses that this species was associated with were oak and pine forests, with participation of deciduous trees, in moderately wet soil. Such a range corresponds to the ecological properties of *Mercurialis perennis* as a megatroph, mesohygrophyte, and sciophyte. Because of a comparatively high demand for soil fertility, the plant is abscent in acidophilic pine-leaved forests in poor soil. The vegetative propagation by long roots makes *Mercurialis perennis* a quite competitive species, which is able to effectively compete against other plants of the ground cover.

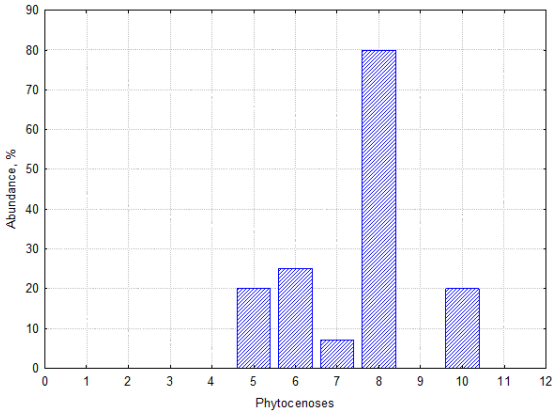

Fig. 11. The phytocoenotic range of *Mercurialis perennis* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

In the north of Sumy Oblast, in the Polissia, *Orthilia secunda* has formed a phytocoenotic range comprising six vegetation classes (Fig. 12). The plant was the most persistent in three classes: *Vaccinio-Piceetea*, *Vaccinio-Piceetea*, and *Querco-Fagetea*. The ecological-phytocoenotic conditions in phytocoenoses of those vegetation classes corresponded to the ecological properties of *Orthilia secunda*, a typical sylvatic plant that is green in winter and has low light requirements. The plant grows in soils of various mechanical compositions, usually podzolized, poor in mineral nitrogen, and well aerated. It propagates both by seeds and vegetatively through underground stems, which form daughter plants after sprouting. Ultimately, it leads to formation of clones that provide this species with high competitive ability. At the same time, *Orthilia secunda* has also high seed productivity: one peduncle bears 11 capsules on average, each containing 150 to 500 seeds.

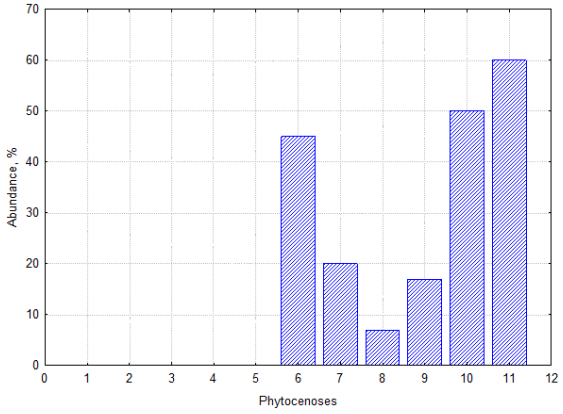

Fig. 12. The phytocoenotic range of *Orthilia secunda* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

The phytocoenotic range of *Rubus saxatilis* in the forest phytocoenoses of the Ukrainian Polissia included six associations of six vegetation classes (Fig. 13). According to the parameters, it was partly similar to the phytocoenotic range of *Orthilia secunda*: the highest occurrence frequency was seen in two associations, *Querco-Piceetum*

of the vegetation class *Vaccinio-Piceetea* and *Corylo avellanae-Pinetum sylvestris* of the class *Querco-Fagetea*, measuring 100% and 76%, respectively. The close similarity between the phytocoenotic ranges of *Rubus saxatilis* and *Orthilia secunda* is associated with the similarity of their growth forms and the main ecological specifics. Both species are perennial, rhizomatous plants, mesotrophs, mesophytes, silvatic plants, and oligotherms.

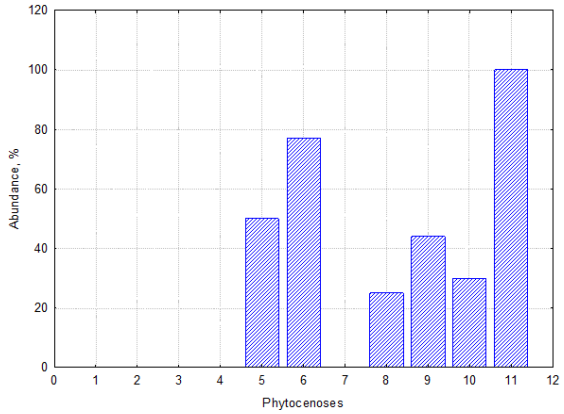

Fig. 13. The phytocoenotic range of *Rubus saxatilis* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

Of the group of 14 examined forest plants, *Vaccinium myrtillus* had the broadest phytocoenotic range. It included the associations of nine vegetation classes (Fig. 14). The plant's 100% occurence, in high numbers, was seen in three associations of vegetation classes *Quercetea robori-Petraeae* and *Vaccinio-Piceetea*. Those are pine and spruce forests with admixtures of leaved trees in acidic-soddy-podzolized and podzolized soils of average fertility. As a perennial rhizomatous shrub, it exerts a high competitive ability. *Vaccinium myrtillus* is a mesopyte and mesotroph, but with a high amplitude in relation to humidity and soil fertility. Therefore, with high constancy it grew in the associations such as *Eriophoro vaginati-Pinetum sylvestris*, *Carici elongatae-Alnetum*, and *Betulo-Salicetum repentis* on peat wetland soil. The phyocoenotic range of *Vaccinium myrtillus* also included the association *Lathyro nigri-Quercetum roboris*, a phytocoenosis with *Quercus* in fertile soil.

