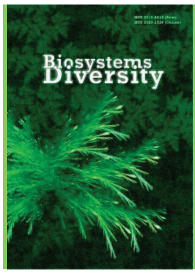

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Adaptation strategies of *Heracleum sosnowskyi* in Ukrainian Polissia

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Heracleum sosnowskyi is an invasive transformer species dangerous for biodiversity and human health. The materials for this study were the standard geobotanical descriptions made on the territory of Ukrainian Polissia in the period from 2004 to 2022. The relevés were classified using the Braun-Blanquet methods and used for synphytoindication evaluation of the environmental factors, rating ecofactors, estimated based on the ecological scales of the species that form a phytocoenosis. *Heracleum sosnowskyi* was observed to occur in plant communities belonging to 13 classes, 16 orders, 21 alliances, and 29 associations. According to the synphytoindication, it most often grew in mesophyte, hemihydrocontrasthophobic (moderately moistened habitats that are sporadically moistened), subacidophilic, semieutrophic, acarbonataphilic, nitrophilic, hemiaerophobic (moderately aerated habitats), submicrothermal (habitats that receives 20–30 kc/sm^2), subombrophytic, hemioceanic, subcryophytic (habitats with the average temperature of the coldest month of the year is approximately –8), semi-illuminated, euhemerobic (habitats that have been altered or created by humans and are under anthropogenic influence) habitats. The competitive advantages of Sosnowsky's hogweed over the native species are the combination of the ability to change r and K strategies, depending on the environmental conditions, with the production of a large number of seeds that are dispersed from a tall peduncle, maintaining a significant germination rate for several years, and allelopathy and efficient assimilation of nitrogen compounds, which helps it to increase the size of the shoot. Ruderal and natural grass ecosystems are the most vulnerable to the penetration of *H. sosnowskyi* in the early stages of autogenic succession (value of natural dynamic was 3.0–4.0 points). The highest projective cover and the density of its population were observed in the nitrified forest edges of associations *Elytrigio repentis-Aegopodietum podagrariae* var. *Heracleum sosnowskyi* (value of natural dynamic was 4.0–7.0 points). Forest ecosystems with multi-tiered vegetation (value of natural dynamic was above 9.5 points) and meadows with thorough sod (value of natural dynamic was above 4.8 points) were less vulnerable to invasions. At the same time, disruptions of the completeness of the tree stand or the integrity of sod created additional opportunities for the species to invade the territory. Once penetrating into natural or ruderal ecosystems, *H. sosnowskyi* most often transforms their autotrophic blocks into a variant of association *Agropyretum repentis* var. *Heracleum sosnowskyi* of class *Artemisietea vulgaris*, which is a more favorable phytocenosis for its intensive reproduction and spread. The results of the study can be used to prevent the spread of *H. sosnowskyi*.

Keywords: invasions; transformer species; synatropization; ecosystems; synphytoindication; plant communities.

Introduction

In the pursuit of high, easy, but short-term benefits, people lay ticking bombs beneath their feet. This is related not only to formation of policy or construction of economic systems. Our relations with the environment have been illustrated by a great number of negative examples. Events that had occurred in the second half of the 20th century and in early 21st century are conspicuous examples of how people lack strategic foresight when they develop and realize their plans of using natural resources. Such shortsightedness has entailed numerous evident implications. One of them is ruination of the natural ecosystems and decrease in biodiversity (Harbar et al., 2021). People often live an illusion of their independence from the number and quality of natural ecosystems. However, despite all those technological achievements of the mankind, we still depend on them directly or indirectly. Therefore, by extensively exploiting agroecosystems, planted forests, and individual types of aquatic ecosystems, we forget about several important conditions for their sustainable existence, first of all, fullness of ecological niches of those ecosystems and their completeness, and secondly, influence of other natural environments on the ecosystems we exploit. For example, monoculture woodlands without saturated econiches are more vulnerable to dangerous climatic and biotic factors; agroecosystems need microclimatic protection from neighboring woodlands, and aquatic ecosystems are dependent on an entire complex of natural ecosystems of their drainage basins. Preservation of biodiversity of exploited and natural ecosystems is a guarantee of sustainable development of mankind.

Negative anthropogenic impacts on biodiversity vary. On the one hand, the outcomes can be direct destruction or exclusion of species from ecosystems, and on the other hand, they could be a transformation of the living environment, altering the optimum environmental parameters for species that live in it. In this case, those are both abiotic and biotic factors. Therefore, the number of redundant ecosystem connections –even despite being high – can decline to such a critical level that the likelihood of existence of a certain species decreases. It is especially dangerous when biotic and abiotic changes occur at the same time. The reason of such changes is often the spread of invasive transformer species. Those species are more competitive than the indigenous species, not only because their generative potential, but also because of their vegetation rates. They alter the entire environment of the ecosystem, causing changes in the chemical composition of soil, light conditions, microclimate, species composition of the main groups of organisms, etc. (Harvey et al., 2020). For example, they affect birds (Grzędzicka & Reif, 2022) and other animals (Čerevková, 2020). In other words, the content of econiches noticeably reformats. Shifts of species' ranges occur all the time. This has been always taking place naturally as a result of events occurring on the surface of our planet. It has to be noted that such actions have been often accompanied by massive extinction, one of the underlying conditions being loss of necessary econiches. Since we do not want to become another kind of fossilized remains, we must first of all support sustainability of ecosystems that surround us. At the same time, we spontaneously or intentionally shift a high number of species beyond their ranges. We cultivate some species, expecting a fast and easy profit. However, some species go out of our control, and begin to reproduce and spread on their own. In the case when they occupy a free ecological niche and do not transform the ecosystem dramatically, they only enrich the species and cenotic diversity. Despite the fact that many species have naturalized in this particular way, this occurs rarely, since ecological niches in natural ecosystems of most regions are full (Sax & Brown, 2002). Therefore, most species capable of active invasions are aggressive transformers (Oitsius et al., 2020). It is a global problem, and Polissia is one of specific regions under threat. After the last ice age, this region has been re-inhabited by the higher vascular plants. It is similar to the nemoral zone by the climatic conditions, and to the boreal zone by the edaphic conditions, which makes it a universal study ground for behavior of invasive species (Khomiak, 2018). On the other hand, despite being largely forested, there are areas with significantly disturbed vegetative cover, with not all the niches filled. This makes such territories extremely vulnerable to invasions (Khomiak et al., 2019).

