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# BIOECOLOGICAL ASSESSMENT OF THE STATE OF THE ADVENTITIOUS FRACTION OF THE DENDROFLORA OF RECREATIONAL AND PARK LANDSCAPES (DNIPRO)

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**Abstract.** The state of seed self-regeneration of woody plants of Kyrylivka Park (Dnipro, Ukraine) in areas with a strong, moderate and non-existent level of recreational load was studied. Floristic methods (estimates of species richness, determination of floristic community and homogeneity), methods of ecological analysis of vegetation, physico-chemical methods of soil analysis, statistical methods are applied. It was established for the first time that in Kyrylivka Park, artificial stands are capable of forming a sufficient amount of viable undergrowth of autochthonous (53.5 %) and introduced (46.5 %) species. The amount of tree growth of adventitious plants in the areas according to the level of recreational load is distributed as follows: with no load – 32.2 % of the number of self-regenerating trees, with moderate – 41.3 %, with strong – 89.7 %. The indices of species richness of Margalef and Menkhinik of self-regenerating tree species for the site with a strong recreational load turned out to be the largest (at the expense of adventitious species) compared to the sites with a moderate recreational load and without it. The calculated Koch index of biotic dispersion (40.0 %) indicates a certain process of floristic homogenization of the tree stand in the investigated territory of the park. The correlation coefficients between the number of self-restored allochthonous and autochthonous tree species for the studied areas with strong, moderate and absent recreational loads are significant (0.90, 0.92 and 0.88 respectively). The need to analyze and forecast the possible remote consequences of the introduction of alien species in the composition of the dendroflora is emphasized.

**Keywords:** autochthonous and alien species of plants, green zone of the city, tree plantations, seed self-regeneration.

## 1. Introduction

The assessment of the quality of the human living environment remains one of the urgent issues of ecology (Ivanchenko, 2015). Preservation of green spaces in cities, in particular parks, is an important condition for creating a favourable urban human habitat in connection with significant anthropogenic pressure. Therefore, the role of parks in large cities, where the conditions of anthropogenic impact on the environment every year endanger the ecosystems of the city, is invaluable. The most urgent problem is the preservation of flora, the components of which are the best medicine for human health and the main treasure of life (Shamray et al., 2021).

Green plantations improve the human environment and create comfortable living conditions. They regulate the thermal regime, purify and moisten the air, reduce the force of the wind, and improve the sanitary and hygienic situation of the city (Denisyuk et al., 2020; Du et al., 2022; Teixeira et al., 2022), and therefore affect the microclimatic conditions of the city (Melnychuk et al., 2019; Zhang, Gou, 2021). In addition, they are a place for the population to relax (Didur et al., 2019). A wide variety of forms, colors and textures of plants affects the psycho-emotional state of a person (Voiko et al., 2019). The decorative properties of plants contribute to the aesthetic

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satisfaction of people (Karagöz et al., 2017), and improve their emotional and psychological health (He et al., 2020). Therefore, the preservation of green areas in cities, in particular parks, is an important condition for improving the quality of the urban environment, people's health, and their quality of life in general (Liu, Xiao, 2020).

During the arrangement of parks, it is impossible to avoid species that are exotic for a certain area (introduced species). The issue of acclimatization and introduction of plants has always interested scientists (Trimanto, 2014; van Kleunen et al., 2018; Potgieter et al., 2019). Ukraine has made significant progress in the introduction and acclimatization of woody plants, and the number of species of trees and shrubs introduced to the country is several times greater than the number of native species that make up the natural dendroflora (Kohno, 1999, 2007; Vitenko et al., 2020). Thanks to the introduction, species of natural ecosystems in other regions of the world are preserved, biodiversity increases, and the living environment improves (Alvey, 2006). But invasive (allochthonous) species can spread spontaneously and pose a significant threat to local (autochthonous) species, displacing them from the local flora and occupying their ecological niches, which impoverishes the natural flora and can lead to biotic homogenization – increasing the similarity between the biota of different territories (Lososová et al., 2012; Shamray et al., 2021, 2022).

