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The spread of alien vascular plant species in the biotopes of the Moshnohirsky Ridge (Cherkasy region, Ukraine)

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Abstract. Invasion of organisms pose a potential threat to the existence of natural habitats and lead to impoverishment of biological diversity. Particularly pronounced is the negative impact within the boundaries of the Middle Dnieper region, where approximately a quarter of vascular plant species are of alien origin. The purpose of the study was to identify the current species composition of alien vascular plant species, the specific features of their distribution outside the culture, naturalisation, and involvement in plant communities of Moshnohirsky Ridge biotopes. The species composition of plants was recorded by transects and relevés in the habitats of representatives of alien plant species were conducted to achieve this goal. It was determined that the vegetation cover of forest and related biotopes in the research area is significantly contaminated with alien vascular plant species, amounting to 48 species from 45 genera and 29 families. Substantial involvement of alien species is noted in Forest biotopes of hornbeam-oak forests – 35.4%, and oak and pine-oak forests – 29.2%. Among the alien species that have a substantial impact on the structure of plant communities of these broad-leaved forest biotopes are *Impatiens parviflora* DC., *Robinia pseudoacacia* L.,

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Acer negundo L. Over time, the majority of introduced species are considered neophytes (81.3%), with a significant portion originating from North America (43.8%), the Mediterranean region (16.7%), and East Asia (8.3%). In terms of their penetration into natural ecosystems, species that are capable of actively integrating into natural communities, namely agriophytes and agriocoenophytes, hold high positions (a total of 30.2%). In contrast to these groups, limited alien species without active distribution – ephemerophytes and colonophytes are substantially represented in the groupings of the research area (30.6%). The identified patterns of distribution and cenotic distribution of alien species are the primary basis for the formation of optimal measures to counteract new invasions in forest communities and restrain the process of population compaction for species that already have a wide distribution within the research area

Keywords: adventitious fraction; phytointvasions; Middle Dnieper region; kenophytes; agriophytes; naturalisation

Introduction

Increased anthropogenic impact on the environment leads to ecosystem transformation, reduced species diversity, and invasion of alien species into natural phytocenoses. Invasion of alien species, according to the degree of risk to the conservation of biological diversity, is recognised as a highly dangerous phenomenon that causes long-term negative consequences and poses a threat to the existence of natural habitats (Czechowska *et al.*, 2022). Biodiversity is inextricably linked to ecosystem services and human well-being, but in recent decades, the threat from alien plant species to native biodiversity, habitats, ecosystem services, and human health has tended to increase, as reflected in their study by R.L. Macêdo *et al.* (2022). High economic activity in the modern world, in particular, the extensive network of transport routes, population migration, and trade continue to contribute to the spread of an increasing number of alien organisms, through previously insurmountable spatial and ecological barriers, such as freshwater and marine aquatic ecosystems, mountain ranges, and unfavourable climatic zones (Kueffer, 2017). According to P.K. Rai & J.S. Singh (2020), plant invasions, anthropogenic disturbances, climate change,

biodiversity, and social and economic well-being can often have complex and confusing links.

Researchers M. Kourantidou *et al.* (2022) separately raised the global problem of increasing the impact on the economic situation from the spread and naturalisation of alien species in new regions and the invasive activity of their individual representatives.

V.V. Konishchuk *et al.* (2020), L.V. Zavialova *et al.* (2021) proved that the problem of the distribution of alien species is particularly acute for reference territories. These territories hold a protected status and have a specific management regime, encompassing a range of natural vegetation types, primarily forests, steppes, and wetlands. These habitats are essential for the conservation and restoration of indigenous phytocoenotic and cenotic diversity, including within the boundaries of Ukraine's nature reserve objects.

According to V. Wagner *et al.* (2017), for the forest areas of Europe, 53 invasive alien plant species distributed in broad-leaved forests of the temperate zone are indicated, the invasion of which as part of native groups can have a direct or indirect impact on their recovery. Since invasive plant species pose a challenge in terms

of managing the recovery of native tree species, according to the results of the study by M. Langmaier & K. Lapin (2020), the inventory of alien species in forest fund areas and early detection of potentially invasive ones is gaining extraordinary weight to avoid or reduce the negative environmental and economic impact of phytoviasias.

Preventing the spread of invasive alien species and controlling the introduction of such species into natural ecosystems, including marine ones, is one of the tasks of the main principles (strategy) of the state environmental policy of Ukraine for the period up to 2030, approved by the Law of Ukraine “On the Main Principles (strategy) of the state Environmental Policy of Ukraine for the Period up to 2030” (2019).

In the paper by V.V. Konishchuk *et al.* (2020), it is noted that in the territory of Ukraine, there are approximately 1000 plant species that are considered alien, 85 of which are highly invasive. The Law “On the Approval of the List of Invasive Tree Species with a substantial Capacity for Uncontrolled Spread, Prohibited for Use in the Process of Reforestation” (2023) was put into force to reduce the substantial negative impact of phytoviasion on the environment and forest resources of Ukraine.

Considering the above, in view of on the one hand, the high economic development of the Forest-Steppe of Ukraine, on the other hand, the substantial environmental value of the Moshnohirsky Ridge, as an important protected area with various natural settlements, the assessment of biological pollution of its vegetation cover and the spread of alien species by settlements still remains relevant.

Thus, considering the high environmental value of the research area, the purpose of this study was to identify the species composition of alien vascular plant species, the features of their distribution outside the culture and naturalisation by biotopes of the Moshnohirsky Ridge.

Materials and Methods

The study was conducted during the vegetation seasons of 2018-2021 within the territories of Moshnivske and Zakrevske forestry subdivisions of the Cherkasy Forestry Enterprise of the State Enterprise “Forests of Ukraine”. The study utilised approaches described in the “Handbook for collecting vegetation plot data in Minnesota”. The relevé method (2013) and R.I. Burda & O.A. Ignatyuk (2011), considering the available taxonomic, cartographic materials, published information (Chopyk *et al.*, 1998; Gaiova, 2013), herbarium materials (KW), and the results of the authors’ own observations (Churilov, 2018, 2019). Biotopes are identified according to the National Catalogue of Biotopes of Ukraine (Kuzemko *et al.*, 2018).