Of the great number of invasive species, especially dangerous are those that – beside an indirect threat to sustainable development of the area – are also dangerous to the human health. Such a species as common ragweed (*Ambrosia antemisiifolia* L.) is able to cause acute respiratory allergy, and some Heracleum plants (first of all, *Heracleum mantegazzianum* Sommier & Levier and *Heracleum sosnowskyi* Manden) cause acute phytodermatitis (Jermendy & Visolyi, 2022). Since those species are synantrophic and mostly occur in areas around people, they pose a double threat – to the environment and the human health. Despite the awareness of this problem among researchers way back since Carl Linnaeus in the 18th century, as well as public concerns over the recent decade, we have so far come nowhere near a solution (Egerton, 2007). The problem turned out to be not the scales of financial support of our searches for the solution, since attempts to handle invasive species failed in both poor small countries and the global leaders (Cuddington et al., 2022). The reason was most likely direct single-vector means rather that a systemic approach to the issue (Grzędzicka, 2021). Traditional methods, such as use of herbicides, as well as more elaborate methods, all fail (Hpoo et al., 2020).

Another reason of our failures in the combat against dangerous transformer species has been their fast spread. This complicates the process of monitoring and planning of adequate control means. Route-expeditionary and stationary methods of studying populations of invasive species are good for identifying their places in the ecosystems, but do not satisfy the needs of continuous monitoring (Martin et al., 2020). Today, there are more and more suggestions of using a remote monitoring using hyperspectral imaging in different seasons (Bzdęga et al., 2021). This method has its advantages as a monitoring system, but faces a whole number of obstacles (Turénko et al., 2020). In numerous cases, invasive species provide an advantage to ecotone ecosystems that have small horizontal sections. Identification of such living environments at a sufficient level is not always possible (Harbar et al., 2023). This limits the possibility of using satellite images (Visockienė et al., 2020).

One of the most problematic invasive species is *H. sosnowskyi*. On the one hand, it is a synanthropic invasive transformer species, and on the other hand, being able to spread around places of constant human presence, it poses a direct threat to the life and health of people (Jermendy & Visolyi, 2022). This situation is becoming even more complicated because of presence of a large amount of natural and human-created hybrids and complexity of their identification (Gubar & Koniakin, 2021). The abilities of *H. sosnowskyi* to invade natural ecosystems and oppose attempts to destroy it are far more complex than just its individual resilience against changes in the environmental factors or a broad ecological range (Rysiak et al., 2021). We are dealing with a complex set of adaptive mechanisms that come together in the form of a quite successful strategy of spreading across new areas, transforming them, and holding them. The problem of invasive species is not confined to one region of Europe. Their invasions inflict harm on the ecosystems and people all across the continents, while efforts of researchers and practitioners, and also the large costs countries and private funds have spent, have demonstrated no notable success so far (Shackleton et al., 2020). Our experience of studying the adaptive advantages of *H. sosnowskyi* can be used not only to combat it in Eurasia, but to combat other invasive species all around the world.

The objective of the study was a systemic analysis of the adaptive strategies of *H. sosnowskyi* in the territory of Ukrainian Polissia, and to achieve it we set the following goals:

1) to analyze the ecological-cenotic characteristics of *H. sosnowskyi*;

2) model the main adaptive mechanisms of *H. sosnowskyi* in various ecosystems;

3) develop algorithms to predict the spread of *H. sosnowskyi* in the ecosystems of Ukrainian Polissia.

Materials and methods

The materials for the study were standard geobotanical relevés, conducted in the Ukrainian Polissia in the period from 2004 to 2023. To develop the relevés, we used the route-expeditionary field study methods for the entire period of the monitoring and stationary methods between 2007 and 2019. The relevés were written according to the rules of ecological-floristic approaches of the Swiss-French school of Braun-Blanquet (1964). The relevés were done in homogenous areas where the vegetative cover had formed with participation of *H. sosnowskyi*. We concluded on the homogeneity based on according to the visual similarity of the edaphic conditions, physionomics of cenosis, microrelief, and the dominant in visible strata. The sizes of areas correlated with the height of the dominants of the highest stratum. For meadow vegetation, the size was 2 x 2 m, for the shrubs and young forests it was 10 x 10 m, and for mature forests it was 25 x 25 m. If the vegetation was arranged in a band-like formation, the relevé was conducted following its natural boundaries, and in the lengths of 2 m (herbaceous vegetation), 5 m (shrub), and 10 m (forest), respectively (Yakubenko et al., 2020). In addition, the relevés were expanded using the data from the maps of the area and soils, using a GPS navigator and a GPS Test mobile app (manufactured by Chartcross Limited, UK, 2015). The relevé of microrelief included the slope exposure, determined using the Clinometr mobile app (manufactured by Plain Code Limited, UK, 2017). The projective cover of species was identified according to the classic seven-point scale of Braun-Blanquet. The relevé was added to the data base using the Turboveg 2.0 software (Hennekens, 2009).

The stationary study was performed for 12 years in the territory divided into eight orographically and edaphically similar areas. It was on the left bank of the Kamianka River, south of Zhytomyr. At the beginning of the study in 2007, the territory was evenly covered with *H. sosnowskyi* in over 75.0%. Using special measures, all the territory was divided into three zones: meadow, shrub, and forest-shrub. In the meadow zone, we preliminary removed all phanerophytes, in the shrub zone we removed all trees, and the forest-shrub zone remained unaltered. The meadow and forest-shrub zones were divided into three plots where *H. sosnowskyi* plants were subjected to pressure of various degrees. On the first plot, three-time mowing of the herbaceous layer was performed with removal of the mown phytomass outside the plot. On the second plot, only individuals of *H. sosnowskyi* were removed. The removal was performed by cutting the plant with a spade shovel in the region where the root turns into the stem. The third plot was the control. Since the meadow-shrub zone included a large number of undergrowth of phanerophytes, and also representatives of the *Rubus* genus, mowing was the correct practice to employ. Therefore, this zone was divided only into two areas – the control and the one where only *H. sosnowskyi* was removed.