Among the various functions of green spaces in urban areas, recreation is of great importance. However, during the operation of recreational facilities, in the absence of constant care, there is a gradual decrease in the viability of plantations (Skrobala, Diniljuk, 1996). In this connection, the spread of invasive species to new territories is the greatest threat to global biodiversity, and we are already talking about biological invasions here (Macagnan et al., 2011), which can become a problem for the conservation of aboriginal species (Dongli et al., 2022; de Barros Ruas et al., 2022). The aim of the work is the bioecological analysis of the adventitious fraction of dendroflora and its diversity within recreational and park landscapes using the example of Kyrylivka Park (Dnipro, Ukraine).

## 2. Materials and Methods

The research was conducted on the territory of Kyrylivka Park (Dnipro). The park was founded in 1925 and is located on the left bank of the Dnipro (N 48°30'07", E 35°03'16") (Fig. 1). In physical and geographical terms, the territory of the park corresponds to the subzone of various grass-sedge steppes (Belgard, 1950). It has had its modern name (Park of Cossack Glory "Kyrilovka") since 2016. Its length is about 660 m, and its width is 207 m. It is located in a slight lowering of the relief, where groundwater locally reaches the surface of the day and forms aquatic ecosystems.

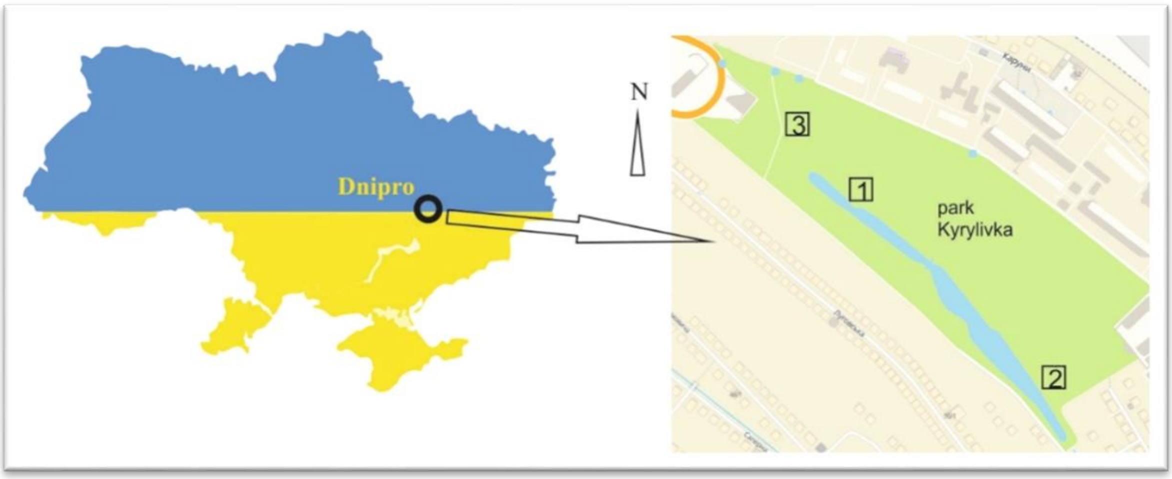


**Fig. 1.** Placement of trial sites within Kyrylivka Park on the territory of the metropolis (Dnipro)

The research was carried out during 2018–2022. Three stationary sites (Fig. 1) measuring 10 m × 10 m were selected for observations. During the selection of experimental sites, the main emphasis was placed on the sites where humans did not interfere in development processes for a long time, and plant communities were formed naturally. Each of the selected sites is characterized by a set of conditions that affect the development of vital indicators of tree species and their self-regeneration. The sites are located at almost the same altitude above sea level and are characterized by different levels of recreational load (Fig. 2): in site 1 – moderate, in site 2 – strong, in site 3 – absent.