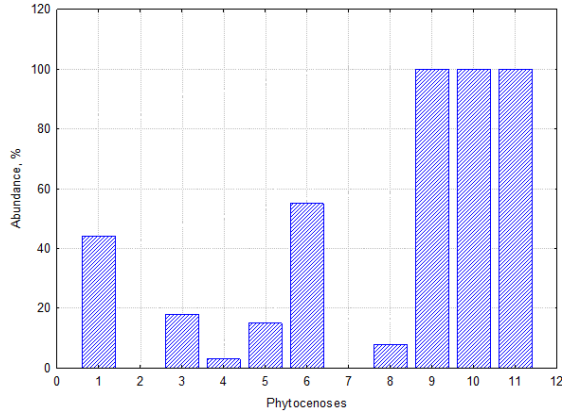

Fig. 14. The phytocoenotic range of *Vaccinium myrtillus* in the forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

The phytocoenotic range of *Vaccinium vitis-idaea*, perennial evergreen shrub, included the associations of five vegetation classes (Fig. 15). The high occurrence of this species, measuring 50–80%, was observed in the spruce, pine, and pine-oak forests of association *Querco-Pinetum typicum* of class *Quercetea robori-Petraeae*, association *Peucedano-Pinetum* of class *Vaccinio-Piceetea*, and association *Querco-Piceetum* of class *Vaccinio-Piceetea*. Those are acidophilic pine and spruce forests (partly with participation of *Quercus* in tree stand). The phytocoenotic range of *Vaccinium vitis-idaea* also included an association *Carici elongatae-Alnetum*, a forest phytocoenosis in alkaline wetland soil with a tree stand made up of *Alnus glutinosa* and an association *Corylo avellanae-Pinetum sylvestris*, which is a pine forest in moderately wet soil. The variety of types of phytocoenoses, which comprised the phytocoenotic range of *Vaccinium vitis-idaea*, reflects its notable adaptability.

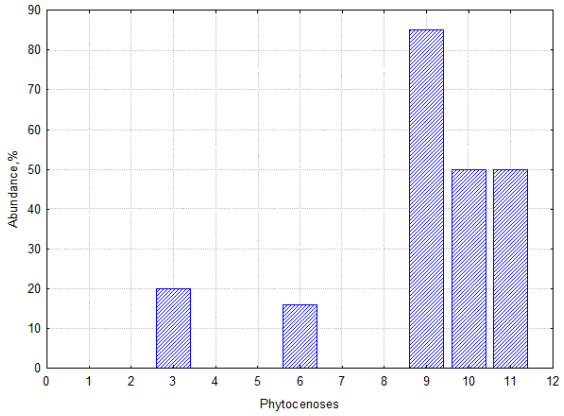

Fig. 15. The phytocoenotic range of *Vaccinium vitis-idaea* in forest phytocoenoses of the Ukrainian Polissia: numeration of phytocoenoses – see Fig. 2

Discussion

The spatial patterns of plant groups depend on the interrelations among the species, and also the impact of physical and chemical environmental factors, such as soil, humidity, temperature, and sunlight (Cosentino et al., 2023). The diversity and stability of the groups are determined not only by ecological factors, but also competitive processes among the species, which can limit their dispersal or promote expantion of their ranges. In places that are close to a plant's optimal conditions, its populations often form dense groups with high species diversity, and outside those zones the structures become rarer and less stable. Natural obstacles, such as rivers or mountain ranges, can also be barriers for species and affect their spatial organization. As a result of limate change, the ranges can shift, as the plants adapt to the new ecological circumstances. Thus, both the structure and functioning of vegetative groups are changing on the global scale (Lenoir et al., 2017). The ecological gradients, such as changes in temperature, humidity, acidity of soil, or height above sea level significantly affect the composition and distribution of plant groups (Gaudichet et al., 2019). In different zones of the gradient, different species were observed, which adapt to specific conditions, creating a mosaic of the groups that vary in composition and structure. The gradients also determine the presence of competitive advantages among the species: in the conditions that are close to their ecological optimum, the species expand their range, displacing less adapted plants. Furthermore, within one gradient, there could be observed transfers from type of group to another, providing multi-layer structure and supporting high biodiversity at the level of landscape. Accurate data on phytocoenotic ranges of species are essential for solving a priority for today – such management and use of forests that would ensure their resilience and biodiversity (Higman et al., 2005; Blakesley et al., 2010). Conservation of forests of the Ukrainian Polissia and managing their economic use are possible only by using the knowledge of the structure and functioning of forest phytocoenoses (Svyrydenko et al., 2006; A Guide for Foresters..., 2016). An important part of the scientific data on forests is reports about the biology and ecology of all species of plants that comprise forest phytocoenoses, and first of all, data regarding their geographic, ecological, and phytocoenotic ranges. The first includes a particular region that corresponds only to a part of the geographic range (as performed in this study), while the other to the territory of the geographic range entirely.

Aegopodium podagraria L. is a long-rhizomatous herbaceous perennial, which is green during summer. The species is a hemicryp-

tophyte, mesohygrophyte, eutrophic, mesotherm, heliosociophyte (shade-tolerant), and sylvatic plant. It grows in fresh, poorly acidic, humus, rich, sandy, crushed-stone, clayey, or silty soils. The shade tolerance and high level of adaptivity of the species to different soils allows it to disperse fast, affecting the biodiversity of natural ecosystems of moderate forests. An invasion by this plant causes changes in the structure of litter layer in forests and inhibition of growth of the local flora (Engelhardt et al., 2022). In disturbed ecosystems, *Aegopodium podagraria* alters the cycle of nutrients – accumulates nitrogen and phosphorus in soil, which can lead to imbalance of nutrients and alter the species composition of local flora (D'Hertefeldt et al., 2014). Therefore, in order to maintain the ecological balance in natural ecosystems, the spread of this species must be controlled (Romanov & Shirnin, 2020). A study of the alelopathic properties of *Polygonum aviculare* and its effect on regeneration of local species revealed (Sarıaltın et al., 2023) that the plant produces chemical compounds that hinder the growth of neighboring plants, thereby limiting the spread of local species. The species could be used in ornamental gardening, but in this case we should note the ecological risks associated with a potential impact on natural ecosystems (Flieger & Flieger, 2020).

Asarum europaeum L. is a herbaceous evergreen rosette, polycarpic, and hemicryptophyte plant. Different authors have assessed it as a long-rhizomatous, as well as short-rhizomatous (Saeedi, et al., 2020). It is green during summer, chamaephyte (Didukh, 2011), sylvatic, hygromesophyte, sciophyte, and mesotherm plant. A study of the species in Germany (Yaroshenko & Skliar, 2022) revealed that it most successfully disperses in moderately humid forests, where the competition for resources is low. The authors underline the necessity of preserving forest ecosystems so asarabacca can survive in the conditions of climate change. The species has been analyzed for its pharmaceutical properties, revealing the presence of the plant's bioactive compounds, which are useful in folk medicine (Akhlaq et al., 2022): the plant has a potential for treating respiratory and inflammatory diseases, but at the same time has a toxic effect, and therefore must be used carefully. Essential oil from Asarum europaeum exerted antimicrobial and antioxidant properties (Hanze & Changhong, 2022) and displayed high efficacy against pathogenic bacteria and fungi. The studies of the ecological role of *Asarum europaeum* in forest undergrowth, especially focusing on its interaction with other plants, revealed (Yaroshenko & Skliar, 2022) that the species supports the soil stability and regulates water balance; the plant has also been confirmed to exhibit allelopathic properties that affect the species composition of undergrowth, limiting the growth of some wild herbaceous plants.