The parameters of environmental factors were determined using the synphytoindication principals, ascribing points to ecofactors, estimated based on the ecological scales of the species that form a phytocoenosis. The values of factors were identified according to points of the unified scales of Didukh-Pliuta (Diduh, 2012). The estimates were carried out using the Simagrl 1.12 software based on the Ecodbase 5d data base (Khomiak et al., 2020). For this purpose, the classical scheme of Braun-Blanquet was transformed into five-point scale. Therefore, the projective cover above 75.0% (5 points by seven-point scale) was rated 5 points; 50.0% to 75.0%

(4 points by seven-point scale) – 4 points; 25.0% to 50.0% (3 points by seven-point scale) – 3 points; 5.0% to 25.0%(2 points by seven-point scale) – 2 points, and below 5.0% (1 point, "+" and "r" by seven-point scale) – 1 point. The integrated parameter of anthropogenic transformation is provided according to the 18-point scale of Didukh-Khomiak (Khomiak et al., 2020). The parameter of natural dynamics was described by a 21-point scale, developed in the Theory of Ecosystems laboratory of the Ivan Franko Zhytomyr State University (Khomiak et al., 2019).

The vegetative groups were classified using the JUICE 7.0 software (Hennekens, 2009) and identified according to Prodrome of the Vegetation of Ukraine (Dubina et al., 2019). Names of species of vascular plants are provided taking into account the recommendations of "Vascular plants of Ukraine. A nomenclatural checklist" (Mosyakin & Fedoronchuk, 1999).

Results

During the field studies and further analysis of the collected materials, we determined that the vegetation of the living environments with participation of *H. sosnowskyi* included 13 classes, 16 orders, 21 alliances, and 29 associations. Syntaxonomic scheme of the vegetation was as follows:

Molinio-Arrhenatheretea R. Tx 1937: *Galietalia veri* Mirk. et Naum. 1986: *Agrostion vinealis* Sipaylova, Mirk., Shelyag et V.Sl. 1985: *Carici praecoci-Alopecuretum pratensis* Mirkin in Denisova et al. 1986, *Achillea submiefolium-Dactyletum glomeratae* Smetana, Derpoluk, Krasova 1997; *Arrhenatheretalia elatioris* Tüxen 1931: *Arrhenatherion elatioris* Luquet 1926: *Poëtum pratensis* Ravarut, Cazac et Turenschi 1956, *Trifolio-Festucetum rubrae* Oberdorfer 1957, *Deschampsion caespitosae* Horvatic 1930: *Deschampsietum caespitosae* Horvatic 1930, *Poo palustris–Alopecuretum pratensis* Shel.-Sos. et al. 1987.

Epilobietea angustifolii Tx. et Preising ex von Rochow 1951: *Galeopsio-Senecionetalia sylvatici* Passarge 1981: *Epilobion angustifolii* Oberd. 1957: *Calamagrostietum epigii* Juraszek 1928; *Senecioni sylvatici-Epilobietum angustifolii* Tx. 1937, *Rubetum idaei* Gams 1927.

Rhamno-Prunetea Rivas Goday et Borja Carbonell ex Tüxen 1962: *Prunetalia spinosae* R. Tx 1952: *Pruno spinosae-Rubion radulae* Weber 1974: *Rubo fruticosi-Prunetum spinosae* Web 1974 n.inv. Witting 1974; *Berberidion vulgaris* Br.-Bl. ex Tx. 1952: *Sambuco-Prunetum spinosae* Doing 1962.

Lonicero-Rubetea plicati Haveman, Schaminée et Stortelder in Stortelder et al. 1993: *Rubetalia plicati* Weber in Pott 1995: *Lonicero-Rubion silvatici* Tx. et Neumann ex Wittig 1977: *Frangulo-Rubetum plicati* Neum. in R. Tx. 1952.

Robinietea Jurco ex Hadac et Sofron 1980: *Cheledonio-Robinietalia* Jurco ex Hadâc et Sofron 1980: *Chelidonio-Acerion negundo* L. Ishbirdin et A. Ishbirdin 1991: *Cheledonio-Aceratum negundi* L. Ishbirdin et A. Ishbirdin 1991; *Cheledonio-Robinion* Hadâc et Sofron in Chytrý 2013: *Sambuco nigrae-Robinietum* Scepka 1982, *Cheledonio-Robinietum* Jurco 1963; *Sambucetalia racemosae* Oberd. ex Doing 1962: *Sambuco-Salicion capreae* Tx. et Neum et Oberd.1957: *Salicetum capreae* Schreier 1955.

Alnetea glutinosae Br.-Bl. et Tüxen ex Westhoff, Dijk et al. 1946: *Alnetalia glutinosae* R. Tx 1937: *Alnion glutinosae* Malcuit 1929: *Ribeso nigri-Alnetum* Sol.-Gorn (1975) 1987.

Franguletea Doing ex Westhoff in Westhoff et Den Held 1969: *Salicetalia auritae* Doing 1962: *Salicion cinereae* Th. Müll et Görs ex Pass 1961: *Salicetum pentandro-cinereae* Pass 1961.

Salicetea purpeurea Moor 1958: *Salicetalia purpureae* Moor 1958: *Salicion albae* R.Tx 1955: *Salicetum albae-fragilis* R.Tx 1955, *Salicetum triandro-viminalis* Lohm. 1952, *Salicetum triandrae* Malcuit 1929.

Trifolio-geranietea Th. Müll 1962: *Origanetalia* Th. Müll 1962: *Trifolion medii* Th. Müll 1962: *Agrimonio eupatoriae-Trifolietum medii* (T. Müller 1962) Dengler et al. 2003.

Artemisietea vulgaris Lohmeyer et al. ex von Rochow 1951: *Agropyretalia intermedio-repentsis* Th. Müll et Görs 1969: *Convolvulo-Agropyrion repentis* Görs 1966: *Agropyretum repentis* Felföldy 1942; *Onopordetalia acanthii* Br.-Bl. et Tx. ex Klika et Hadač 1944: *Arction lappae* R. Tx 1937: *Arctietum lappae* Felföldy 1942, *Arctio-Artemisietum vulgaris* Oberd. ex Seybold. et Th. Mull. 1972, *Echio-Verbascetum* Sissingh 1950.

Polygono arenastri-Poëtea annuae Rivas-Martínez 1975: *Polygono arenastri-Poëtalia annuae* Tx. in Géhu et al. 1972 corr. Rivas Martínez et al. 1991: *Polygono-Coronopion* Sissingh 1969: *Poo annuae-Coronopodetum squamati* Gutte 1966.