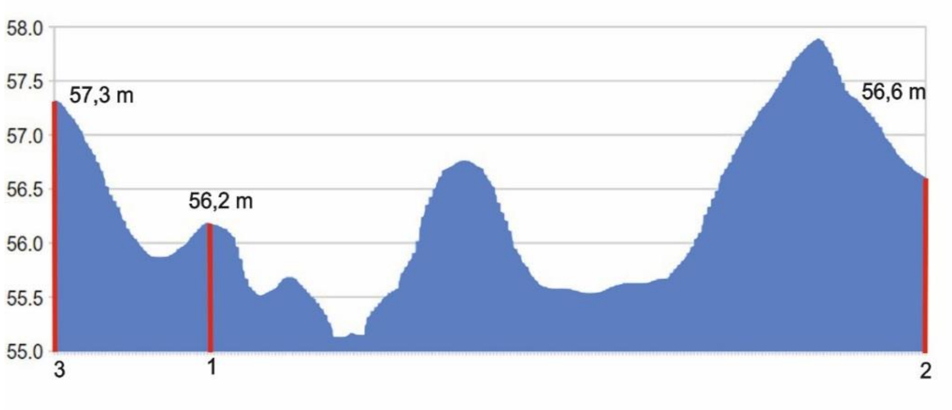


**Fig. 2.** Location of experimental sites in Kyrylivka Park (Dnipro) by altitude and level of recreational load: 1 – site with moderate recreational load, 2 – site with strong recreational load, 3 – site with no recreational load

The climate of the study region is moderately continental, characterized by warm summers andmoderately mild winters. However, there is also its specificity, associated with excessive drought at the end of the summer period and significant temperature fluctuations in the autumn-winter and winter-spring periods of the year (Lykholat et al., 2018, 2022).

In the course of the study, floristic methods were applied (inventory of taxonomic composition, comparative analysis of the species composition of native and introduced dendroflora plants, determination of floristic community and floristic homogeneity), methods of ecological analysis (by biomorphs and ecomorphs), physical, physicochemical, and chemical methods of soil analysis, statistical methods of data processing.

The species composition was determined according to Dobrochayeva et al. (1987), and plant nomenclature is given according to the Angiosperm Phylogeny Group classification (APG III, 2009). The coefficient of the floristic community of species between experimental sites (Jaccard index) was calculated according to (Kunz et al., 2009; Borges et al., 2011) and expressed as a percentage. To find out the level of floristic homogeneity, the Koch index of biotic dispersion (IBD) was used (Stikhareva et al., 2021). Ecological certification of plant species was carried out according to ecomorphs (Belgard, 1950). The clarification of ecomorphs was carried out according to the “Analysis of the flora of the Orilskyi National Nature Park” (Baranovski et al., 2017). The analysis of the biomorphological structure is based on the system of life forms of V. M. Golubev (Tarasov, 2012). The species richness of the flora of the experimental sites was evaluated according to the Margalef and Menkhinik indices (Battaglia, 2022; Divakara et al., 2022)

To determine the chemical and physical parameters of the soil, test samples were taken from the upper part of the root-saturated horizon (0–25 cm). Physico-chemical properties of the soil (pH $H_2O$ and pH KCl ) were estimated by the potentiometric method (Tan, 1998). The content of organic carbon (humus) was determined titrimetrically (according to Tyurin) (Shamrikova et al., 2022), dry residue – by weight method. The granulometric composition of the soil was determined according to N. A. Kaczynskii. All determinations were performed in triplicate.

The results of the chemical analysis were processed by the methods of descriptive statistics ($x \pm SD$). The relationship between the number of introduced and self-regenerating autochthonous species was evaluated using the correlation coefficient and the level of significance. Calculations from and existed in the Statistica 6.0 application program package.