Calamagrostis arundinacea (L.) Roth. is a perennial loose-sod herbaceous grass. The plant is green in winter. The rhizomes are short, ramified. It is a sylvatic plant, mesophyte, and mesotroph. The plant is a shade-tolerant and sod-forming grass. It grows in clumps and actively vegetatively propagates and has a broad amplitude in relation to the soil fertility and light regime (Kovalenko, 2016). It prefers light soils. The plant is mesotherm. In the ecosystems of boreal forests, different species of *Calamagrostis*, including *C. arundinacea*, greatly support biodiversity (Lieffers et al., 2011; Sass et al., 2018). This species also has a significant effect on the recovery of trees in mixed forests (Vacek et al., 2020). The presence of *Calamagrostis arundinacea* in an ecosystem affects the soil microbiome and its activity in the process of decomposition of organic matter (Fiala et al., 2019).

Calamagrostis epigejos (L.) Roth. is a perennial herbaceous plant with long creeping rhizomes, and also a xeromesophyte and meso- or eutrophic plant. Its ecological amplitude is broad, but the plant has a strong affinity to light and poorly tolerates drought. It is a heliophyte and oligotherm. Against the background of the spread of *Calamagrostis epigejos* in mountain meadows, changes in the soil seed bank were observed, which further drove changes in the plant groups (Pruchniewicz et al., 2016). A similar effect was seen in semiarid meadows (Somodi et al., 2008). Studies have also analyzed and identified the factors that determine the presence of *Calamagrostis epigejos* in ecosystems of inland sandy dunes and their roles in sucessions (Süß et al., 2004).

Calluna vulgaris (L.) Hull. It is a significantly ramified evergreen shrub. It grows mostly in dry soil, preferring sandy soil, and also soils with varying humidity. The vegetative propagation takes place through rooting of lateral stems. It was confirmed that the soil characteristics significantly affect the biodiversity of pollinators of *Calluna vulgaris*, and, therefore, the guarantee of healthy ecosystems is reclamation of disturbed soils (De la Peña et al., 2012). *Calluna vulgaris* was observed to play an appreciable role in the formation of forest litter, and also influences the ecosystemic stability. It affects the biodiversity in the conditions of the forest environment, and its presence contributes to the resilience of the ecosystems to stressors. Therefore, preservation of this species is important to the support of the ecological balance (Schellenberg & Bergmeier, 2022). The study of the regenerative cycles of *Calluna vulgaris* in the groups in peatlands (Harris et al., 2011) revealed the ecological resilience and dynamics of these plant communities. The excessive content of nitrogen in soil affects the growth and development of *Calluna vulgaris* in ecosystems (Neumann et al., 2021). The authors analyzed the changes in the structure of plants and functioning of photosynthetic processes subject to heightened nitrogen level. The results indicated potential disturbances of the ecosystems' stability, which may occur due to excessive accumulation of nitrogen in the environment. Those changes have consequences for long-term ecological stability of *Calluna vulgaris* landscapes.

Carex pilosa Scop. is a perennial herbaceous plant with long, underground creeping rhizomes. It is a sylvatic, mesophyte, mesoeutrophic, and shade-tolerant plant. The plant prefers clayey, loamy, or sabulous, grey forest, rich sod-podzolized, or chernozem soils. It is sciophyte and mesotherm. The persistence of populations of this species is also provided by the plant's ability to actively vegetatively propagate (Lukash, 2020). Studies have been conducted on the modern changes in the range of *Carex pilosa* in Latvia and Lithuania (Gudžinskas et al., 2023), in particular, the expansion of the northern boundary of its range, the reason of which is the climatic changes and the peculiarities of relief. The study on the status of the populations of *Carex pilosa* in different forest ecosystems revealed the capabilities of this species to adapt to the environmental changes (Martín-Bravo et al., 2019). Based on the multi-year study on the dynamics of the populations in different regions of the Baltic countries (Leht et al., 2003), an analysis of ethe cological growing conditions of *Carex pilosa* was conducted with the focus on the impact of climate changes and anthropogenic factors of the species' dispersal. The study on the recovery of biogeocoenoses in the Northern Bukovyna (Zhuk et al., 2021) revealed the dynamics of species composition and functional groups in clearings, a frequent representative of which was *Carex pilosa*.

Equisetum sylvaticum L. is a herbaceous perennial polycarpic plant, geophyte. This spore plant is green in summer, and can be long-rhizomed, or short-rhizomed. It is a sylvatic plant, mesotroph, mesohygrophyte, heliosciophyte, and oligotherm. Species of the *Equisetum* genus have absorptive properties concerning cadmium, lead, and zinc, and at the same time their capability to concentrate toxic compounds in biomass has no negative effect on growth (Andrejić et al., 2023). This occurs due to effective accumulation, immobilization, and detoxification of those elements in their underground parts; therefore the plant can be used for cleaning degraded ecosystems. Studies have been conducted on the ecological role of *Equisetum sylvaticum* in shrub wetlands of Alaska (Marsh et al., 2000), in particular, its effect on the circulation of nutrients in soil. Studies have confirmed the potential of *Equisetum sylvaticum* as a natural source of antioxidants and antimicrobial agents in pharmaceutics (Patova et al., 2019), because its extracts were observed to be effective against bacterial and fungal pathogens and able to neutralize free radicals (Wang et al., 2022; Eren et al., 2024).

Glechoma hederacea L. is a herbaceous perennial plant with creeping, rooted vegetative shoots. It is green during summer and winter. It mostly expands through vegetative propagation. The plant is a geophyte and hemicryptophyte. It grows in fresh, humus, mineral-compound-rich soil in deciduous forests. It is sciophyte, mesophyte, and oligotherm. *Glechoma hederacea* has the ability to phytoremedi-

ate heavy metals such as lead and cadmium in wetland soils (Agarwal et al., 2021), and can absorb a large amount of toxic metals, which makes it a valuable plant for recovery of wetland ecosystems. The study of allelopathic interaction among *Glechoma hederacea* and other herbaceous species of the undergrowth revealed (Stuefer & Hutchings, 1994; Šeremet et al., 2022) that the production of chemical compounds can inhibit the growth of competitors, which aids the plant in dominating in the ecosystem. Because of the active compounds in *Glechoma hederacea*, including flavonoids, triterpenoids, and phenol compounds, this plant can be utilized in medicine, in particular, for treatment of respiratory and gastrointestinal diseases (Kumarasamy et al., 2002). *Glechoma hederacea* affects the soil's health, in particular, the activity of soil microorganisms and composition of organic compounds. Also, the plant promotes increase in soil fertility and supports a healthy ecosystem by improving the microbial activity (Chou et al., 2019).