Galio-Urticetea Passrge et Kopecký 1969: *Galio aparines-Alliarietalia petiolatae* Oberdorfer ex Görs et. T. Müller 1969: *Aegopodion podagrariae* R. Tx 1967: *Elytrigio repentis-Aegopodietum podagrariae* Tüxen 1967, *Myosotido sparsiflorae-Alliarietum petiolatae* Gutte 1973, *Calystegio-Angelicetum archangelicae* Pass 1959.

Bidentetea tripartite R. Tx., Lohmaer et Preising 1950: *Bidentalia tripartiti* Br.-Bl. et R.Tx 1943: *Bidention tripartiti* Nordhagen 1940: *Polygono-Bidentetum* Lohmaer 1950.

Most of the described growing locations were ruderal with noticeable degree of synanthropization. Most often, those were classes *Artemisietea vulgaris* and *Galio-Urticetea*, which represented 35.6% and 23.3% of all the relevés, respectively (Table 1). All the mentioned classes of the plant groups can be divided into four groups according to the number of relevés containing *Heracleum sosnowskyi*. The first group included classes *Artemisietea vulgaris* and *Galio-Urticetea*, the second – *Molinio-Arrhenatheretea*, *Epilobietea angustifolii* and *Robinietea*, the third – *Alnetea glutinosae*, *Salicetea purpeurea*, and *Rhamno-Prunetea*, and the fourth – *Lonicero-Rubetea plicati*, *Franguletea*, *Trifolio-geranietea*, *Polygono arenastri-Poëtea annuae*, and *Bidentetea tripartite*. At the level of associations, *Heracleum sosnowskyi* was the commonest in *Urtico-Aegopodietum podagrariae* of class *Galio-Urticetea* (20.8%) and *Agropyretum repentis* of class *Artemisietea vulgaris* (16.4%).

Table 1
Phytocenotic diversity of classes of plant groups containing *H. sosnowskyi*

Class of plant groups	Number of associations	Percentage of the overall number of *relevés*
Artemisietea vulgaris	5	35.6
Galio-Urticetea	3	23.3
Molinio-Arrhenatheretea	3	10.9
Epilobietea angustifolii	2	6.9
Robinietea	3	5.5
Alnetea glutinosae	1	4.1
Salicetea purpeurea	3	4.1
Rhamno-Prunetea	2	2.7
Lonicero-Rubetea plicati	1	1.4
Franguletea	1	1.4
Trifolio-geranietea	1	1.4
Polygono arenastri-Poëtea annuae	1	1.4
Bidentetea tripartite	1	1.4

During the stationary studies, we determined that decline in the number of individuals down to complete vanishing of *H. sosnowskyi* occurred on the meadow plot where separate individuals had been removed (after 3 years) and on the control forest-shrub plot, where the natural multistratum vegetation of association *Ribeso nigri-Alnetum* was formed (11 years later). On the meadow plot, where regular mowing was conducted during the study period, 2–3 individuals appeared each year (the projective cover near 10.0%), and remained unaltered on the control plot. At the same time, the latter underwent active succession processes, with formation of a nitrophile group of association *Urtico-Aegopodietum podagrariae*. There, the projective cover of *H. sosnowskyi* increased from 75.0% to 90.0%. After the completion of the 12-year cycle of the studies, mowing of the meadow plots in the territory continued, but without removal of phytomass. As a result, available-to-plants nitrogen compounds started to accumulate in the soil. This was indicated by the synphytoindication data and increase in the areas of nitrophile species (*Aegopodium podagraria* L. and *Urtica dioica* L.). This led to increase in the number of *H. sosnowskyi* individuals to 4–6. This was observed to be especially active on the periphery of the area in the forest-edge zone. Currently, new individuals of *H. sosnowskyi* occur exclusively in forestsedges of our study plot. The areas where *H. sosnowskyi* has been seen for a long time period were mostly a variant of associations of vegetative groups *Elytrigio repentis-Aegopodietum podagrariae* var. *Heracleum sosnowskyi* (Table 2).

According to the data obtained by the method of synphytoindication of *H. sosnowskyi*, occurred in mesophyte, hemihydrocontrasthophobic (moderately moistened habitats that are sporadically moistened), subacidophilic, semieutrophic, acarbonataphilic, nitrophilic, hemiaerophobic (moderately aerated habitats), submicrothermal (habitats that receives 20–

30 kc/sm^2), subombrophytic, hemioceanic, subcryophytic (habitats with the average temperature of the coldest month of the year is approximately –8), semi-illuminated, euhemerobic (habitats that have been altered or created by humans and are under anthropogenic influence) habitats (Table 3).

Table 2
Phytocenotic table of variant of associations of Elytrigio repentis-Aegopodietum var. Heracleum sosnowskyi (class Galio-Urticetea)