## 3. Results and Discussion

According to the results of the agrochemical studies, the soils in the studied areas are represented by urbo-meadow-swamp medium and slightly saline salt marshes on modern alluvium, belong to the medium level of fertility and are favorable for landscaping with zonal tree and shrub plantings. Chemical and physical parameters of soils of the Kyrylivka park (sampling depth 0–25 cm) with different levels of recreational load (the first indicators correspond to the condition of the soil of the site with a strong recreational load): content humus, from 3.30 % to 5.21 %; dry residue, from 0.059 % to 0.262 %; pH $H_2O$ – from 7.86 to 7.39; pH of KCl – from 6.47 to 6.22; granulometric composition – heavy loam, with the number of particles of physical clay 48.7 % and silt, with the number of particles of physical clay 12.0 %.

Species such as *Acer negundo* L., *Fraxinus excelsior* L., *Quercus robur* L., *Morus alba* L. The height of the upper tier of the crowns of woody plant species in the forest stand of this area reaches 12–14 m. These are artificially planted *Acer negundo*, *Morus alba*, which make up 1,6% of the total number of woody plants of the research area and are 15 to 20 years old. Crown closure in this plantation is 68.2 ± 10.0 %, relative illuminance is 7.06 ± 0.30 %, the light structure is semi-shaded. The type of soil moisture is fresh. The grass cover of the site is mixed, from a sinuous structure to interspersed with individual species such as *Geum urbanum* L., *Lactuca serriola* L., *Solidago canadensis* L., *Chelidonium majus* L., *Erigeron annuus* L., *Galium aparine* L., *Carex sylvatica* Huds., *Arctium lappa* L., *Torilis japonica* (Houtt.) DC.

However, in this area there is a significant number of young plants (98.4 %), mainly self-sowing, young plants under 6 years old, in particular *Acer negundo* (41.3 %), *Fraxinus excelsior* (57.9 %), *Quercus robur* (0.8 %), which grew by natural regeneration. Among these plants, adventitious is *Acer negundo* (41.3 % of the total number of self-regenerating woody plants). The correlation coefficient between the number of introduced and self-regenerating autochthonous tree species is 0.92 (P = 0.03).

In the tree stand and in the shrub layer of site 2, with a strong recreational load, the following species occur: *Acer negundo*, *Ulmus pumila* L., *Quercus robur*, *Juglans regia* L., *Fraxinus excelsior*, *Salix babylonica* L., *Celtis occidentalis* L., *Morus alba*, *Populus nigra* L. The height of the upper tier of the crowns of woody plant species in the stand is 10–15 m. These are artificially planted plants: *Acer negundo*, *Ulmus pumila*, *Salix babylonica*, which make up 3.8 % of the total number of tree species in the entire sample area with an age of about 20–30 years. The canopy density in this plantation is from 67.4 ± 3.0 %, the relative illumination is from 2.86 ± 0.82 %, the light structure is semi-shade, and the type of soil moisture is fresh. The grass cover of the site is formed by such species as *Lactuca serriola* L., *Chelidonium majus* L., *Parthenocissus quinquefolia* L. (Planch.), *Geum urbanum* L., *Solidago canadensis* L., *Calamagrostis epigejos* L., *Erigeron annuus* L., *Gallium aparine* L., *Chenopodium album* L., *Campanula bononiensis* L.

In this area, under the main canopy, there is a significant number of young woody plants (96.2 %), mainly self-sowing, undergrowth under 10 years old, in particular *Acer negundo* (74.6 %), *Ulmus pumila* (7.9 %), *Quercus robur* (5.6 %), *Juglans regia* (4.8 %), *Fraxinus excelsior* (4.0 %), *Celtis occidentalis* (1.6 %), *Populus nigra* (0.8 %), *Morus alba* (0.8 %). Among the specified plants, the following species are adventitious: *Acer negundo*, *Ulmus pumila*, *Juglans regia*, *Celtis occidentalis*, *Morus alba*, which make up 89.7 % of the total number of self-regenerating woody plants. The correlation coefficient between the number of introduced and self-regenerating autochthonous tree species is 0.90 (P = 0.04).

In the tree stand and in the shrub layer of site 3 with no recreational load, the following species occur: *Acer negundo*, *Quercus robur*, *Fraxinus excelsior*, *Salix babylonica*, *Fraxinus pennsylvanica* Marsh.