Maianthemum bifolium (L.) F. W. Schmidt is a perennial long-rhizome herbaceous plant. The rhizomes are thin, creeping, often give off underground shoots. It is a mesohygrophyte, mesotroph, and shade-tolerant plant, which is green in summer. It is a sylvatic, sciophyte, and oligotherm plant. *Maianthemum bifolium* affects the circulation of nutrients and the structure of soil in forest ecosystems, promotes preservation of soil moisture and nutrients, which makes it an important component of undergrowth for the support of ecosystem stability (D'Hertefeldt & Jónsdóttir, 1994). The species is indicatory for assessment of soil health (Castrén et al., 1990; Arens et al., 2005) – presence and status of *Maianthemum bifolium* can indicate the level of organic compounds and microbial activity in soil. Therefore, the plant is a useful tool for monitoring ecosystem status (Bierza, 2022). Studies have also focused on the adaptation of *Maianthemum bifolium* to the climate change – the plant reacts by adjusting its physiological processes to preserve the stability of populations (Puchałka et al., 2023).

Mercurialis perennis L. is a perennial dioecious plant, 20–30 cm tall, with long creeping rhizomes. It is green during summer and occurs in mixed and broad-leaved forests in rich and humid soils. The species is a sylvatic, mesohygrophyte, sciophyte, and mesotherm plant. Studies were also conducted on small-scale changes in the shape of *Mercurialis perennis* leaves subject to anthropogenic loading (Vujić et al., 2016), revealing that the plant is quite sensitive. A model of the seasonal structure of carbon consumption by *Mercurialis perennis* (Graves, 1990) has been developed. Researchers have also examined the impact of the environmental factors (soil humidity, light, and soil composition) on the dispersal of *Mercurialis perennis* (Miljković et al., 2018), finding that the plant can well adapt to various environmental conditions and is resilient to ecosystemic changes.

Orthilia secunda (L.) House is a perennial plant in the form of herb or semishrub, 20 cm tall, green during winter. The rhizomes are creeping, long, branchy, and produce perennial shoots. The plant is mesophyte; not demanding to light, growing both in shade and open spaces; sylvatic, mesophyte, oligotroph, sciophyte, and oligotherm plant. The phytochemical composition of *Orthilia secunda* and its antioxidant properties make the species promising for natural medicine and cosmetology (Figura et al., 2019). The studies on the allelopathic properties of *Orthilia secunda* in subalpine ecosystems (Malysheva et al., 2017) revealed that the plant produces chemical compounds that inhibit the growth of neighboring plants, giving it a competitive advantage and affecting the composition of the plant cover. *Orthilia secunda* is cold-tolerant, and its refugial persistence was studied in the context of its post-glacial colonization of the North America (Beatty & Provan, 2010). This species has been noted for its high adaptability, increasing the chances of its survival even in the conditions of rapid climate change.

Rubus saxatilis L. is a perennial short-rhizome herbaceous plant or semi-shrub, up to 30 cm tall, which is green during summer. It is confined to humid forests, mostly coniferous. The species is a sylvatic, mesotroph, mesophyte, heliosciophyte, and oligotherm plant. It produces chemical compounds into the soil environment, which can inhibit the growth of other plants, thus gaining competitive advantages (Ibadullayeva et al., 2023). Studies were conducted on the phytochemical composition of the fruits of Rubus saxatilis and their antioxidant properties (Smolnikova et al., 2019). Modern laboratory studies also confirmed the efficiency of biologically active compounds of the plant, such as antimicrobial and anti-inflammatory agents, which can be a basis for developing novel phytodrugs (Diasamidze & Kalandia, 2018).

Vaccinium myrtillus L. is a perennial shrub, 10–50 cm tall, which is green in summer. The plant has creeping rhizomes, which produce a high number of shoots. It is mesophyte, mesotroph; sensitive to late-spring and early-summer frosts, especially in the blossoming periods; sylvatic plant, heliosciophyte, and oligotherm. *Vaccinium myrtillus* is one of the key species in boreal forests, especially in the conditions of climate change, because the adaptation strategies of the plant – including its ability to survive in high temperatures and varying levels of moisture – are extremely important for its preservation in the aspect of supporting ecosystems (Kovalenko, 2016). Researchers also analyzed the chemical composition of berries of *Vaccinium myrtillus* for their antioxidant properties (Sharma & Lee, 2022). The high content of anthocyanins and other biologically active compounds displayed a significant potential for neutralizing free radicals and therefore can be used in development of functional nutrition products and medical drugs. Extracts from *Vaccinium myrtillus* also exerted anti-inflammatory neuroprotectory properties (Ștefănescu et al., 2020). The high level of air contamination in urban areas reduces the nutrient content in the berries and, thus, their beneficial properties for human health (Mikulic-Petkovsek et al., 2015). The genetic variability of *Vaccinium myrtillus* was found to be important for the long-term survival of the species, especially under the conditions of growing anthropogenic pressure (Zoratti et al., 2016).

Vaccinium vitis-idaea L. is a perennial shrub with horizontal rhizomes and branching shoots that elevate, 15–20 cm, green in winter. It grows in dry and damp coniferous forests and deciduous forests, shrubs, sometimes in peat wetlands. It is a sylvatic plant; light-loving and frost-tolerant; mesophyte, oligotroph, and heliosciophyte. The analysis of the phytochemical composition of berries of *Vaccinium vitis-idaea*, grown in alpine conditions, revealed a high content of phenolic compounds and vitamin C, suggesting a potential for the application in the food industry and for creating products with antioxidant properties (Shamilov et al., 2020). Air and soil contamination in the urban environment negatively affects the chemical composition and nutritional value of lingonberry, and conservation of this species under the conditions of anthropogenic impact is critical (Vilkickyte et al., 2020). Studies focusing on the chemical composition of berries (Vilkickyte & Raudone, 2020) also proposed the plant as raw material for developing drugs for prophylaxis of neurodegenerative diseases.

