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α-Diversity of plant communities, forest birds and wood-decaying fungi in urban parks of a metropolis

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Abstract

The biodiversity of urban parks is an indicator object of monitoring biodiversity under conditions of constant recreational pressure. The main approaches to these issues are based on measuring the indices of vertical and horizontal heterogeneity of parklands, which make it possible to identify links between plant, wood-decaying fungi and bird diversities. As in the case of Kyiv, Ukraine, we augmented existing published data with new compositions, links and α-diversity indices of plant, fungi and bird communities in the parks of a metropolis! The infraction of α-diversity (diversity, dominance, and evenness indices) and the compositions in the communities depending on the level of recreational transformation of the parks were established. The main driving factors of α-diversity in urban parks were shown. Further research is needed to use these relationships to indicate the state of park ecosystems.

Keywords: plant, vegetation, forest birds, wood-decaying fungi, recreational impact, diversity index, dominance index, evenness index

Introduction

Biodiversity conservation is an important component of the sustainable development of each city. Occupying less than 6% of Europe's area Ukraine possesses 35% of its biodiversity (MENRU 2015). Parks are among the sites of conservation and enrichment of biodiversity. The birds and wood-decaying fungi are widely represented in cultural parklands. The biodiversity of urban parks is an indicator of monitoring biodiversity under constant man-made pressure. The main ecological threats to biodiversity in urban areas are related to man-made activities, which include the transformation and degradation of habitats, over exploitation of ecosystem resources, the spread of alien species, pests and diseases, excessive recreational activities, etc. The pollution of urban areas is caused by emissions of point and mobile pollution sources emitting the most dangerous substances for green plantations, such as NH_3, NO, NO_2, NO_3, SO_2, formaldehyde, phenol, and trace metal ions, into the surface layer of the atmosphere. 85% of air pollution in the city is caused by vehicle emissions (Blinkova et al. 2020).

The study of the overall biodiversity of urban parks, and its drivers as specific environmental phenomena is presently topical (Blinkova and Ivanenko 2014, Blinkova and Shupova 2018, Blinkova et al 2020). In this context, the community relations of woody plants, forest birds and wood-decaying fungi should be highlighted. Consideration of the transformation of links in the line of "plant vegetation – forest birds – wood-decaying fungi" in the deepening knowledge on recreational changes of parklands is important. Therefore, the number of studies on the search for informative diagnostic indicators of environmental change in urban parks has been growing rapidly. The most important functional role of aphilophoroid macromycetes in forests and parks is the succession of various compositions of tree vegetation (tree weakening, stand damage, accumulation of woody debris and the rate of its decomposition by fungi) (Storozhenko et al. 1992, Arefev 2010, Blinkova and Ivanenko 2014, 2016, 2018). The birds easily prevail transformed urban habitats (Palomino and Carrascal 2005, Sekercioglu 2006, Fischer et al. 2007, Khera et al. 2009) and adapt to the existence of constant man-made and recreational pressure. Variations in the certain characteristics of tree stand formed under man-made influence make it possible to identify bonds between plant vegetation parameters and bird communities (Blinkova and Shupova 2018). The degree of the structural complexity of parklands is the main indicator of the links between bird and plant communities (Hinsley et al. 1995). In general, the obtained data indicate the presence of certain relationships between the floristic diversity of parks and the bird and fungi communities. The main approaches to these issues are based on measuring the indices of vertical and horizontal heterogeneity of ecosystems, which allow to identify links between plant, aphilophoroid macromycetes and bird diversities (MacArthur and MacArthur 1961, Conner and Dickson 1997, Willson et al. 2001, Blinkova et al. 2020). Thus, the relevance of the study is beyond doubt.