The height of the tree stand in the plantation is 10–15 m. Its upper tier includes *Salix babylonica*, *Fraxinus excelsior*, which make up 2.7 % of the total number of woody plants. These are artificially planted plants with an age of 20–30 years. The canopy density in the plantation is 75.6 ± 7.0 %, the relative illumination is from 8.90 ± 0.48 %, the light structure is semi-shade, the type of soil moisture is fresh. The grass cover of the site is formed by the following species: *Parthenocissus quinquefolia* L. (Planch.), *Chelidonium majus* L., *Geum urbanum* L., *Lactuca serriola* L., *Agrimonia eupatoria* L., *Solidago canadensis* L., *Erigeron annuus* L., *Torilis japonica*, *Galium aparine* L.

However, in this area, there is a significant number of young plants (97.3 %), mostly self-sowing, young plants under nine years old, in particular *Acer negundo* (30.4 %), *Quercus robur* (0.3 %), *Fraxinus excelsior* (67.5 %), and *Fraxinus pennsylvanica* (1.7 %), which grew by natural regeneration. Among these young plants, Acer negundo, and Fraxinus pennsylvanica are introduced, which make up 32.1 % of the total number of self- regenerating woody plants. The correlation coefficient between the number of introduced and self-regeneratingautochthonous tree species is 0.88 (P = 0.05). The plant community of the studied area is represented by ten tree species (Table 1). Thus, in site 1, where the recreational load is moderate, there are three self-regenerating tree species, one of which is adventitious, and two are native species. *Fraxinus excelsior* dominates in number (57.9 %) and

*Acer negundo* (41.3 %) of the total number of self-sowing tree species.

In site 2, with a strong recreation load, there are eight self-regenerating tree species, five of which are adventive, and three are native species. *Acer negundo* dominates in number (74.6 %) of the total number of self- sowing tree species.

In site 3 with no recreational load, four self-regenerating tree species occur, two of which are adventive species, and two are native species. *Fraxinus excelsior* dominates in number (67.5 %) and *Acer negundo* (30.4 %) of the total number of self-sowing tree species.

The Margalef index of species richness for the site with a strong recreational load turned out to be the highest (1.64, due to adventive species), compared to the sites with a moderate level of recreation or its absence (0.54 and 0.70), respectively (Table 2). The same trend can be noted for Menkhinik's index of species diversity.

Evaluation of the qualitative commonality of the species composition of the experimental sites with self-regenerating tree species showed that there is a trend towards a decrease in the diversity of the flora of the sites due to an increase in the number of common species (Table 3).

*Table 1*

**Taxonomic composition of plant groups and bioecological characteristics of plant species of Kyrylivka Park**

| No. | Family of plants | Species of plants | Biomorphological and ecological characteristics of species | Amount of individuals, specimens | | |
|---|---|---|---|---|---|---|
| | | | | Sites | | |
| | | | | 1 | 2 | 3 |
| 1 | Cannabaceae | *Celtis occidentalis* L. | Arb, Ph, SilCu, OgMs–Mg Tr, MsKs, ScHe, Anph, Adv | – | 2 | – |
| 2 | Fagaceae | *Quercus robur* L. | Arb, tap root, vegetatively immobile, Ph, Sil, OgMs–AlkMgTr, MsKs–MsHg, ScHe, Ent, Synz | 2 | 7 | 1 |
| 3 | Juglandaceae | *Juglans regia* L. | Arb, vegetatively immobile, Ph, SilCu, MsMgTr, Ms, He, Anph(Ent), Synz, Adv | – | 6 | – |
| 4 | Moraceae | *Morus alba* L. | Arb, tap root, vegetatively immobile, Ph, SilCuRu, MsTr, KsMs, ScHe, Anph, Endz, Adv | 1 | 1 | – |
| 5 | Oleaceae | *Fraxinus excelsior* L. | Arb, tap root, vegetatively immobile, Ph, Sil, MsMgTr, KsMs–MsHg, ScHe, Ent, Anch | 147 | 5 | 199 |
| 6 | Oleaceae | *Fraxinus pennsylvanica* Marsh. | Arb, tap root, vegetatively immobile, Ph, Sil, MsTr, KsMs, ScHe, Ent, Anch, Adv | – | – | 5 |
| 7 | Salicaceae | *Salix babylonica* L. | Arb, Ph, Sil, MsTr, Ms, He, Ent, Anch, Adv | – | 2 | 4 |
| 8 | Salicaceae | *Populus nigra* L. | Arb, Ph, Sil, MsT, Ms, ScHe, Anph, Anch | – | 1 | – |
| 9 | Sapindaceae | *Acer negundo* L. | Arb, Ph, SilCuRu, Og–MgTr, MsKs–HgMs, He, Ent, Anch, Adv | 108 | 96 | 88 |
| 10 | Ulmaceae | *Ulmus pumila* L. | Arb, tap root, root sprout, vegetatively mobile, Ph, Sil CuRu, OgMsTr, MsKs, ScHe, Anph, Anch, Adv | – | 11 | – |