Characteristics of *relevés*	Standard geobotanical *relevés*														
Number of *relevés*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Species	Projective coverage*														
D.s. var. *Elytrigio repentis-Aegopodietum podagrariae* var. *Heracleum sosnowskyi***															
Heracleum sosnowskyi Manden.	5	5	5	5	4	3	2	2	1	+	+	+	+	+	+
D.s. As. *Elytrigio repentis-Aegopodietum podagrariae****															
Aegopodium podagraria L.	4	3	2	–	2	4	+	–	5	4	+	+	+	–	–
D.s. Ord. *Aegopodion podagrariae*****															
Urtica dioica L.	3	2		5	2	3	+	+	–	2	5	3	2	4	2
D.s. Cl. *Galio–Urticetea******															
Chelidonium majus L.	+	+	–	–	2	+	+	–	–	+	+	–	–	+	+
Galium aparine L.	2	+	–	–	2	2	–	–	–	–	4	+	+	–	+
Lamium maculatum (L.) L.	+	3	–	–	4	+	–	+	–	–	–	2	2	–	2
Glechoma hederacea L.	+	–	–	–	–	+	–	3	–	4	–	2	2	–	3
Rubus caesius L.	–	–	–	–	–	–	4	+	–	1	5	–	–	5	–
Geum urbanum L.	–	–	–	–	–	–	+	–	–	2	+	–	–	–	–
Humulus lupulus L.	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–
Impatiens parviflora DC.	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
D.s. Cl. *Molinio-Arrhenatheretea******															
Poa pratensis L.	+	–	–	–	–	+	–	2	–	–	–	2	2	–	2
Agrostis capillaris L.	–	–	–	–	–	–	+	2	–	+	–	2	2	–	–
Ranunculus acris L.	–	–	–	–	–	–	–	4	–		–	3	–	–	3
Dactylis glomerata L.	–	–	–	–	–	–	+	–	–	–	+	–	–	–	–
Rumex acetosa L.	–	–	–	–	–	–	–	–	–	–	–	r	r	–	–
Achillea submillefolium Klok. et Krytzka	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
Other species															
Rubus idaeuc L.	+	2	+	–	2	+	–	–	–	2	–	–	–	+	r
Elymus repens (L.) Gould.	–	–	5	2	–	–	–	–	2	2	–	–	–	1	–
Stellaria nemorum L.	+	–	–	–	–	+	–	–	–	–	+	–	–	–	+
Equisetum arvense L.	–	–	–	–	–	–	2	–	–	–	–	+	+	–	–
Poa angustifolia L.	–	–	–	–	–	–	–	2	–	–	–	+	+	–	–
Taraxacum officinale Webb. ex Wigg.	–	–	+	2	–	–	–	–	–	–	+	–	–	–	–
Veronica chamaedrys L.	–	–	–	–	–	–	–	+	–	–	–	2	2	–	–
Cardamine dentata Schult.	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–
Erigeron canadensis L.	–	–	–	–	–	–	+	–	–	r	–	–	–	–	–
Geum rivale L.	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–
Luzula pallescens Sw.	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–
Plantago major L.	–	–	–	5	–	–	–	–	1	–	–	–	–	–	–
Potentilla anserina L.	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–
Rumex confertus Willd.	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–
Sambucus nigra L.	–	–	–	–	–	–	–	–	–	+	1	–	–	–	–
Stellaria media (L.) Vill.	–	–	–	–	–	–	–	3	–	–	–	–	–	–	+
Alnus glutinosa (L.) Gaertn.	–	–	–	–	–	–	–	–	–	4	–	–	–	–	–
Salix caprea L.	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–
Euonymus europaea L.	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–
Ranunculus acris L.	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–
Pyrus communis L.	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–
Ficaria verna Huds.	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–
Chenopodium album L.	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
Sonchus arvensis L.	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
Arctium lappa L.	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
Acer negundo L. (IV)	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Betula pendula Roth. (III)	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Cirsium arvense (L.) Scop.	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Euphorbia virgultosa Klok.	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Malus sylvestris Mill.	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Stenactis annua Nees.	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–
Deschampsia caespitosa (L.) Beauv.	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
Fragaria vesca L.	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–
Alnus glutinosa (L.) Gaertn. (III)	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
Prunus cerasifera Ehrh.	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
Prunus domestica L.	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
Lamium purpureum L.	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–
Myosotis sporsiflora J.C.Mikan. ex Pohl.	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–
Myosotis arvensis (L.) Hill.	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–
Prunus padus L.	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–
Athyrium filix-femina (L.) Roth.	–	–	–	–	–	–	–	–	–	–	–	–	–	+	

Note: * – parameters of the projective cover according to the seven-point Braun-Blanquet scale (5 points – projective cover over 75.0%, 4 pints – 50.0–75.0%, 3 points – 25.0–50.0%, 2 points 5.0–25.0%, 1 point – many individuals with the projective cover below 5.0% or one individual with over 50.0%, + – number of individuals with the projective cover below 5.0%, r – single individual with projective cover of less than 5.0%); ** – block of diagnostic species of variant of association *Elytrigio repentis-Aegopodietum podagrariae* var. *Heracleum sosnowskyi*; *** – block of diagnostic species of association *Elytrigio repentis-Aegopodietum podagrariae*; **** – block of diagnostic species of variant of alliance *Aegopodion podagrariae*; ***** – block of diagnostic species of variant of class *Galio-Urticetea*; ****** – block of diagnostic species of class *Molinio-Arrhenatheretea*; “–“ – species is absent in the relevé.

Table 3
Statistical parameters of the environmental factors, identified using the synphytoindication methods

Statistical parameter	Parameters of the environmental factors *													
	HD	FH	RC	SL	CA	NT	AE	TM	OM	KN	CR	LC	HE	ST
Mean	12.3	6.4	7.9	7.7	6.8	7.3	7.3	8.4	12.4	8.7	7.6	6.9	9.3	5.7
Maximum	14.6	9.1	8.5	9.3	8.4	8.5	9.2	9.2	13.7	9.6	8.4	7.8	10.8	9.5
Minimum	10.8	4.8	6.6	6.6	5.3	6.3	5.9	7.4	10.4	7.7	6.5	5.3	7.4	3.3
Amplitude	3.8	4.7	1.8	2.7	3.1	2.2	3.3	1.9	3.3	1.9	1.9	2.4	3.4	6.2
Share of the scale overlap (%)	16.7	34.9	32.7	9.7	20.9	27.9	14.7	19.2	8.0	19.4	12.4	21.0	13.4	16.3

Note: * HD – multi-year moisture regime, FH – moisture variance, RC – acidity, SL – saline regime, CA – content of carbonates, NT – content of available nitrogen, AE – edaphotope (pedosphere) aeration, TM – thermal regime, OM – ombroregime or aridity-humidity, KN – continentality, CR – cryoregime, LC – light conditions, HE – value of anthropogenic transformation, ST – value of natural dynamics.

The share of overlapping of the synphytoindicatory scale indicates a broad tolerance amplitude of the species according to the variety of moistening (34.9%) and acidity of soil (32.7%). At the same time, according to the omboregime parameters (8.0%) and the general saline regime (9.7%), its amplitude was the lowest. According to the parameter of anthropogenic transformation, *H. sosnowskyi* can be classified to the intermediate position between mesohemeroby and euhemeroby, gravitating towards the latter. According to the parameter of dynamics, its position corresponded to the transition from the stage of grassland to shrub-grass stage of autogenic succession.

Discussion

Successful invasion of the natural and synantropized ecosystems by *H. sosnowskyi*, its resilience against human activity, and expansion of the areas it occupies cannot be explained by some of its characteristic alone. The plant achieves success by a complex of adaptations and a complex mechanism of management and control of their interaction. Furthermore, the activities of *H. sosnowskyi* are promoted by some kinds of human activities and specifics of some types of growing environments (Grzędzicka, 2022).