Identification of higher vascular plants was conducted according to the key to determination of vascular plant species of Ukraine (Dobrochaeva *et al.*, 1987), the nomenclature was consistent with the lists of the Catalogue of Life (n.d.) and Plants of the World Online (POWO) (n.d.). Plants were classified as alien species considering published reports on the occurrence of alien species within Ukraine (Protopopova & Shevera, 2014; Onyshchenko, 2019; Burda & Koniakin, 2019) and the research area (Protopopova *et al.*, 2010, Protopopova & Shevera, 2019; Fedoronchuk *et al.*, 2020). The quantitative involvement of plants in biotope communities is shown in accordance with the values of projective coverage on the Tensley scale, considering recommendations for field mapping of habitats (Kuzemko *et al.*, 2018). During the study, the requirements of the Convention on Biological Diversity (1992) were met.

The Moshnohirsky Ridge is a geomorphological formation of glacial origin, separated from the southern part of the Kaniv dislocations by the valley of the Vilshanka River (Fig. 1). This includes wet alder forests along the floodplain of the river Irdynka.

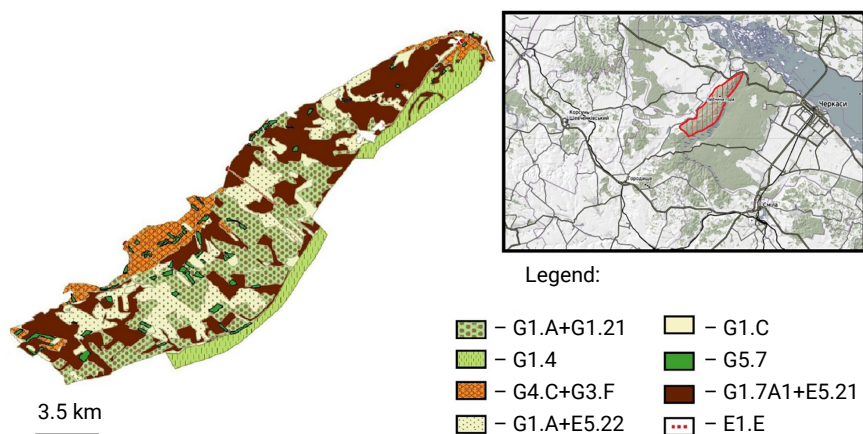


Figure 1. Scheme of the spatial distribution of biotopes on the territory of the Moshnohirsky Ridge

Source: developed by the authors in the QGIS environment (v. 2.8) based on taxonomical materials of the Cherkasy Forestry branch of the State Enterprise “Forests of Ukraine”

In addition, anthropically transformed edges and roadsides of forest roads with ruderal vegetation are hotbeds of synanthropisation and subsequent invasion of alien species into the natural vegetation cover of the Moshnohirsky Ridge. Therefore, to investigate the invasion of alien species into forest communities, the biotopes with recently disturbed tree layers was investigated. These biotopes included

clearings, young stands before canopy closure, as well as glades and understory areas along forest paths. These forest paths play a crucial role as primary habitats for alien plant species, facilitating their entry into forest communities.

Results and Discussion

Forest and related biotopes present within the Moshnohirsky Ridge are shown in Table 1.

Table 1. Moshnohirsky Ridge biotopes

No.	Biotopes according to European University Information Systems (EUNIS)	Biotopes in accordance with the National Habitat Catalogue of Ukraine
1	G1.A Meso- and eutrophic <i>Quercus</i> , <i>Carpinus</i> , <i>Fraxinus</i> , <i>Acer</i> , <i>Tilia</i> , <i>Ulmus</i> and related woodland	Central European oak-hornbeam forests (G1.A1 <i>Quercus</i> – <i>Fraxinus</i> – <i>Carpinus betulus</i> woodland on eutrophic and mesotrophic soils)*
2	G4.C Mixed <i>Pinus sylvestris</i> -thermophilous <i>Quercus</i> woodland	Subacidophilous species-rich oak and pine-oak forests (G1.7 Thermophilous deciduous woodland)*
3	G1.7A1 Euro-Siberian steppe <i>Quercus</i> woods	Continental thermophilous oak forests (G1.7 Thermophilous deciduous woodland)*
4	G1.21 Riverine <i>Fraxinus</i> - <i>Alnus</i> woodland, wet at high but not at low water	Ash-alder alluvial forests (G1.21 Riverine <i>Fraxinus</i> - <i>Alnus</i> woodland, wet at high but not at low water)*
5	G1.4 Broadleaved swamp woodland not on acid peat	Eutrophic swamps with layer of black alder or birch (G1.41 <i>Alnus</i> Swamp Woods not on acid peat)*

Table 1, Continued

No.	Biotores according to European University Information Systems (EUNIS)	Biotores in accordance with the National Habitat Catalogue of Ukraine
6	G1.C Highly artificial broadleaved deciduous forestry plantations	Anthropogenic broad-leaved forests
7	G3.F Highly artificial coniferous plantations	Anthropogenic coniferous forests
8	G5.7 Coppice and early-stage plantations	Areas with recently removed tree layer
9	E5. 21 Xero-thermophile fringes	Thermo-xerophilous fringes
10	E5. 22 Mesophile fringes	Mesophilous fringes and glades on neutral and base-rich soils
11	E1.E Trampled xeric grasslands with annuals	Trampled habitats

Note: * – localisations included in Resolution No. 4. “Listing Endangered Natural Habitats Requiring Specific Conservation Measures” (1996) to Convention on the Conservation of European Wildlife and Natural Habitats (1979)

Source: compiled by the authors according to A. Kuzemko *et al.* (2018)

Overall, 5 of the 11 available biotores within the ridge are important for conservation and are protected in accordance with Resolution No. 4. “Listing Endangered Natural Habitats Requiring Specific Conservation Measures” (1996).