**Notes.** *Life forms*: Arb (arbor) – tree, Fr (frutex, fruticetum) – bush (brush); Ph – phanerophytes, nPh – low trees, tall bushes; *Ecomorphs*: OgTr – oligotrophs, MsTr – mesotrophs, MgTr – megatrophs, AlkTr – alkotrophs; Ks – xerophytes, Ms – mesophytes, Hg – hygrophytes; He – heliophytes, Sc – sciophytes; Ru – ruderants, Sil – sylvants, Cu – culturants; *Diasporochores* (*ecobiochores*): Endz – endozoochores, Anch – anemochores, Bal – ballistas, Bar – barochors, Synz – synzoochores. *Pollenochores*: Anph – anemophilia, Ent – entomophilia. Adv – adventitious species.

*Table 2*

**Indices of species richness of the studied areas of Kyrylivka Park in the territory of megacities depending on the level of recreational load**

| Indicator | Recreational load | | |
|---|---|---|---|
| | moderate (site 1) | strong (site 2) | absent (site 3) |
| Margalef index | 0.54 | 1.64 | 0.70 |
| Menkhinik index | 0.25 | 0.79 | 0.29 |

*Table 3*

**Qualitative community of experimental sites with self-regenerating tree species, under conditions of different levels of recreational load of Kyrylivka Park**

| Recreational load | Moderate (site 1) | Strong (site 2) | Absent (site 3) |
|---|---|---|---|
| Moderate (site 1) | (4) | **4** | **3** |
| Strong (site 2) | 44.4 % | (9) | **4** |
| Absent (site 3) | 50.0 % | 40.0 % | (5) |

**Note.** The number of species in parentheses, the number of common species in bold.

To establish the floristic homogeneity of the experimental sites, the Koch index of biotic dispersion was calculated, the value of which is 40.0 %. This indicates a relatively high level of floristic homogenization in the territory of the park.

Degradation and destruction of natural ecosystems (Adla et al., 2022) are considered as the main cause of terrestrial biodiversity loss worldwide (Fernández-Palacios et al., 2021; von Staden et al., 2022). In these studies, the authors discuss the theoretical and practical aspects of each of the indirect drivers, as well as the direct human impact on biodiversity. These studies include monitoring human impact on land cover, the impact of land use on species diversity. As shown by Rosenthal et al. (2022), recreational activities are one of the most common threats to species at risk. In the studies of da Rocha et al. (2020) showed that landscape position (relief) is not a specific factor that controls soil quality and determines the ability of these areas to provide ecological services, but observed variations in soil quality are a consequence of differences in land use practices. This conclusion also confirms our methodological approach regarding the division of the studied territory of Kyrylivka Park in the conditions of a metropolis into areas with different levels of recreational load (strong, moderate and absent).