Considering results of previous studies, we hypothesized that: 1) α-diversity of plant, bird, and wood-decaying communities depends on the level of recreational transformation of urban parks; 2) the indices of vertical and horizontal heterogeneity, diversity, dominance and evenness of studied communities does not have a stability since they depend on the level of recreational transformation. The study aimed to assess the compositions and diversity rate of plant, wood-decaying fungi and bird communities depending on recreational pressure on the city parks of the metropolis, on the example of Kyiv.

Material and methods

Study site

The urban parks of Kyiv were selected for the investigations since the human impact is maximised in these site amenities.

Kyiv is situated on the right and left banks of the Dnipro River at the border between the Forest-Steppe zone and the Polissya of Ukraine following the geo-botanical division of Ukraine. The area of the city is 835.6 km², of which 43.6 km^2 (5.2%) are park areas. The climate is of a semi-continental type which is characteristic of the Forest-Steppe zone. The geomorphologic structure of Kyiv belongs to 3 zones: South Polissya, Dnipro, and Azov-Dnipro ones. Soddy-podzolic soils, grey forest soils and sod meadow soils are the main soil types in Kyiv area. Kyiv is located at the transitional belt between two geobotanical zones, European broad-leaved forests, represented by the sub-province of mixed coniferous-broad-leaved forests of Polissya, and the European steppe region, represented by the Ukrainian forest-steppe sub-province of oak forests, steppificated meadows and meadow steppes (Andriienko et al. 1977). In the survey conducted between September 5–25, 2018, we distinguished four parks in Kyiv.

Within each park studied, the mapping of dominant tree vegetation was carried out at experimental plots EP1–EP4 (EP1 − Park 'Peremoha', EP2 – 'Maksym Rylskyi' Park, EP3 − Park 'Syretskyi Hai', EP4 – Park 'Nyvky', a landmark of landscape art). All experimental plots represent the parks and were chosen using the biological reconnaissance method. Each experimental plot was established according to the detailed route method (Mirkin et al. 2002). By taking into account basic characteristics of recreational changes of parks in Kyiv (the state of tree stratum, undergrowth, soil surface layer, herbaceous cover and leaf litter), the level (II–V) of recreational transformation rate was specified for each experimental plot from minimal to maximal consequences (Rysin et al. 2003).

Plant community description

Four experimental plots 100 × 100 m (EP1–EP4) for phytocenotic characteristics were laid out in each city park. Field studies were conducted using standard ecological and botanical methods (Mirkin et al. 2002). We identified the species in the field, and all identifications were verified in the laboratory. Taxa nomenclature was given after Mosyakin and Fedoronchuk (1999), considering the "International Code of Nomenclature for algae, fungi, and plants" (Turland et al. 2018). Ecological strategy types were described according to Grime (1977). The adventivization index of plant communities was calculated according to Burda and Ihnatiuk (2011):

$$I_{adv} = \frac{S_{adv}}{S}, \quad (1)$$

where

S_{adv} is the number of adventitious species;

S is the total number of species.

Morphometric parameters of stand were calculated by an optical altimeter Suunto PM-5 and callipers Waldmeister 100 alu. Trees and shrubs were considered mechanically damaged if they had a felled or sawn branch, a wound on the trunk up to the cambium, or obvious signs of such damage regardless of the time when they were inflicted. The tree health condition (category of tree state) was determined by a set of morphological features (crown density, colour and nature of leaf distribution, damage by insects and pathogens, the condition of the bark, the presence of dry branches, etc.) and evaluated according to the following (The Cabinet of Ministers of Ukraine 1995) The stand state index was calculated using the formula:

$$I_S = \frac{\Sigma\, k_i n_i}{N}, \quad (2)$$

where

k_i is the category of tree state (I–VI);

n_i is the number of trees in a certain category of tree state;

N is the total number of trees.

The stands with index values ranging from 1 to 1.5 are considered as healthy (I), 1.51−2.50 as weakened ones (II), 2.51−3.50 as heavily weakened ones (III), 3.51−4.50 as wilting ones (IV), 4.51−5.50 as recently dead (V) and 5.51−6.50 old dead stands (VI).