Previous studies have confirmed the botanical uniqueness and conservation value of the Moshnogirya area (Udra, 1983; Didukh *et al.*, 1987; Gaiova, 2008). Within the territory, a number of objects of the nature reserve fund have been established, including two local landscape reserves (“Moshnohirsky” and “Moshnivsky”), a nationally significant natural monument “Moshenska Dibrova”, three botanical monuments (“Velvet Amur Plantation”, “Group of Mature Firs”, “Alder Tree with Oak”), a local zoological reserve “Moshnivsky Conservation Zone”, and two hydrological monuments (“Cascade of Forest Lakes”, “Subterranean Spring”). Since 2016, the territory of the Moshnohirsky Ridge has been included in the Cherkaskyi Bir (UA0000254) (Emerald Network – General Viewer, n.d.).

Information about alien plant species was first found in the descriptions of the Moshnohirsky English-style park by Michal Grabovsky in 1853, where the distribution was noted *Robinia pseudoacacia* L., a representative of the genus *Parthenocissus* Planch., *Pinus nigra*

subsp. *pallasiana* (Lamb.) Holmboe. O. Spryagailo (2010) indicates that among the introduced plants, there were *Larix gmelinii* (Rupr.) Rupr. and *Picea abies* (L.) H. Karst. However, to this day there are no records of the full range of introducing plants that were cultivated on the territory of park of Knyaz M.S. Vorontsov. In the 80s of the 20th century, the territory of the Moshnohirsky Ridge in part of the cultivated area of the sanatorium “Moshnohirsky” was replenished with introducents, hybrids, and cultivars – *Cercidiphyllum japonicum* Siebold et Zucc., *Yucca filamentosa* L., *Tamarix ramosissima* Ledeb., *Robinia viscosa* Vent., *Campsis radicans* (L.) Seem., *Spiraea × vanhouttei* (Briot) Zabel, *Thuja occidentalis* ‘Ericoides’ (Spryagailo, 2015), whose spontaneous spread outside the culture has not been observed by this study.

In the current stage of research on alien species in the Middle Dnieper region, particularly regarding the question of synanthropization of the meadow floristic complex, it has been noted that 109 species of vascular plants from the category of adventives are widespread (Protopopova *et al.*, 2010). For forest and shrub flora complexes V.V. Protopopova *et al.* (2014), M.M. Fedoronchuk *et al.* (2020) established the distribution of 162 adventitious species, of which the following have a substantial negative

impact on native phytodiversity: *Bidens frondosa* L., *Erigeron annuus* (L.) Desf., *Echinocystis lobata* (Michx.) Torr. et A. Gray, a *Acer negundo* L., *Impatiens parviflora* DC., *Robinia pseudoacacia* L., *Amorpha fruticosa* L., in addition, are transformer species that actively and massively compact the distribution area.

Regarding phytoinvasias within the Forest-Steppe, was the study by N.A. Pashkevych & R.I. Burda (2017), which also relate to the territories adjacent to Moshnohirsky Rigde, given there are 172 alien species (about 15% of the floral composition) in Feofaniia Park, Golosiivsky National Nature Park (NPP). A study by O.I. Shynder *et al.* (2021) determined the synanthropic fraction of the flora of the biostationary "Hluboki Balyky" (Rzhishchivska City United Territorial Community, Obukhiv District of the Kyiv region), identified 241 species of alien vascular plants (27% of the total floristic

composition), among which the most dangerous invasive species are identified: *Asclepias syriaca* L., *Acer negundo* L., *Amorpha fruticosa*, *Elaeagnus angustifolia* L., *Robinia pseudoacacia*, *Parthenocissus inserta* (A.Kern.) Fritsch, *Impatiens parviflora*. V.V. Protopopova & M.V. Shevera (2019), M.M. Fedoronchuk *et al.* (2020) concluded that the adventisation of the flora of the Middle Dnieper region is increasing, in particular, the fraction of kenophytes listed in the 20th century is substantial. Results obtained by N.A. Pashkevych & R.I. Burda (2017), for floral complexes within the objects of the nature reserve fund in the Forest-Steppe of Ukraine, a high degree of colonisation by alien species of meadow, forest, and shrub floral complexes is indicated.

In the course of the study, the distribution of 48 alien vascular plant species belonging to 45 genera and 29 families by biotopes of the research area was established (Table 2).

Table 2. Annotated list of alien vascular plant species of the Moshnohirsky Ridge

No.	Species name (family)	Characteristics of species	Biotopes of the research area
1	<i>Acer negundo</i> L. (Sapindaceae)	p, nam, kn, ae	G1.A, G1.4 (1), G4.C, E1.E (2), G1.21, G1.C, G5.7 (3)
2	<i>Acer saccharinum</i> L.* (Sapindaceae)	p, nam, kn, ef	G1.C (1)
3	<i>Aesculus hippocastanum</i> L.* (Sapindaceae)	p, mter, kn, ef	G1.A, G4.C, G1.7A1 (1), G1.C (2)
4	<i>Amaranthus retroflexus</i> L. (Amaranthaceae)	t, nam, kn, ep	G1.C (1), G5.7, E1.E (2)
5	<i>Ambrosia artemisiifolia</i> L. (Asteraceae)	t, nam, kn, ae	G3.F (1), G5.7 (3), G1.C (1), E1.E (3)
6	<i>Amelanchier ovalis</i> Medikus (Rosaceae)	p, mter, kn, kl	G4.C (1)
7	<i>Amorpha fruticosa</i> L. (Fabaceae)	p, nam, kn, ae	G1.A, G4.C, G1.21 (2), G1.4 (1)
8	<i>Asclepias syriaca</i> L. (Asclepiadaceae)	he, nam, kn, ep	G1.C (1), G5.7, E1.E (2)
9	<i>Ballota nigra</i> subsp. <i>ruderalis</i> (Sw.) Briq. (Lamiaceae)	he, mtasm, ah, ep	G1.A, G1.C, E1.E (2), G5.7 (3)
10	<i>Berberis vulgaris</i> L. (Berberidaceae)	p, eas, kn, kl	G4.C, G1.7A1 (1)
11	<i>Bidens frondosa</i> L. (Asteraceae)	t, nam, kn, ep	G1.C (1), G4.C, E1.E (2), G1.21, G1.4 (3)
12	<i>Capsella bursa-pastoris</i> (L.) Medikus (Brassicaceae)	t, un, ah, ep	G3.F (2), G5.7, E1.E (3)
13	<i>Celtis occidentalis</i> L.* (Cannabaceae)	p, nam, kn, ef	G1.A (1)
14	<i>Cichorium intybus</i> L. (Asteraceae)	he, mter, ah, gp	G3.F (1), G5.7, E1.E (2)
15	<i>Cotinus coggygria</i> Scop. (Anacardiaceae)	p, mter, kn, kl	G1.7A1 (2)
16	<i>Descurainia sophia</i> (L.) Webb ex Prantl (Brassicaceae)	t, cas, ah, ep	G5.7, E1.E (2)