All the studied species are quite resilient to the climate change, adapt well to significant fluctuations in the temperature and soil humidity, as well as the growing anthropogenic pressure, and have notable allelopathic properties as a mechanism of competitive advantage (Huang et al., 2021). By releasing the chemical compounds into the soil, the plant inhibits other species, components of phytocoenosis. Narrowing of phytocoenotic ranges of forest herbs and shrubs is associated with the population moving farther from their optimal ecological and phytocoenotic conditions. Such a dependence occurs because each species has a specific ecological optimum, where it demostrates maximum vitality, growth, and reproductive parameters (Hanz et al., 2023). Within its optimum, a species can better compete for resources, and effectively use sunlight, water, and nutrients in the soil. However, as the plant moves away from its optimum (Gaudichet et al., 2024), it faces stress factors – temperature changes, lower availability of moisture, and other physical-chemical conditions that inhibit its development and limit its dispersal. In particular, the phytocoenotic ranges of species can narrow as the components of the local ecosystems change, for example, as a result of the climate change, urbanization, or disturbance of forests by human activity. It can force populations to migrate in the direction where the conditions are more favorable, or adapt to new ecological limitations (Lopez-Goldar & Agrawal, 2021, Șandru et al., 2023). In such cases, species often decline in numbers and can be displaced by other species with greater adaptive plasticity, which entails a decrease in biodiversity (Lee & Chun,

2016). Our researches also allow us to assume that moving away from the ecological optimum affects the structure and functioning of phytocoenoses, in particular, the species diversity decreases and the composition of dominants in plant groups alters.

Conclusions

The mechanism of phytocoenotic relations determines the sizes of phytocoenotic ranges of plants. In the studied group of plants, the broadest phytocoenotic ranges, which included 7–9 types of phytocoenoses, were observed in *Vaccinium myrtillus* and *Maianthemum bifolium*. Narrow phytocoenotic ranges, comprising only 3–4 phytocoenoses, were observed in *Calluna vulgaris* and *Aegopodium podagraria*. Narrowing of the phytocoenotic ranges of forest herbs and shrubs was noted as the populations migrated farther from their ecological-phytocoenotic optimum. As the stress factors grew, the individuals and populations underwent the following transformations: decrease in the level of productive process, with decrease in the size of phytomass of individuals – fragmentation of plants; decline in the reproductive potential of individuals; reduced population density; changes occured in the age composition of populations where the share of older plants increased, while the share of pre-generative plants declined; and the vital structure of populations, which reflects their diversity by vital condition, decreased from prospering to depressing. In general, those processes function as a limiting mechanism of expantion of the plants' phytocoenotic ranges. The species individuality of phytocoenotic ranges of forest herbaceous and shrub plants of the Ukrainian Polissia is determined by the two main parameters: the width of phytocoenotic range and the occurrence in the phytocoenoses that belong to their phytocoenotic range.

References

Agarwal, H., Nakara, A., & Shanmugam, V. K. (2019). Anti-inflammatory mechanism of various metal and metal oxide nanoparticles synthesized using plant extracts: A review. Biomedicine and Pharmacotherapy, 109, 2561–2572.

Akhlaq, S., Ara, S. A., Fazil, M., Ahmad, B., Akram, U., Haque, M., & Khan, A. A. (2022). Ethno pharmacology, phytochemical analysis, safety profile, prophylactic aspects, and therapeutic potential of *Asarum europaeum* L. in Unani medicine: An evidence-based appraisal. Phytomedicine Plus, 2(2), 100226.

American Tree Farm System (2016). A guide for foresters and other natural resource professionals on using: Managing your woodlands: A template for your plans for the future. Natural Resources Conservation Service, New York.

Andrejić, G., Kovačević, M., Dželetović, Ž., Aleksić, U., Grdović, I., & Rakić, T. (2023). Potentially toxic element accumulation in two *Equisetum* species spontaneously grown in the flotation tailings. Journal of the Serbian Chemical Society, 88(10), 1055–1064.

Arens, P., Grashof-Bokdam, C., Van der Sluis, T. & Smulders, M. J. M. (2005). Clonal diversity and genetic differentiation of *Maianthemum bifolium* among forest fragments of different age. Plant Ecology, 179, 169–180.

Beatty, G. E., & Provan, J. (2010). Refugial persistence and postglacial recolonization of North America by the cold-tolerant herbaceous plant *Orthilia secunda*. Molecular Ecology, 19(22), 5009–5021.

Berehovyi, P. M., & Prakhov, M. M. (1969). Botanichna heohrafiia [Botanical geography]. Vyshcha Shkola, Kyiv (in Ukrainian).

Bierza, K. (2022). Metal accumulation and functional traits of *Maianthemum bifolium* (L.) F. W. Schmidt in acid beech forests differing with pollution level. Water, Air, and Soil Pollution, 233, 60.

Blakesley, D., & Buckley P. (2010). Managing your woodland for wildlife. Newbury, Berkshire.

Carvalho, M., Gomide, L., Santos, R., Scolforo, J. R., de Carvalho, L. M. T., & de Mello J. M. (2017). Modeling ecological niche of tree species in Brazilian tropical area. Cerne, 23(2), 229–240.

Castrén, M., Haavisto, T., Kari, P. L., Poutanen, H., & Nuorteva, P. (1990). The influence of soil preparation on the concentrations of iron, aluminium, zinc and cadmium in leaves of *Betula* spp. and *Maianthemum bifolium*. Annales Botanici Fennici, 27(2), 139–143.

Chou, S.-T., Lin, T.-H., Peng, H.-Y., & Chao, W.-W. (2019). Phytochemical profile of hot water extract of *Glechoma hederacea* and its antioxidant, and anti-inflammatory activities. Life Sciences, 231, 116519.

Corlett, R. T. (2016). Plant diversity in a changing world: Status, trends, and conservation needs. Plant Diversity, 38(1), 10–16.

Cosentino, F., Seamark, E. S. J., Van Cakenberghe, V., & Maiorano, L. (2023). Not only climate: The importance of biotic interactions in shaping species distributions at macro scales. Ecology and Evolution, 13(3), e9855.

D'Hertefeldt, T., Eneström, J. M., & Pettersson, L. B. (2014). Geographic and habitat origin influence biomass production and storage translocation in the clonal plant *Aegopodium podagraria*. PLoS One, 9(1), e85407.

De la Peña, E., Van De Velde, H., Lens, L., & Bonte, D. (2012). Soil conditions in natural, declining, and restored heathlands influence plant–pollinator interactions of *Calluna vulgaris*. Restoration Ecology, 20(5), 603–611.

D'Hertefeldt, T., & Jónsdóttir, I. S. (1994). Effects of resource availability on integration and clonal growth in *Maianthemum bifolium*. Folia Geobotanica, 29, 167–179.