As we see from the results of the studies, there were types of plant groups that often included this species, those where it was rare, and those where it was absent. We did not consider wetlands, where moisture parameters are beyond the ecological range of this species. We only considered dryland ecosystems. *Heracleum sosnowskyi* did not occur in mature complete forest with thorough tree coverage. Also, it did not occur in mesophyte and mesohygrophyte meadows with dense sod and multi-stratum herbaceous vegetation. Therefore, for an initial invasion, it required ecosystems whose autotrphic blocks provided no thorough shading from the tree and shrub strata, or had no dense herbaceous sod, impenetrable for fruits and seeds of the hogweed. In the first case, despite significant growth of vegetative organs of the hogweed (1.5–1.7 m), several strata of trees and tall shrubs were able to obstruct the access of the light energy it requires. On our research plot, the first stratum of trees comprised *Alnus glutinosa* (L.) Gaertn. and *Salix fragilis* L., about 9 m tall. The second stratum, 4–7 m tall, contained (in addition to *Alnus glutinosa*) – *Betula pendula* Roth., *Prunus padus* L. and *Prunus cerasifera* Ehrh. Dense shrub stratum (70.0%) included *Sambucus nigra* L. and *Swida sanquinea* (L.) Opiz, 2.0–2.5 m tall. The herbaceous coverage was thinned out, measuring 25.0%.

We assume that the hogweed was unable to invade the meadows with dense sod because its seeds would have had no chance of a full contact with the soil. As revealed by our stationary experiment, there germinated only seeds that infiltrated the environment where the formation of a dense multi-stratum grass stand had not been completed (Nathan & Safriel, 2020). Often mentioned attempts to dig out the hogweed gave no positive result, because the disturbed sod was a convenient place for its seed diaspora. In our experiment, we made the section only through the soil cover and sod in the area of the upper part of the root. Then, the plant was pulled out, while the sod was pressed back down to cover the area, preventing the penetration of new seeds. Despite the ability of the seeds to maintain the germination rate for a long time, they stopped germinating in the meadow region of our research plot after three years. We may assume that the sod that had formed over time not only obstructed the penetration and germination of the seeds, but also blocked sprouts that belonged to the seed bank of the examined phytocenosis. In some cases, absence of the ability of the plant cover of the agroecosystem to block the spread of hogweed makes it a potential weed (Makukh et al., 2015).

Invasion by *H. sosnowskyi* and development of its cenopopulation of can be blocked by one of the two mechanisms – shading from 2.5–3.0 m-tall multi-stratum vegetation or formation of a thorough sod with multi-tiered herbaceous vegetation on open grounds. While tree species are able to form forestlands without grass cover on their own, one layer we created was enough to block the invasion. After the experiment, on the stationary study plot, fruit trees were planted, including *Morus nigra* L. Under this tree, the herbaceous cover had notably thinned out (up to 10.0%), exposing the soil. However, there were no individuals of *H. sosnowskyi* under *M. nigra*. At the same time, some single individuals emerged around the perimeter of action of its influence zone, phytorange. This is because in such ecotone areas, shading is not thick enough to inhibit the plant, but it does not promote the formation of thorough herbaceous cover of the meadow vegetation, and therefore thorough sod. On the other hand, such ecotones are invaded by species from neighboring ecosystems, which enrich their phytodiversity, but some econiches nonetheless remain vacant and the vegetative coverage interrupted. The ecotone character of spread of *H. sosnowskyi* was pointed out by other researchers (Baležentienė et al., 2021).

A similar effect could be caused by human activity. Such ecotones are formed between completely human-altered technotopes and cultivated or spontaneous tree stands (Gubar & Koniakin, 2021), for example, on roadsides, along the windbreaks or rivers. The same situation was also well described in the territory of Latvia (Baleћentiene, 2013). Furthermore, on early stages of vegetation recovery on fallows, there developed ecosystems with vegetation that was not thorough enough and had many vacant econiches (Khomiak, 2018). This category contained a large number of ecosystems with autotrophic block appearing as the class of groups of *Artemisietea vulgaris*. The definite leader there was the *Elymus* plants of association *Agropyretum repentis*, which are often the first stage of recovery of disturbed vegetation. The same process can occur during formation of incomplete meadow cenoses of the order *Galietalia veri* (class *Molinio-Arrhenatheretea*). According to our data, the most vulnerable there were the associations *Carici praecoci-Alopecuretum pratensis* and *Achillea submiefolium-Dactyletum glomeratae*. Theoretically, other associations of this order were targets for invasion by *H. sosnowskyi*, but its active development was suppressed by lower moisture and richness of soil, necessary for its fast and powerful growth. Mesophyte meadows of the order *Arrhenatheretalia elatioris* were observed to be invaded by *H. sosnowskyi* through local disturbances of sod around their perimeter, where the vegetation had been inhibited by partial shade dropped from phanerophytes (Oitsius et al., 2020).

At the same time, not only are there ecosystems which are vulnerable to the spread of hogweed, but, likewise, this plant is able to directly transform its environment locally in the direction it would benefit from. In places where it had existed for many years and had been a dominating species, within its phytorange, there developed a variant of association *Agropyretum repentis* var. *Heracleum sosnowskyi*. This variant represented 16.4% of the relevés with participation of *H. sosnowskyi*. This occurs due to the ability of the plant to grow at fast rates and cast shade from its leaves on less tall plants. Therefore, it promotes the formation of favorable conditions for new generation of its seeds to germinate. Since the projective cover of this species in a local phytocenosis can be considered a feature of its vitality, according to it one can identify its competitiveness and effect on the content of econiches in the ecosystem (Diduh, 2012). Our analysis of the correlation between species of plants in groups with participation of *H. sosnowskyi* and its projective cover revealed that the plant demonstrated the best vitality parameters when its phytocenosis contained 4–5 species (Fig. 1). They remained relatively high until the number of species exceeded 7–8. Correlation between the mean values of the projective cover of *H. sosnowskyi* and the number of species of plants in the groups with its participation was observed for the approximation significance equaing 0.2 and correlation parameter accounting for 0.4.