To avoid the influence of the irregular intensity of silvicultural practice upon the index of stand state, for each category of states the weighted average Kraft classes

(*WAKC*; vitality composition of tree vegetation) was calculated (Blinkova and Ivanenko 2014):

$$WAKC = \frac{\Sigma\, k_{kc} I_C}{n_i} \quad , \tag{3}$$

where

k_{kc} is the number of trees in each Kraft class;
I_C is the stand state index;
n_i is the number of trees in a certain state category.

Indices of horizontal heterogeneity of vegetation and vertical heterogeneity of vegetation (IHH and IVH, respectively) were calculated to describe the woody vegetation composition as the feeding and breeding stations of birds on trees as well as a nutrient substrate for wood-decaying fungi (Sekercioglu 2002):

$$IHH = \frac{S.D.AD}{AD_{ave}} \quad , \tag{4}$$

where

AD is the distance between the trees;
AD_{ave} is the average distance between trees;
$S.D.$ is standard deviation.

IVH is the Shannon-Weaver diversity index for vertical vegetation distribution. The condition of the soil surface layer was described after Poliakov and Plugatar (2009).

Birds community surveys

Bird community surveys were conducted using the generally accepted method of bird counting on transect method (Bibby et al. 2000, Gregory et al. 2004) on the experimental plots in forest parks of Kyiv from May to June 2018. Eleven transects from 800 to 1,000 m long and 100 m wide have been established on 4 experimental plots. To determine the average bird nesting density (pairs/ha), the standard deviation was calculated. We compared the bird communities by the share of ecological groups in general and the share of nesting strategies of birds on the trees (Blinkova et al. 2020). An analysis of the ecological groups of communities was carried out according to Belik (2006). The synanthropization index of nesting bird communities was calculated after Jedryczkowski (Klausnitzer 1996):

$$W_S = \frac{L_S}{L_O} \quad , \tag{5}$$

where

L_S is the number of synanthropic species;
L_O is the total number of species.

Species of birds forming both synanthropic and natural populations were isolated into the group of hemi-synanthropes and those that nest only in urban habitats in Ukraine – into the group of obligate synanthropes. The presence of invasive alien species in the species composition was evaluated.

According to the source of food, we divided the birds into 6 groups: 1 – collect food mainly in tree canopies (on thin branches, leaves, buds, fruits – Golden Oriole (*Oriolus oriolus*), Blackcap (*Sylvia atricapilla*), warblers (*Phylloscopus*); 2 – feed in canopies and on the main thick branches (Great Tit (*Parus major*)); 3 – collect invertebrates on tree trunks and main branches (woodpeckers (*Picidae*), Nuthatch (*Sitta europaea*), Eurasian Treecreeper (*Certhia familiaris*)); 4 – gather food in the canopy of the lower tiers and on the ground (flycatchers (*Ficedula*, *Muscicapa*), European Robin (*Erithacus rubecula*), Thrush Nightingale (*Luscinia luscinia*), European Greenfinch (*Chloris chloris*), Blackbirds (*Turdus merula*)); 5 – fed mainly on the ground (birds of order Columbiformes), Tree Pipit (*Anthus trivialis*), Linnet (*Acanthis cannabina*)); 6 – birds that use a wide range of foraging statia, including ravage the other species' nests – Eurasian Jay (*Garrulus glandarius*), Eurasian Magpie (*Pica pica*), Hooded Crow (*Corvus cornix*).