Diasamidze, M., & Kalandia, A. (2018). The research of phenolic compounds of raspberry (*Rubus saxatilis* L.) fruit by HPLC. Global Journal of Current Research, 6(1), 50–53.

Didukh, Y. P. (2007). Heohrafichnyi analiz flory: Mynule suchasne, maibutnie [Geographical analysis of flora: Past, present, future]. Ukrainian Botanical Journal, 64(4), 485–507 (in Ukrainian).

Didukh, Y. P. (2011). The ecological scales for the species of Ukrainian flora and their use in synphytoindication. Phitosociocentre, Kyiv.

Dubyna, D. V., & Dziuba, T. P. (Eds.). (2019). Prodromus roslynnosti Ukrayiny [Prodrome of the vegetation of Ukraine]. Naukova Dumka, Kyiv (in Ukrainian).

Engelhardt, L., Pöhnl, T., & Neugart, S. (2022). Edible wild vegetables *Urtica dioica* L. and *Aegopodium podagraria* L. – antioxidants affected by processing. Plants, 11(20), 2710.

Eren, A., İnci, Ş., & Kirbag, S. (2024). The antimicrobial and antioxidant effects of *Equisetum arvense* extracts. Turkish Journal of Science and Technology, 19(2), 373–378.

Fiala, K., Tůma, I., Holub, P., & Jandák, J. (2005). The role of *Calamagrostis* communities in preventing soil acidification and base cation losses in a deforested mountain area affected by acid deposition. Plant and Soil, 268, 35–49.

Figura, T., Tylová, E., Šoch, J., Selosse, M.-A., & Ponert, J. (2019). *In vitro* axenic germination and cultivation of mixotrophic Pyroloideae (Ericaceae) and their post-germination ontogenetic development. Annals of Botany, 123(4), 625–639.

Flieger, J., & Flieger, M. (2020). The [DPPH●/DPPH-H]-HPLC-DAD method on tracking the antioxidant activity of pure antioxidants and goutweed (*Aegopodium podagraria* L.) hydroalcoholic extracts. Molecules, 25(24), 6005.

Gaudichet, C., Greulich, S., Grellier, S., Janssen, P., & Rodrigues, S. (2024). Influence of local environmental gradients on ecological strategies of herbaceous communities in riverine side channels. Journal of Vegetation Science, 35(1), e13227.

Graves, J. D. (1990). A model of the seasonal pattern of carbon acquisition in two woodland herbs, *Mercurialis perennis* L. and *Geum urbanum* L. Oecologia, 83, 479–484.

Gudžinskas, Z., Krampis, I., & Laiviņš, M. (2010). Spread of *Carex pilosa* in Latvia and Lithuania. Latvijas Veģetācija, 21, 127–132.

Hanz, D. M., Cutts, V., Barajas-Barbosa, M. P., Algar, A., Beierkuhnlein, C., Collart, F., Fernández-Palacios, J. M., Field, R., Karger, D. N., Kienle, D. R., Kreft, H., Patiño, J., Schrodt, F., Steinbauer, M. J., Weigelt, P., & Irl, S. D. H. (2023). Effects of climate change on the distribution of plant species and plant functional strategies on the Canary Islands. Diversity and Distributions, 29(5), 1157–1171.

Hanze, L., & Changhong, W. (2022). The genus *Asarum*: A review on phytochemistry, ethnopharmacology, toxicology and pharmacokinetics. Journal of Ethnopharmacology, 282, 114642.

Haq, S. M., Waheed, M., Darwish, M., Siddiqui, M. H., Goursi, U. H., Kumar, M., Song, L., & Bussmann, R. W. (2024). Biodiversity and carbon stocks of the understory vegetation as indicators for forest health in the Zabarwan Mountain Range, Indian Western Himalaya. Ecological Indicators, 159, 111685.

Harris, M. P. K., Allen, K. A., Mcallister, H., Eyre, G., Le Duc, M., & Marrs, R. (2011). Factors affecting moorland plant communities and component species in relation to prescribed burning. Journal of Applied Ecology, 48(6), 1411–1421.

Higman, S., Mayers, J., Bass, S., Judd, N., & Nussbaum, R. (2005). The sustainable forestry handbook. Sterling VA, London.

Huang, E., Chen, Y., Fang, M., Zheng, Y., & Yu, S. (2021). Environmental drivers of plant distributions at global and regional scales. Global Ecology and Biogeography, 30(3), 697–709.

Ibadullayeva, S. J., Shiraliyeva, G. S., & Movsumova, N. V. (2023). Prospects of use of useful species of the family Rosaceae Juss. found in forest and shrub vegetation of Azerbaijan. Acta Botanica Caucasica, 2(1), 9–17.

Ishii, H. R., Tanabe, S., & Hiura, T. (2004). Exploring the relationships among canopy structure, stand productivity, and biodiversity of temperate forest ecosystems. Forest Science, 50(3), 342–355.