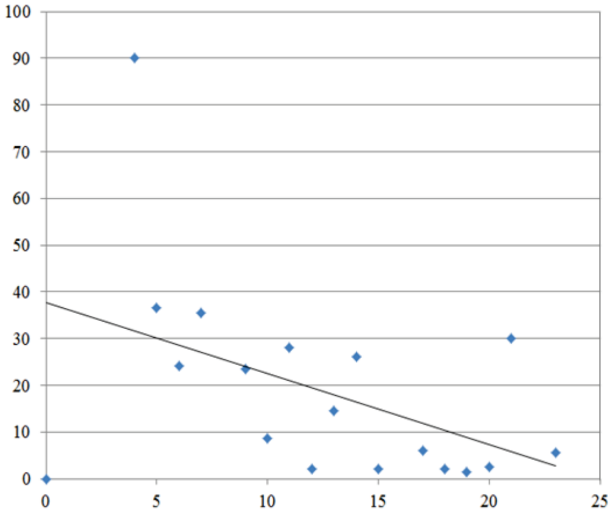

Fig. 1. Correlation between the number of species in relevé (abscissa) and the mean value of the *H. sosnowskyi* projective cover (ordinate), approximated with the linear trend line

Decline in the number of species in Sosnovskyi's hogweed's phytocenoses is promoted not only by shade it drops on the herbaceous vegetation, but also by allelopathy (Burlėgaitė et al., 2012). This was observed in our experiment, conducted in order to identify effect of the extract from *H. sosnowskyi* on germinating qualities of the seeds of cucumbers, and also studies by other researchers (Moshkivska, 2015). Most often, the coenoses with *H. sosnowskyi* contained *Elytrigia repens* (L.) Nevski (43.9%), *Urtica dioica* L. (38.6%), *Artemisia vulgaris* L. (29.8%), *Aegopodium podagraria* L. (28.1%), *Taraxacum officinale* Webb. ex Wigg. (26.3), and *Arctium lappa* L. (21.1%).

Heracleum sosnowskyi attains its competitive advantage through active growth and achieving large sizes in short time period because of more effective reaction to available nitrogen (nitrates and ammonium salt) in the soil. The distinction between nitrophile plants and other plants does not always lie in an expanded tolerance range that shifts towards higher levels of nitrogen compounds to avoid both deficiency and toxicity. They are usually more effective in using those compounds. In the laboratory experiments, most species positively reacted to increase in nitrates, similar to such observed in some ecotopes. However, in the natural environment, this efficiency gives them the competitive advantage from an increase in the body size, first of all, photosynthetic apparatus (Johnson et al., 2008). Thus, upon infiltration of a nitrates- and ammonium-salts-enriched soil, hogweed grows much faster than many other species, including most native nitrophiles. Since groups of class *Galio-Urticetea* combine a forest-edge effect, necessary for invasion by hogweed, and necessary amount of compounds in soil for its intensive growth, such nitrified forest edges are the main living environment this species spreads to Dubyna et al. (2021).

There are three ways in which available nitrogen accumulates in the ecosystems: anthropogenic, through nitrifying symbionts or migration with groundwater. The anthropogenic way is movement of nitrogen-containing mineral and organic fertilizers, and also accumulation of organic wastes. Combined with disturbance of the vegetation cover, anthropogenic sources of nitrogen create favorable conditions for mass spread of *H. sosnowskyi* in roadside ditches, on landfills, along neglected tree and shrub populations, near windbreaks, etc. (Martin et al., 2020). In such cases, it grows in associations *Urtico-Aegopodietum podagrariae* and *Myosotido sparsiflorae-Alliarietum petiolatae* of class *Galio-Urticetea* or *Agropyretum repentis*, *Arctio-Artemisietum vulgaris* and *Echio-Verbascetum* of class *Artemisietea vulgaris*. Another source of available nitrogen is nitrifying symbiotic microorganisms, associated with dominant species of the phytocenoses. It was observed to be the most pronounced in the vegetative groups with participation of *Alnus glutinosa* and *Robinia pseudoacacia* L., particularly the association *Ribeso nigri-Alnetum* of class *Alnetea glutinosae* and the associations *Cheledonio-Aceratum negundi* and *Cheledonio-Robinietum* of class *Robinietea*. Nitrogen compounds migrate with groundwater and accumulate in relief lowlands. This was seen most often in river valleys. This becomess combined with the influence of foliage movement on the valley slopes and the presence of other dead plant remains. As this detritus decomposes, it produces additional nitrates and ammonium salts into the environment. Typically, it is association *Salicetum pentandro-cinerea* of class *Franguletea*. By forming large amounts of phytomass, *H. sosnowskyi* limits available nitrogen in its growing locations. Breakdown of such detritus is accompanied by development of humic acids that fixate salts solved in groundwater. Thus, a long life of hogweed in a certain territory entails a transformation of edaphotope, which is being adjusted for the plant.

Obtaining a competitive advantage over other species as a result of intensity of growth and body sizes allows *H. sosnowskyi* to be classified as a K-strategy species (Finno & Tschirhart, 2009). It can act as a classical biennial or perennial, accumulating a reserve of nutrients in the roots over years, and only produces the peduncle. Also, it uses this mechanism to protect the shoot from critical damage. Due to the starch stored in the root, it can recover the above-ground part completely several times throughout a season. At the same time, as a reaction to damage, the root becomes several times thicker (from 3–5 to 7–10 cm). In other living conditions, the plant can blossom ad produce fruits as early as in the first year of vegetation. Thus, *H. sosnowskyi* can be an annual, biennial, or perennial plant. Flexibility with which the plant transitions from *K* to *r* strategy, depending on environment, makes it resilient against many methods used against it. In the experiment, during removal of some individuals of hogweed from the plot, we noted that cutting the upper part at the moment of generating the peduncle deprived the plant of the ability to use the reserves of nutrients and recover the damaged shoot. We may assume that starch in the root dissolved, with further loss of glucose, making the root incapable of producing a new shoot. This suggests that the plant has certain ontogenesis stages when it becomes vulnerable to certain external effects. For instance, hogweed was found vulnerable to herbicides mostly between the stage of complete formation of cotyledons and the stage of 6 leaves (Moshkivska, 2015a).

In favorable conditions, *H. sosnowskyi* switches to *r* strategy. According to the data of Ligita Baležentienė, one plant is able to produce 15,444–16,164 thou seeds (Baleħentiene, 2013). Their energy of germination equaled 78.0% and could maintain at this level for a long time (Moshkivska, 2015). Because of its tall peduncle (up to 3–5 m), the seeds spread in the radius of 5–6 m. Some part of the seeds can migrate large distances, carried by strong winds, which is especially noticeable during winter blizzards. However, most of the seeds were observed to remain around the mother plant, where its influence had prepared the soil and thinned the vegetative cover out for the seeds to germinate (Nathan & Safriel, 2020).