Table 2, Continued

No.	Species name (family)	Characteristics of species	Biotopes of the research area
17	<i>Echinochloa crus-galli</i> (L.) Beauv. (Poaceae)	t, as, ah, ep	G5.7 (1), E1.E (2)
18	<i>Echinocystis lobata</i> (Michx.) Torr. et A. Gray (Cucurbitaceae)	t, nam, kn, ae	G1.21, G1.4 (2)
19	<i>Erigeron annuus</i> (L.) Desf. (Asteraceae)	t, nam, kn, ag	G3.F (1), G1.A, G4.C, G1.C, E5.21, E5.22, E1.E (2), G5.7 (3)
20	<i>Erigeron canadensis</i> L. (Asteraceae)	t, nam, kn, ep	G4.C, G1.C (1), G3.F, E1.E (2), G5.7 (3)
21	<i>Erysimum cheiranthoides</i> L. (Brassicaceae)	t, un, ah, ep	G5.7, E1.E (2)
22	<i>Galinsoga parviflora</i> Cav. (Asteraceae)	t, sam, kn, ep	G1.A, G4.C (1), G1.C, G5.7, E1.E (2)
23	<i>Gleditsia triacanthos</i> L.* (Fabaceae)	p, nam, kn, ef	G1.A, G1.7A1 (1), G1.C (3)
24	<i>Heracleum sosnowskyi</i> Manden. (Apiaceae)	he, ccs, kn, ae	E5.21, G5.7, E1.E (1)
25	<i>Impatiens parviflora</i> DC. (Balsaminaceae)	t, cas, kn, ae	G1.21, E1.E (2), G1.A, G4.C, G1.C, G5.7 (3)
26	<i>Juglans regia</i> L.* (Juglandaceae)	p, bcas, kn, ef	E5. 21, G1.A, G1.7A1, G1.C (1)
27	<i>Lepidium densiflorum</i> Schrad. (Brassicaceae)	t, nam, kn, ep	G3.F (1), G1.C, E1.E (2), G5.7 (3)
28	<i>Morus alba</i> L.* (Moraceae)	p, eas, kn, ef	E5. 22, G1.C, G5.7, E1.E (1)
29	<i>Oenothera biennis</i> L. (Onagraceae)	he, nam, kn, ag	G3.F, G1.C, E1.E (1), G5.7 (2)
30	<i>Oxalis stricta</i> L. (Oxalidaceae)	t, nam, kn, ep	E1.E (1), G5.7 (2), G1.C (3)
31	<i>Oxybaphus nyctagineus</i> (Michx.) Sweet* (Nyctaginaceae)	he, nam, kn, ep	G1.21, E1.E (1)
32	<i>Parthenocissus inserta</i> (A.Kern.) Fritsch (Vitaceae)	p, nam, kn, ae	G1.A, G4.C (1), G1.C (2)
33	<i>Phellodendron amurense</i> Rupr. (Rutaceae)	p, eas, kn, kl	G5.7 (1), G1.C (3)
34	<i>Pinus nigra</i> subsp. <i>pallasiana</i> (Lamb.) Holmboe* (Pinaceae)	p, crm, kn, ef	G1.A (2)
35	<i>Prunus armeniaca</i> L.* (Rosaceae)	p, eas, kn, ef	G1.C (1)
36	<i>Prunus cerasifera</i> Ehrh. (Rosaceae)	p, mter, kn, ef	G3.F, G1.7a1, E5.22 (1), G1.C (2)
37	<i>Pyrus communis</i> L. (Rosaceae)	p, un, kn, ag	E5.21 (1), E5.22, G1.A, G4.C, G1.7A1, G1.C, G5.7 (2)
38	<i>Quercus rubra</i> L. (Fagaceae)	p, nam, kn, ag	E5.21, E5.22 (1), G1.7a1 (2), G1.A, G4.C, G1.C, G5.7 (3)
39	<i>Robinia pseudoacacia</i> L. (Fabaceae)	p, nam, kn, ep	E1.E (1), E5.21, E5.22, G4.C, G1.7A1 (2), G1.A, G1.C, G5.7 (3)
40	<i>Rudbeckia laciniata</i> L. (Asteraceae)	he, nam, kn, ae	E1.E (2)
41	<i>Salix × fragilis</i> L. (Salicaceae)	p, asm, ah, ag	G1.21, G1.4 (2)
42	<i>Saponaria officinalis</i> L. (Caryophyllaceae)	he, mter, kn, ae	E1.E (1), E5.21, E5.22 (2), G5.7 (3)
43	<i>Setaria viridis</i> (L.) Beauv. (Poaceae)	t, mter, ah, ep	G5.7, E1.E (2)
44	<i>Solanum nigrum</i> L. (Solanaceae)	t, seu, ah, ep	G1.C (1), E1.E (2), G5.7 (3)
45	<i>Solidago canadensis</i> L. (Asteraceae)	he, nam, kn, ae	E5.21, E5.22 (1), E1.E (2), G5.7 (3)