Kermavnar, J., Kutnar, L., & Marinšek, A. (2021). Disentangling the ecological determinants of species and functional trait diversity in herb-layer plant communities in European temperate forests. Forests, 12(5), 552.
Kovalenko, I. M. (2015). Fitotsenotychni zviazky lisovykh trav [Phytocoenotic relationships of forest herbs]. Pytannia Stepovoho Lisoznavstva ta Lisovoyi Rekultyvatsiyi Zemel', 44, 3–9 (in Ukrainian).
Kovalenko, I. M. (2016). Ekolohichni arealy lisovykh trav u fitotsenozakh klasu *Querceto-Fagetea* Br.-Bl. et Vlieg [Ecological ranges of forest grasses in phytocoenoses of the class *Querceto-Fagetea* Br.-Bl. et Vlieg]. Biological Resources and Nature Management, 8(1–2), 27–35 (in Ukrainian).
Krasnov, V. P., Orlov, O. O., & Vedmid, M. M. (2009). Atlas roslyn-indykatoriv i typiv lisoroslynnykh umov Ukrainskoho Polissia [Atlas of indicator plants and types of forest vegetation conditions of Ukrainian Polissya]. Novohrad, Novhorod-Volynskyi (in Ukrainian).
Kumarasamy, Y., Cox, P. J., Jaspars, M., Nahar, L., & Sarker, S. D. (2002). Biological activity of *Glechoma hederacea*. Fitoterapia, 73(7–8), 721–723.
Kuzmishyna, I. (2017). Heohrafiia roslyn [Geography of plants]. Vezha Druk, Lutsk (in Ukrainian).
Lee, C.-B., & Chun, J.-H. (2016). Environmental drivers of patterns of plant diversity along a wide environmental gradient in Korean temperate forests. Forests, 7(1), 19.
Leht, M., Kuusk, V., Tabaka, L., & Jankeviciene, R. (2003). Flora of the Baltic countries: Compendium of vascular plants. Taxon, 52(2), 396.
Lenoir, J., Hattab, T., & Pierre, G. (2017). Climatic microrefugia under anthropogenic climate change: Implications for species redistribution. Ecography, 40(2), 253–266.
Lieffers, V. J., Macdonald, S. E., & Hogg, E. H. (2011). Ecology of and control strategies for *Calamagrostis canadensis* in boreal forest sites. Canadian Journal of Forest Research, 23(10), 2070–2077.
Lopez-Goldar, X., & Agrawal, A. A. (2021). Ecological interactions, environmental gradients, and gene flow in local adaptation. Trends in Plant Science, 26(8), 796–809.
Lukash, O. V. (2008). Ekolohotsenotychna pryurochenist' vydiv rodyny Cyperaceae Juss. na Skhidnomu Polissi [Ecological and community affiliation of species of the family Cyperaceae Juss. in Eastern Polissya]. Ukrainian Botanical Journal, 65(8), 198–209.
Lukash, O., Melnyk, V., Danko, H., Rak, O., Karpenko, Y., & Buzunko, P. (2020). Phytocenotic features of *Calluna vularis* (L.) Hill. in Ukrainian Polesie. Ecological Questions, 31(3), 73–107.
Malysheva, V. F., Malysheva, E. F., Voronina, E. Y., Fedosova, A. G., Bibikov, N. M., Kiseleva, D. S., Tiunov, A. V., & Kovalenko, A. E. (2017). Mycorrhiza of pyroloids (*Pyrola rotundifolia*, *P. media* and *Orthilia secunda*): Species composition of symbionts and trophic status of plants. Mikologiya i Fitopatologiya, 51(6), 350–364.
Marsh, A. S., Arnone, J. A., Bormann, B. T., & Gordon, J. C. (2000). The role of *Equisetum* in nutrient cycling in an Alaskan shrub wetland. Journal of Ecology, 88(6), 999–1011.
Martín-Bravo, S., Jiménez-Mejías, P., Villaverde, T., Escudero, M., Hahn, M., Spalink, D., Roalson, E. H., Hipp, A. L., the Global Carex Group, Benítez-Benítez, C., Bruederle, L. P., Fitzek, E., Ford, B. A., Ford, K. A., Garner, M., Gebauer, S., Hoffmann, M. H., Jin, X.-F., Larridon, I., Léveillé-Bourret, É. E., Lu, Y.-F., Luceño, M., Maguilla, E., Márquez-Corro, J. I., Míguez, M., Naczi, R., Reznicek, A. A., & Starr, J. R. (2019). A tale of worldwide success: Behind the scenes of *Carex* (Cyperaceae) biogeography and diversification. Journal of Systematics and Evolution, 57(6), 695–718.
Mikulic-Petkovsek, M., Schmitzer, V., Slatnar, A., Stampar, F., Veberic, R. (2015). A comparison of fruit quality parameters of wild bilberry (*Vaccinium myrtillus* L.) growing at different locations. Journal of the Science of Food and Agriculture, 95(4), 776–785.
Miljković, D., Selaković, S., Vujić, V., Stanisavljević, N., Radović, S., & Cvetković, D. (2018). Patterns of herbivore damage, developmental stability, morphological and biochemical traits in female and male *Mercurialis perennis* in contrasting light habitats. Alpine Botany, 128, 193–206.
Neumann, C., Schindhelm, A., Müller, J., Weiss, G., Liu, A., &Itzerott, S. (2021). The regenerative potential of managed *Calluna* heathlands – revealing optical and structural traits for predicting recovery dynamics. Remote Sensing, 13(4), 625.
Onyshchenko, V. A. (2006). Florystychna klasyfikatsiya roslynnosti Ukrains'koho Polissia [Floristic classification of vegetation of Ukrainian Polissya]. In: Andriienko, T. L. (Ed.). Fitoriznomanittia Ukrayins'kogo Polissia ta yoho okhorona. Phitosotsiotsentre, Kyiv. Pp. 43–84 (in Ukrainian).
Onyshchenko, V. A. (2009). Lisy poriadku *Fagetalia sylvaticae* v Ukrayini [Forests of the order Fagetalia sylvaticae in Ukraine]. Alterpres, Kyiv (in Ukrainian).
Panchenko, S. M. (2013). Lisova roslynnist' Natsional'noho pryrodnoho parku "Desniansko-Starohutskyi" [Forest vegetation of the National Nature Park "Desniansko-Starohutskyi"]. University Book, Sumy (in Ukrainian).
Patova, O. A., Smirnov, V. V., Golovchenko, V. V., Vityazev, F. V., Shashkov, A. S., & Popov, S. V. (2019). Structural, rheological and antioxidant properties of pectins from *Equisetum arvense* L. and *Equisetum sylvaticum* L. Carbohydrate Polymers, 209(1), 239–249.
Pruchniewicz, D., Żołnierz, L., Donath, T. W., Otte, A., & Eckstein, R. L. (2016). The influence of expansive species on seed rain and soil seed bank of mountain mesic meadows. Tuexenia, 36, 81–96.
Puchałka, R., Paź-Dyderska, S., Dylewski, Ł., Czortek, P., Vítková, M., Sádlo, J., Klisz, M., Koniakin, S., Čarni, A., Rašomavičius, V., De Sanctis, M., & Dyderski, M. K. (2023). Forest herb species with similar European geographic ranges may respond differently to climate change. Science of the Total Environment, 905, 167303.
Rios, E. B., Sadler, J., Graham, L., & Matthews, T. J. (2024). Species distribution models and island biogeography: Challenges and prospects. Global Ecology and Conservation, 51, e02943.
Romanov, D., & Shirnin, S. (2020). Geographical distribution and ecotope features of goutweed (*Aegopodium podagraria*). Research on Crops, 21(2), 248–252.
Saeedi, M., Vahedi-Mazdabadi, Y., Rastegari, A., Soleimani, M., Eftekhari, M., Akbarzadeh, T., & Khanavi, M. (2020). Evaluation of *Asarum europaeum* L. rhizome for the biological activities related to Alzheimer's. Research Journal of Pharmacognosy Disease, 7(3), 25–33.
Șandru, M. D., Golea, C.-M., &Blaga, D. D. (2023). Vascular flora from ecoton zones of the Slatioara Secular Forest. Open Journal of Forestry, 13(1), 75–91.
Sarıaltın, S. Y., Polat, D. Ç., & Yalçın, C. Ö. (2023). Cytotoxic and antioxidant activities and phytochemical analysis of *Smilax excelsa* L. and *Aegopodium podagraria* L. Food Bioscience, 52, 102–359.
Sass, E. M., D'Amato, A. W., & Foster, D. R. (2018). Lasting legacies of historical clearcutting, wind, and salvage logging on old-growth *Tsuga canadensis-Pinus strobus* forests. Forest Ecology and Management, 419–420, 31–41.
Schellenberg, J., & Bergmeier, E. (2022). The *Calluna* life cycle concept revisited: Implications for heathland management. Biodiversity and Conservation, 31, 119–141.
Šeremet, D., Jokić, S., Aladić, K., Butorac, A., Lovrić, M., Tušek, A. J., Obranović, M., Mandura, J. A., Vojvodić Cebin, A., Carović-Stanko, K., & Komes, D. (2022). Comprehensive study of traditional plant ground ivy (*Glechoma hederacea* L.) grown in Croatia in terms of nutritional and bioactive composition. Foods, 11(5), 658.
Shamilov, A. A., Bubenchikova, V. N., Chernikov, M. V., Pozdnyakov, D. I., & Garsiya, E. R. (2020). *Vaccinium vitis-idaea* L.: Chemical contents, pharmacological activities. Pharmaceutical Sciences, 26(4), 344–362.
Sharma, A., & Lee, H.-J. (2022). Anti-inflammatory activity of bilberry (*Vaccinium myrtillus* L.). Current Issues in Molecular Biology, 44(10), 4570–4583.
Smolnikova, Y. V., Rygalova, E. A., Belyakov, A. A., & Tarnopol'skaya, V. V. (2019). Enzymatic treatment of *Rubus saxatilis* L. wild growing berries: Technological parameters optimization. IOP Conference Series: Earth and Environmental Science, 315, 072017.
Somodi, I., Virágh, K., & Podani, J. (2008). The effect of the expansion of the clonal grass *Calamagrostis epigejos* on the species turnover of a semi-arid grassland. Applied Vegetation Science, 11, 187–192.
Ștefănescu, B.-E., Călinoiu, L. F., Floricuța, R., Florinela, F., Mocan, A., Vodnar, D. C., & Crișan, G. (2020). Chemical composition and biological activities of the Nord-West Romanian wild bilberry (*Vaccinium myrtillus* L.) and lingonberry (*Vaccinium vitis-idaea* L.) leaves. Antioxidants, 9(6), 495.
Stuefer, J. F., & Hutchings, M. J. (1994). Environmental heterogeneity and clonal growth: A study of the capacity for reciprocal translocation in *Glechoma hederacea* L. Oecologia, 100, 302–308.
Süß, K., Storm, C., Zehm, A., & Schwabe, A. (2004). Succession in inland sand ecosystems: Which factors determine the occurrence of the tall grass species *Calamagrostis epigejos* (L.) Roth and *Stipa capillata* L. Plant Biology, 6, 465–476.
Svyrydenko, V. Y., Babich, O. H., & Kyrychok, L. S. (2006). Lisivnytstvo [Forestry]. Aristei, Kyiv (in Ukrainian).
The Food and Agriculture Organization of the United Nation (2020). Global forest resources assessment 2020: Main report. The Food and Agriculture Organization of the United Nation, Rome.
Thuiller, W. (2024). Ecological niche modelling. Current Biology, 34(6), R225–R229.
Tsymbalista, I. I., & Herts, N. V. (2020). Suchasnyi stan doslidzhen' fitoinvaziyi v Ukrayini ta sviti [The current state of research on phytoinvasions in Ukraine and the world]. In: Stepaniuk, A. V., Kot, T. Y., & Mishchuk, N. Y. (Eds.). Shliakh u nauku: Pershi kroky. Materialy Vseukrayinskoyi naukovo-praktychnoyi konferentsiyi (27.05.2020, Ternopil). Pp. 48–51 (in Ukrainian).
Vacek, Z., Vacek, S., & Moser, W. K. (2020). Effects of herb layer dominants on tree regeneration in Central European forests. Forests, 11(7), 745.