The results of the stationary studies revealed a relationship between the dynamics of ecosystems and their vulnerability to invasions. Ecosystems can have autotrophic blocks that belong to one syntaxon, but differ by parameters of natural dynamics, which reflect their position in successive series. That means they could have a developed block of diagnostic species and content of econiches, but not enough individuals to fill this niche. In addition, there can be a dynamic ecotone, when at certain stages of succession, there are species present from groups located nearby in the successive order. For example, in meadows, there were spotted pioneering ruderal species at early stages and phanerophages at late stages (Khomiak et al., 2019).

Ecosystems, where *H. sosnowskyi* lives, play different roles in its spread. There are ecosystems that are the most vulnerable to its initial invasion. They are easily infiltrated by the seeds of this species, which have a high chance to germinate there. However, it is not just any ecosystem that the plant invades which allows it to thrive with a powerful and numerous population. Sosnovskyi's hogweed benefits from the second type of ecosystem, where it lives in the optimum ecological conditions. The third type of ecosystem is those it can infiltrate sporadically and where it has poor chances of high percentage of germinated seeds and developed mature plants, and therefore little prospects of developing a powerful cenopopulation (Khomiak et al., 2019). Ecosystems in the early grassland stages of autogenic succession were found to be the most vulnerable to invasions. According to the scale of natural dynamics, this corresponded to the level of 3.0–4.0 points. According to the data of the phytocenosis library of the Laboratory of the Theory of Ecosystems of the Ivan Franko Zhytomyr State University, this category included 50.0% of the relevés of the associations *Poa annuae-Coronopodetum squamati* (class *Polygono arenastri-Poëtea annuae*), 49.9% of *Agropyretum repentis*, 33.3% of *Echio-Verbascetum*, and 23.3% of *Arctio-Artemisietum vulgaris* (class *Artemisietea vulgaris*), 25.0% of *Trifolio-Festucetum rubrae*, and 14.3% of *Deschampsietum caespitosae* and *Poëtum pratensis* (class *Molinio-Arrhenatheretea*). Presence of such groups and their sustainable existence in settlements and the zone of spread of hogweed seeds pose a potential threat to its spread. Exceptions can include ecosystems that have other factors that limit its spread. Therefore, for an ecosystem with the association *Poo annuae-Coronopodetum squamati* – this would be excessive tramping, for *Echio-Verbascetum* – low moisture (10.3 points on average), and for all groups of class *Bidentetea tripartiti*, which have natural-dynamics parameters within 2.4–6.3 points, those factors would be too high moisture parameters (on average 15.0 points according to the unified Diduh-Pliuta scale). Thus, hogweed infiltrates such areas sporadically and has little opportunity to transform those ecosystems in the way it needs to spread further.

According to the projective cover and number of individuals, the species reaches the maximum in ecosystems with the dynamics parameter equaling 4.0–7.0 points. The most promising for its local flourish was observed to be association *Elytrigio repentis-Aegopodietum podagrariae*, with 33.3% of the relevés corresponding to this range. The largest share of the relevés in this range of dynamics parameters were seen for groups of associations *Agrimonio eupatoriae-Trifolietalia medii* (93.3%). However, we observed a very small number of growing locations of *H. sosnowskyi* in those groups. This can be explained by low content of available nitrogen (4.5–6.7 points at the average value of 5.5 points) and relatively low moisture (10.3–12.9 points at the average value of 11.1 points) (Zavialova et al., 2021).

The highest value of natural dynamics in which *H. sosnowskyi* was found accounted for 9.5 points. Decline in hogweed in the groups of phanerophytes during autogenic succession was confirmed by the stationary studies. Following the formation of a stable group *Ribeso nigri-Alnetum* in the stationary plot, the number of specimens reduced from 12 in 2007 to 2 in 2019. Since 2021, *H. sosnowskyi* was not seen on this plot. A similar situation was observed again during another examination of the territory of the Slovechansko-Ovrutskyi Ridge. Because some parts of it have been exposed to lower levels of anthropogenic pressure in recent years, autogenic succession has been activated, leading to restoration of the natural vegetation (Harbar et al., 2021). The population of *H. sosnowskyi* in a thinned-out beech forest in the area of the Sorokopen village, belonging to association *Salicetum capreae* of class *Robinietea*, disappeared.

Conclusions

Heracleum sosnowskyi occurred in vegetative groups belonging to 13 classes, 16 orders, 21 alliances, and 29 associations. According to the data of synphytoindication, it was most often present in mesophyte, hemihydrocontrasthophobic moderately moistened habitats that are sporadically moistened), subacidophilic, semieutrophic, acarbonataphilic, nitrophilic, hemiaerophobic (moderately aerated habitats), submicrothermal (habitats that receives 20–30 kc/sm^2), subombrophytic, hemioceanic, subcryophytic (habitats with the average temperature of the coldest month of the year is approximately –8), semi-illuminated, euhemerobic (habitats that have been altered or created by humans and are under anthropogenic influence) habitats. The competitive advantage of *H. sosnowskyi* over the native species comprised the following characteristics: ability to switch from *r* to *K* strategy, depending on the environmental conditions; producing a large number of seeds, spread from a tall peduncle, which maintained a high germination rate for several years; and allelopathy and efficient absorption of nitrogen compounds, which fostered the sizes of the shoot. Ruderal and natural environments of grasslands at early stages of autogenic succession (3.0–4.0 points of natural dynamics) were the most vulnerable to invasion by *H. sosnowskyi*. The highest projective cover and density of its population was observed on the nitrified forest edges of the variant of association *Elytrigio repentis-Aegopodietum podagrariae* var. *Heracleum sosnowskyi* (the parameter of natural dynamics of 4.0–7.0 points). Forest ecosystems with multi-stratum vegetation (the parameter of dynamics above 9.5 points) and meadows with thorough sod (parameter of dynamics above 4.8 points) were less vulnerable to invasion. At the same time, disturbance of the completeness of the tree stand or integrity of sod created additional opportunities for its infiltration of this territory. Having invaded the natural or ruderal ecosystems, *H. sosnowskyi* most often transformed their autotrophic blocks into a variant of association *Agropyretum repentis* var. *Heracleum sosnowskyi* of class *Artemisietea vulgaris*, which are a more favorable phytocenosis for its intensive reproduction and spread.

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