Table 2, Continued

No.	Species name (family)	Characteristics of species	Biotopes of the research area
46	<i>Syringa vulgaris</i> L.* (Oleaceae)	p, seu, kn, kl	G1.A (1), G1.C (2)
47	<i>Vinca minor</i> L. (Apocynaceae)	ha, mter, kn, ef	E1.E (1), G1.C (2), G1.A (3)
48	<i>Vitis vinifera</i> L.* (Vitaceae)	p, un, kn, ef	G1.C (1)

Note: * – species for which there is no active natural renewal and distribution to adjacent areas. In Column 3: *Life form* (Raunkiaer, 1937): p (phanerophyte), ha (hamefite), he (hemicryptophyte), t (terophyte). *Geographical origin of species* (Protopopova & Shevera, 2019): as (Asian), asm (Asia Minor), bcas (Balkan-Central Asian), cas (Central Asian), ccs (Caucasian), ceu (Central European), crm (Crimean), eas (East Asian), mter (Mediterranean), mtasm (Mediterranean-Asia Minor), nam (North American), sam (South American), sas (South Asian); seu (South European), un (unknown), weu (West European). *Groups of species by the time of introduction* (Protopopova & Shevera, 2019): kn (kenophyte), ah (archaeophyte). *Groups of species by degree of naturalisation* (Protopopova & Shevera, 2019): ag (agriophytes), ae (agriophytes), ep (epycophytes), gp (hemiepecophytes), ef (ephemerophytes), kl (colonophytes)

Source: compiled by the authors

According to the data provided by Yu. Gaiova (2008), Yu. Gaiova (2013), the species richness of the ridge flora includes about 170 species of vascular plants. Thus, alien plants make up 28.2% of the species richness of broad-leaved

forests of the Moshnohirsky Ridge. There are only three genera in the structure of the generic spectrum – *Acer* L., *Erigeron* L. and *Prunus* L. have two species each, while the remaining 42 genera are represented by one species each (Table 3).

Table 3. Families spectrum of alien vascular plant species

Families by number of species	Names of families and the number of species in each (units)	Number of families, units. (%)	Number of species in families, units. (%)
four or more species each	(8 types) <i>Asteraceae</i> , (4) <i>Brassicaceae</i> , <i>Rosaceae</i>	3 (10.3)	16 (33.3)
from two to three	(3) <i>Fabaceae</i> , <i>Sapindaceae</i> , (2) <i>Poaceae</i> , <i>Vitaceae</i>	4 (13.8)	10 (20.8)
one species	<i>Amaranthaceae</i> , <i>Anacardiaceae</i> , <i>Apiaceae</i> , <i>Apocynaceae</i> , <i>Asclepiadaceae</i> , <i>Balsaminaceae</i> , <i>Berberidaceae</i> , <i>Cannabaceae</i> , <i>Caryophyllaceae</i> , <i>Cucurbitaceae</i> , <i>Fagaceae</i> , <i>Juglandaceae</i> , <i>Lamiaceae</i> , <i>Moraceae</i> , <i>Nyctaginaceae</i> , <i>Oleaceae</i> , <i>Onagraceae</i> , <i>Oxalidaceae</i> , <i>Pinaceae</i> , <i>Rutaceae</i> , <i>Salicaceae</i> , <i>Solanaceae</i>	22 (75.9)	22 (45.8)
Total		29 (100)	48 (100)

Note: (%) - share of the total number

Source: compiled by the authors

The detected number of alien species is 29.6% of the total amount of adventitious fraction in the structure of tree and shrub biotopes of the Middle Dnieper region, which is represented by 162 species (Fedoronchuk *et al.*, 2020).

Comparing the level of adventization of floristic complexes within the studied territory to similar indicators for the “Holosivskyi” National Natural Park and the Kaniv Nature Reserve, both located in the Middle Dnieper

region and characterized by a significant presence of broad-leaved forests in their vegetation cover, it has been established that for the Moshnohirsky Ridge, the ratio of alien species to native species is 1:3.5 (28.2% of alien species), similarly for the “Holosiivskiy” National Natural Park, the ratio is 1:3.5 (28.9% of alien species) (Onyshchenko *et al.*, 2016), and for Kanevsky nature reserve 1:4.1 (24.1%) (Nechitaylo *et al.*, 2002).

Such indicators can be explained by significant anthropogenic factors, primarily recreational pressures on the floristic complexes and the introduction of alien plant species. This is especially relevant for the “Holosiivskiy” National Natural Park, which is situated within the urban environment of Kyiv, where recreational activities and human influence are intensified.

Similarly, for the Moshnohirsky Ridge, its historical past as an English-style park might have contributed to the presence of alien species in the vegetation cover. Phanerophytes predominate in the spectrum of climamorphs (Raunkiaer, 1937) among alien vascular plant species (45.8%), and therophytes are substantially involved (33.3%). Hemicryptophytes are slightly less involved (21.4%), only one species – *Vinca minor* belongs to the hamefits.

In the spectrum of life forms (Didukh *et al.*, 2000), trees of 16 species (33.3%) and annuals (33.3%), less polycarpics (16.8%) and shrubs (8.4%), the rest of biomorphs are lianas (*Parthenocissus inserta*, *Vitis vinifera*), and biennials (*Heracleum sosnowskiyi*, *Oenothera biennis*) account for 4.2% of the total number of identified alien plant species (Table 4).

Table 4. Spectrum of biomorphs of alien plants distributed by broad-leaved and derived biotopes of the Moshnohirsky Ridge

Biomorph (according to Raunkiaer)	Number of species, units (%)	Biomorph (according to Serebriakov)	Number of species, units (%)
1. Phanerophytes	22 (45.8)	1. Annuals	16 (33.3)
2. Therophytes	16 (33.3)	2. Trees	16 (33.3)
3. Hemicryptophytes	9 (18.8)	3. Polycarpics	8 (16.8)
4. Hamephytes	1 (2.1)	4. Shrubs	4 (8.4)
–	–	5. Lianas	2 (4.2)
–	–	6. Biennials	2 (4.2)
Total: 4	48 (100)	6	48 (100)

Source: compiled by the authors according to K. Raunkiaer (1937), Ya. Didukh *et al.* (2000)

The detected distribution of biomorphs is consistent with the ecological conditions of the habitats of the investigated biotopes and is largely similar to the indicators for the Middle Dnieper region (Fedoronchuk *et al.*, 2020), indicating, simultaneously, their anthropic disturbance (Goncharenko, 2017).