Vasiliev, D. (2022). The role of biodiversity in ecosystem resilience. IOP Conference Series Earth and Environmental Science, 1072(1), 012012.
Vilkickyte, G., & Raudone, L. (2021). *Vaccinium vitis-idaea* L. fruits: Chromatographic analysis of seasonal and geographical variation in bioactive compounds. Foods, 10(10), 2243.
Vilkickyte, G., Raudone, L., & Petrikaite, V. (2020). Phenolic fractions from *Vaccinium vitis-idaea* L. and their antioxidant and anticancer activities assessment. Antioxidants, 9(12), 1261.
Vujić, V., Rubinjoni, L., Selaković, S., & Cvetković, D. (2016). Small-scale variations in leaf shape under anthropogenic disturbance in dioecious forest forb *Mercurialis perennis*: A geometric morphometric examination. Archives of Biological Sciences, 68, 705–713.
Wang, Z., Tian, Y., Sugimoto, S., Yamano, Y., Kawakami, S., Otsuka, H., & Matsunami, K. (2022). Four new glucosides from the aerial parts of *Equisetum sylvaticum*. Journal of Natural Medicines, 76, 832–841.
Yaroshenko, N., & Skliar, V. (2022). Onthogenetic and vitality structure of *Asarum europaeum* in terms of forest management in Goettingen forest, Low Saxony, Germany. International Multidisciplinary Scientific GeoConference, 22(3.2), 397.
Zhuk, A. V., Kostyshyn, S. S., & Fedoriak, M. M. (2021). Vidnovlennia bioheotsenoziv zrubiv *Fagus sylvatica* L. v umovakh Pivnichnoyi Bukovyny [Restoration of biogeocenoses of *Fagus sylvatica* L. logs in Northern Bukovina]. Chernivets'kyi Natsional'nyi Universytet imeni Yuriya Fedkovycha, Chernivtsi (in Ukrainian).
Zoratti, L., Klemettilä, H., & Jaakola, L. (2016). Chapter 4 – Bilberry (*Vaccinium myrtillus* L.) ecotypes. In: Simmonds, M. S. J., & Preedy, V. R. (Eds.). Nutritional composition of fruit cultivars. Elsevier. Pp. 83–99.