Lakicevic et al. (2022) studied the dendrofloristic diversity of five city parks located in Novi Sad (Serbia). These scientists emphasized that biodiversity indices provide key information for monitoring species diversity. They found that parks play an important role in maintaining biodiversity in cities, as they provide habitat for native vegetation and support natural processes in ecosystems. According to their research, the Jaccard index between the parks varied from 41.4 % to 72.4 %, which indicated trends of probable homogenization and was explained by the influence of climatic conditions and management methods. In our study the Jaccard index between all sites is almost close in magnitude and ranges from 40.0 % to 50.0 % (Table 3). This proves that there is a certain similarity of the dendroflora of the areas and there is a tendency towards their homogenization, which is confirmed by the value Koch's index of biotic dispersion, which is equal to 40.0 %.

Lakicevic et al. (2022) analyzed invasive tree species in parks in Serbia, noting that such species may contribute to biodiversity loss in the long term. According to their data, the share of non-native species ranged from 40 % to 57 %. Species *Acer negundo*, *Ailanthus altissima* and *Ulmus pumila*, due to their high spread potential, turned out to be the most aggressive invasive species. These authors note that these species are frequent invasive species throughout Serbia. In our study, adventitious species consist of 32.2 % to 89.7 %, which correlates with the different recreational load of the studied areas.

A wide range of scientists emphasizes the need to carefully monitor the emergence of invasive species, as they can potentially affect the loss of biodiversity in the long term (Guo et al., 2022; Xu et al., 2022) and practical application of appropriate measures, mainly including mechanical removal of the most aggressive invasive species to control their further spread (Lakicevic et al., 2022). According to our research, positive invasiveness of *Acer negundo* was noted among adventive species, also happens invasive species *Ulmus pumila*.

Zarghi, Hosseini (2014) investigated the impact of ecotourism on plant biodiversity in the Chelmir Tandoore zone (Khorasan-Razavi Province, Iran). To characterize the species richness of the national park, these scientists used both the Margalef and Menkhinik indexes and showed that the Margalef index varied from 1.4 to 0.6, and the Menkhinik index from 0.8 to 0.5, respectively, from the low recreational load to high. The obtained values of the indicators are associated with the influence of ecotourism, which can be considered as one of the forms of recreational load. In our study, these indicators vary from 1.64 to 0.54 (Margalef index) and from 0.79 to 0.25 (Menkhinik index), respectively, from high to low recreational load. This pattern, in our opinion, can be explained by the greater number of adventive species in the area with a strong recreational load of Kyrylivka Park.

## 4. Conclusions

It was established that 10 tree species that are capable of seed self-regeneration and which belong to 9 genera and 8 families occur in experimental areas with different degrees of recreational load of Kyrylivka Park in the conditions of the city (Dnipro, Ukraine). Of these, 7 adventive species were registered, taxonomically represented by 7 genera and 7 families with the leading family *Sapindaceae* (in quantitative terms). Among the adventitious tree species, for which invasiveness is known within the study region, maple *Acer negundo* (family *Sapindaceae*) shows the highest activity in the experimental areas. Its total number in all areas is a record (292 specimens), while in the area with a strong recreational load, the share of this species is 74.6 % of the total number of undergrowth of seed origin, which is explained by a combination of environmental and anthropogenic factors. The indexes of species richness of Margalef and Menkhinik of self-regenerating tree species for the site with a strong recreational load turned out to be the largest (due to adventitious species) compared to the sites with no or moderate recreational load. Koch's index of biotic dispersion (40.0 %) indicates a certain process of floristic homogenization in the studied territory of the park. Therefore, the ecological analysis of the biodiversity of the self-regenerating dendroflora and its adventitious fraction for the conditions of Kyrylivka Park allowed to reveal, in addition to the positive invasion of Acer negundo, the occurrence of such neophyte species as Celtis occidentalis and Ulmus pumila, which indicates the constant invasion of alien species into the local flora and potential threat to natural floral diversity. In the future, it is necessary to predict the possible consequences of the introduction of alien species in the composition of the dendroflora of Kyrylivka Park in the conditions of a city.

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