Important indicators for alien plant species are the time of introduction and the degree of naturalisation by natural and disturbed plant communities, which allows understanding

their invasive potential and the nature of relationships with native species in recipient ecosystems (Richardson *et al.*, 2000, Burda *et al.*, 2015).

It was established that among the alien species distributed by broad-leaved forest biotopes of the Moshnohirsky Ridge, only 16.1% (nine species) are archaeophytes, mostly distributed in areas with recently removed tree layer – *Ballota nigra* subsp. *ruderalis*, *Capsella bursa-pastoris*, *Cichorium intybus*, *Descurainia*

sophia, *Echinochloa crus-galli*, *Erysimum cheiranthoides*, *Setaria viridis*, *Solanum nigrum*, less commonly in anthropogenic broad-leaved forests – *B. nigra* subsp. *ruderalis*, *S. nigrum*. In the

forest-covered areas the following species can be located – *Salix × fragilis* (Eutrophic swamps with layer of black alder or birch, Ash-alder alluvial forests) (Table 5).

Table 5. Distribution of alien species of vascular plants of broad-leaved forests of the Moshnohirsky Ridge by time, method of introduction, and degree of naturalisation

Groups of species, units(%)		acolutophytes 18 (37,5)	ergasiophytes 25 (52,1)	ergasiophytes- xenophytes 5 (10,5)
kenophytes 39 (81,3)	agriophytes 4 (8,3)	2 (4.2)	1 (2.1)	1 (2.1)
	agri-epicophytes 10 (20,8)	2 (4.2)	4 (8.4)	4 (8.4)
	epicophytes 9 (18,8)	6 (12.5)	3 (6.3)	–
	ephemerophytes 11 (29,2)	–	11 (29.2)	–
	colonophytes 5 (10,4)	–	5 (10.4)	–
archaeophytes 9 (18,8)	agriophytes 1 (2,1)	–	1 (2.1)	–
	hemiepicophytes 1 (2,1)	1 (2.1)	–	–
	epicophytes 7 (14,6)	7 (14.6)	–	–

Source: compiled by the authors based on the classification of alien species by time, method of introduction, and degree of naturalisation of V. Protopopova & M. Shevera (2014), V. Protopopova & M. Shevera (2019)

According to the degree of naturalisation, only *S. fragilis* is an agriophyte that has naturalised in the natural ecosystems of the territory of Ukraine, with stands competition with local species and hybridises with *Salix alba* L. (Fedoronchuk *et al.*, 2020).

The vast majority of alien species (83.9%) are kenophytes, among them species that entered the territory of Ukraine in the early 20th century – *Ambrosia artemisiifolia*, *Echinocystis lobata*, *Bidens frondosa*, *Impatiens parviflora*, they have a high invasive capacity (Protopopova & Shevera, 2014) and are widely distributed by ecologically relevant biotopes of the Moshnohirsky Ridge.

In addition to these, species with substantial invasive capacity are *Acer negundo*, *Amorpha fruticosa*, *Heracleum sosnowskyi*, *Solidago canadensis*, are assigned to the group of transformer plants that can have a substantial impact on native biodiversity by changing the

parameters of the recipient ecosystem (Burda *et al.*, 2015).

An important component of the characterisation of alien species is information about their origin, which helps to better understand the reasons for adaptation and the success of passing barriers to naturalisation by alien species in the recipient ecosystem in the new distribution region (Richardson *et al.*, 2000; Protopopova & Shevera, 2019).

As a result of the analysis, 13 horologic groups by origin for alien species of the research area were identified. It was established that 43.8% (21) of alien species in the research area are of North American origin, and by the time of introduction, they are exclusively kenophytes. Species from the Mediterranean Region (8 species or 16.7%) are substantially involved, which is associated with the location of the regions of origin and the Moshnohirsky Ridge in similar climatic conditions of tem-

perate latitudes of the Northern Hemisphere. Species of East Asian and unknown origin – archaeophytes (*Capsella bursa-pastoris*, *Erysimum cheiranthoides*) and kenophytes *Pyrus communis*, *Vitis vinifera* (Protopopova & Shevera, 2014)

account for 8.3% each (4 species). Two species each have groups of southern European and Central Asian origin. The remaining seven species (14.6%) are distributed among seven centres of origin (Table 6).

Table 6. Distribution of alien vascular plant species of broad-leaved forests of the Moshnohirsky Ridge by time of introduction and origin

Alien species by the time of introduction By Origin	Archaeophytes	Kenophytes	Total
1. North American	–	21	21 (43,8%)
2. Mediterranean	2	6	8 (16,7)
3. East Asian	1	3	4 (8,3)
4. The Unknown	2	2	4
5. Southern European	1	1	2 (4,2)
6. Central Asian	1	1	2
7. Mediterranean-Asia Minor	1	–	1 (2,1)
8. Balkan-Central Asian	–	1	1
9. Caucasian	–	1	1
10. Crimean	–	1	1
11. Asia Minor	1	–	1
12. Asian	1	–	1
13. South American	–	1	1
Total	10	38	48

Source: compiled by the authors based on groups of species by origin according to V. Protopopova & M. Shevera (2014), V. Protopopova & M. Shevera (2019)

In general, the dominance of native species for North America and the Mediterranean in the biotopes of the Moshnohirsky Ridge corresponds to the structure of the adventitious fraction of the forest and shrub flora complexes of the Middle Dnieper region (Fedoronchuk *et al.*, 2020). A special feature of the adventitious phytobiota is the same involvement of species of East Asian and unknown origin of 8.3% each, which is associated with introduction tests within the specified territory during the 19th-20th centuries.

Analysis of the distribution of species by the investigated biotopes naturally showed the highest representation of species in Anthropogenic broad-leaved forests (29 species or 60.4% of the detected number of alien species), Trampled habitats (28 species or 58.3%),

and Areas with recently removed tree layer (27 species or 56.3%) (Fig. 2).

Substantial involvement of alien species is noted in the forest biotopes Central European oak-hornbeam forests (17 species or 35.4%) and Subacidophilic species-rich oak and pine-oak forests (14 species or 29.2%), which indicates a violation of the structure of their groups and is explained in particular, by the presence of alien species that have a limited occurrence in their composition, for example, *Aesculus hippocastanum*, *Celtis occidentalis*, *Gleditsia triacanthos*, *Juglans regia*, *Syringa vulgaris*.

A small number of alien plant species were established in the structure of optimal plant communities (Ash-alder alluvial forests) and excessively moistened (Eutrophic swamps with

layer of black alder or birch) forest-type biotopes. In particular, the most common species for Chornovil forests and eutrophic swamps are the floodplain of the river Irdynka within the Moshnohirsky Ridge is *Bidens frondosa*, *Acer*

negundo, *Echinocystis lobata*, *Amorpha fruticosa*, have a lower prevalence of *Salix × fragilis*, *Impatiens parviflora*, *Parthenocissus inserta*, and single plants of the species *Oxybaphus nyctagineus* detected only in one locality.

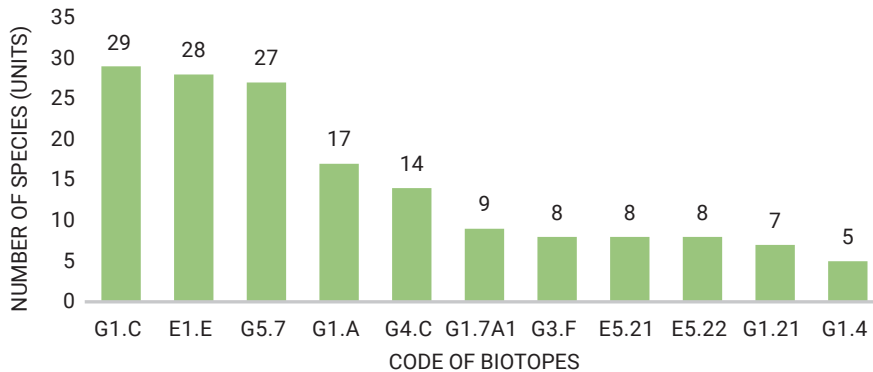


Figure 2. Distribution of alien species by biotopes of the research area

Source: compiled by the authors

With involvement in the composition of groups and occurrence of the investigated biotopes, it was established that a widespread species with a substantial projective coating is *Impatiens parviflora*, which is distributed by six biotopes.

According to the studies of B. Jarcuska *et al.* (2016), A. Florianová & Z. Münzbergová (2017), this species is one of the most common invasive plants established in temperate and northern regions of Europe, characterised by ecological plasticity, high seed productivity and long fruiting during the growing season, now within Ukraine it is classified as a transformer species (Golivets, 2014, Burda *et al.*, 2015), recent studies by V.V. Protopopova & M.V. Shevera (2019) show that it tends to continue compacting its almost formed range. The high degree of projective coverage *I. parviflora* is inherent in nutrient-rich substrates (Burda, 2012, Jarcuska *et al.*, 2016). Coenotically, the species acts as a diagnostic tool for groups of the Epilobietea angustifolii R classes. Tx. et Prsg 1950, Alno

glutinosae-Populetea albae P. Fukarek et Fabijanić 1968 (Mucina *et al.*, 2016) and Robinietaea Jurko ex Hadač et Sofron 1980 (Davydov, 2019). A substantial development of this species serves as a marker of anthropic disturbance of forest phytocenoses and occurs in conditions of reduced occurrence and abundance for spring ephemerooids (Burda, 2012, Goncharenko, 2017).

In the research area, the coverage of this species sometimes reaches from 10 to 60% as part of the shrub-grass layer of forest communities with the involvement of *Quercus robur* L., *Carpinus betulus* L., with an admixture of *Fraxinus excelsior* L. and *Acer platanoides* L. Together with *Impatiens parviflora* as part of the shrub-grass tier with a coating of 3-5%, there are *Alliaria petiolate* (M. Bieb.) Cavara & Grande, *Lamium galeobdolon* (L.) L., *Mercurialis perennis* L., *Lamium maculatum* (L.) L., *Glechoma hederacea* L., *Aegopodium podagraria* L., coated 1-3%: *Poa nemoralis* L., *Asarum europaeum* L., *Viola odorata* L., *Polygonatum multiflorum* (L.) All., *Brachypodium sylvaticum* (Huds.) P.

Beauv., *Stachys sylvatica* L., *Chelidonium majus* L., singly, having about 1% – *Mycelis muralis* (L.)

Dumort., *Geum urbanum* L., *Scrophularia nodosa* L. and some other species (Fig. 3).



Figure 3. Areas of broad-leaved forests of the Moshnohirsky Ridge dominated by the transformer species *Impatiens parviflora* in the shrub-grass layer

Source: photos by Andrii Churilov ©

According to M. Hejda (2012), a minimal degree of negative impact of *I. parviflora* for native mixed grasses of living ground cover of forests is indicated due to a poorly developed root system and features of the phenology of annual populations. Shoots and active vegetation of *I. parviflora* is during the period of completion of flowering of ephemeroïds, which allowed researchers to assume a slight effect on their ability to grow and develop within forest communities (Burda, 2012; Hejda, 2012).

Results obtained by A. Florianová & Z. Münzbergová (2017) show that the negative impact that has *I. parviflora* on the native representatives in the vegetation cover of the recipient group can be levelled on a local scale by mechanically removing this transformer species from the plant group, which contributes to the restoration of the native grass tier for several years. However, physical withdrawal of *I. parviflora* from large plots is unrealistic in practice due to its intensive distribution, high seed productivity, and substantial economic costs.

In addition to the above example, other species that have substantial involvement in groupings (sometimes up to 20%) are *Erigeron annuus* (distributed in 8 biotopes), a widespread species with up to 10% coverage are *Quercus rubra* (distributed in 7 biotopes), *Robinia pseudoacacia* (distributed in 8 biotopes), *Acer negundo* (in 7 biotopes).

The data obtained coincide with those given for forest areas in Europe in general (Wagner et al., 2017), and for natural zones of Ukraine (Onyshchenko, 2019), where a substantial frequency of occurrence is noted for species that are widely distributed in the research area (*Impatiens parviflora*, *Robinia pseudoacacia*, *Quercus rubra*, *Bidens frondosa*, *Acer negundo*, *Erigeron annuus*), however, for such a species as *Prunus serotina* Ehrh., no distribution was observed within the research area.

The group, representatives of which are established locally includes *Acer saccharinum*, *Helianthus tuberosus*, *Juglans regia*, *Morus alba*, *Prunus cerasifera*, *Rudbeckia laciniata*,

Syringa vulgaris, meanwhile, the ability to actively spread and form stable populations for *Pinus nigra* subsp. *pallasiana*, *Celtis occidentalis*, *Prunus armeniaca*, *Vitis vinifera*.

The results show a weakening of the possibility of natural restoration of forest vegetation areas, which requires balanced approaches, both at the stage of reforestation, contributing to natural renewal for native species, and maintaining existing plantings with gradual removal, primarily of species that are listed as invasive with a substantial ability to spread uncontrollably (Order of the Ministry of Environmental Protection and Natural Resources of Ukraine No. 184..., 2023).

Considering the substantial distribution areas and the involvement of a number of alien species in the forest plant communities of the research area, a substantial violation of the structure of broad-leaved forest biotopes of the Moshnohirsky Ridge was identified.

Conclusions

It was established that the Moshnohirsky Ridge, as an area of high conservation value, which has substantial areas of broad-leaved and mixed forests, meadow and swamp biotopes, has substantially biologically polluted vegetation cover with alien vascular plant species – 48 species or about a third of the floral composition of broad-leaved forests.

A substantial potential threat to the native phytodiversity of the research area are kenophytes of the North American (*Echinocystis lobata*, *Amorpha fruticosa*, *Quercus rubra*, *Robinia pseudoacacia*) and Asian (*Impatiens parviflora*) origin, which successfully adapted to existence in the broad-leaved forests of the Moshnohirsky Ridge. Based on the analysis of species distribution in the studied habitats, it was consistently

observed that the highest number of alien species occurred in anthropogenically disturbed biotopes (Anthropogenic broad-leaved forests – 60.4%, Trampled habitats – 58.3%, Areas with recently removed tree layer – 56.2%). However, it is significant to note that these alien species are also present in natural forest biotopes (Central European oak-hornbeam forests – 35.4%, Subacidophilous species-rich oak and pine-oak forests – 29.2%), indicating disturbances in the structural integrity of their communities and providing conditions for their further transformation.

It was established that a numerical group is a group of plants whose representatives occur locally and do not show an active ability to spread further, for example, *Acer saccharinum*, *Celtis occidentalis*, *Gleditsia triacanthos*, *Oxybaphus nyctagineus*, which, with timely measures taken to remove them from the natural environment, will reduce the invasive activity of alien vascular plants in the region.

Further research in the region should be directed towards understanding the population structure of alien species, their impact on trophic and topical interactions within recipient ecosystems, as well as the development of methods to control their spread and weaken their ability to expand their range.

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Conflict of Interest

The authors declare no conflict of interest.

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Поширення чужорідних видів судинних рослин біотопами Мошногірського кряжу (Черкаська область, Україна)

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Анотація. Інвазії організмів несуть потенційну загрозу існуванню природних оселищ та призводять до збіднення біологічного різноманіття. Особливо негативний вплив помітно у межах Середнього Подніпров'я, де близько чверті представників судинних рослин належать до чужорідних видів. Метою дослідження було з'ясування сучасного видового складу чужорідних видів судинних рослин, особливості їхнього поширення за межами культури, натуралізація та участь у рослинних угрупованнях біотопів Мошногірського кряжу. Для досягнення мети проведено реєстрацію видового складу рослин за трансектами, а також здійснено геоботанічні описи місцезростань представників чужорідних видів рослин. Установлено, що рослинний покрив лісових та супутніх їм біотопів дослідженої території істотно забруднені чужорідними видами судинних рослин, які належать до 48 видів з 45 родів та 29 родин. *Значимою участю чужорідних видів відзначаються лісові біотопи грабово-дубових лісів – 35,4 %, дубових і сосново-дубових лісів – 29,2 %. Серед чужорідних видів, які мають суттєвий вплив на структуру рослинних угруповань вказаних біотопів широколистяних лісів є *Impatiens parviflora* DC., *Robinia pseudoacacia* L., *Acer negundo* L.* За часом занесення переважають кенофіти (81,3 %), значима кількість яких мають північноамериканське (43,8 %), середземноморське (16,7 %) та східноазійське походження (8,3 %). За показником проникнення до природних екосистем високі позиції посідають види, здатні активно проникати до складу природних угруповань – агріо- та агріо-епокофіти (сумарно 30,2 %). На противагу вказаним групам, в угрупованнях дослідженого регіону значимо представлено обмежено поширені чужорідні види без проявів активного розповсюдження – ефемерофіти і колонофіти (30,6 %). Виявлені закономірності щодо розповсюдження та ценотичного розподілу чужорідних видів є первинною основою для формування оптимальних заходів протидії новим інвазіям до лісових угруповань та стримування процесу ущільнення популяцій для видів, які вже мають широке розповсюдження досліджуваним регіоном

Ключові слова: адвентивна фракція; фітоінвазії; Середнє Подніпров'я; кенофіти; агріофіти; натуралізація