Data collection and determination of fungi

The ecological research was performed in each experimental plot at different diagnostic levels of wood-decaying fungal existence: organ, tree, population, community. According to Arefiev (2010), the measuring unit is a host tree, on which carpophores of certain fungi species were detected. No less than 100 trees in each experimental plot of all studied parks were analyzed for the development of fruiting bodies of wood-decaying fungi. The collection of factual evidence was carried out during the period of the visible growth and the formation of carpophores of wood-decaying fungi in the vegetation period. The determination of fungi species was based on the methods of Eriksson et al. (1973–1988), Bondartseva (1953), Clémençon (2009) and Bernicchia (2005). The scientific names of fungi and their macrosystems are given according to CORTBASE v. 2.1 (Parmasto et al. 2004) and MycoBank (Robert et al. 2005). The analysis of the functional composition of wood-decaying fungi communities was based on the distribution of wood-decaying fungi on trees. The fungi were classified into four functional groups as follows: eurytrophes of I rank (fungi that develop on different genera of coniferous and deciduous trees), eurytrophes of II rank on coniferous trees (fungi that develop on different genera of coniferous trees), eurytrophes of II rank on deciduous trees (fungi that develop on different genera of deciduous trees), and stenotrophes (fungi that develop on only one genus of woody plants) (Mukhin and Kotiranta 2001).

The dead substrate of the host trees of wood-decaying fungi was divided into three categories, namely deadwood, fallen wood (branches and stems) and stumps. The analysis of the spatial composition of the communities of wood-decaying fungi was based on the distribution of fungi in myco-horizons: root, ground, stem base, stem and canopy (Blinkova and Ivanenko 2016). Stages of decomposition of dead wood and determination of fungal successional stages comminities were not conducted in this study.

Statistical analyses

Mathematical processing of the research results was carried out according to the evaluation indicators of the richness of biodiversity groups following the recommendations given by Magurran (1998). To compare the bird, fungi and plant species diversity of the different EPs, some commonly accepted indices expressing the correlation between the number and density of species were calculated. Since none of the currently developed indices is universal, several commonly accepted indices have been analyzed, as well as data on the relative number (abundance) of indicator species in the community, the formulas of which are provided by Magurran (1998).

1) the relative abundance of species in communities:

$$N = \Sigma N_i , \quad (6)$$

2) dominance indices:

$$D = \Sigma \frac{P_i(N_i - 1)}{N - 1} , \quad (7) \text{ Simpson}$$

$$U = \frac{N - U}{N - \sqrt{N}} , \quad (8) \text{ McIntosh}$$

3) diversity indices:

$$H = -\Sigma (P_i \cdot \ln P_i) , \quad (9) \text{ Shannon}$$

$$D_{Mn} = \frac{S}{\sqrt{N}} , \quad (10) \text{ Menchinick}$$

$$D_{Mg} = \frac{S - 1}{\ln M} , \quad (11) \text{ Margalef}$$

$$D_S = \frac{1}{D} , \quad (12) \text{ Simpson}$$

$$U = \sqrt{\Sigma N_i^2} , \quad (13) \text{ McIntosh}$$

4) evenness indices:

$$E = \frac{H}{\log S} , \quad (14) \text{ Pielou}$$

$$U_S = \frac{N - U}{N - \frac{N}{\sqrt{S}}} , \quad (15) \text{ McIntosh}$$

where

N_i is the density of each species in the community;

N is the total density (the number of individuals per hectare);

S is the total number of the species;

P_i is the ratio of each species.

The assessment of the evenness of the species by abundance was conducted based on a comparison of the rank curves of the relative abundance of species in communities of plants, fungi, and birds. Species abundance distribution is the most complete mathematical description of all the information collected from a community (Magurran 1998).

Data processing was performed using OriginPro 9 software package (OriginLab 2012) designed for scientific graphing and data analysis. Descriptive statistical analysis was used for the general analysis of the obtained field data (min, max, mean, standard deviation, standard error). Interdependence relationships between diversity, dominance, and evenness indicies of the plant, birds and fungi communities were quantified by correlation analysis (matrix), for which statistical certainty was also determined ($p < 0.05$; $p < 0.01$; $p < 0.001$). The hierarchical cluster analysis was conducted between the α-diversity indices of studied communities and the recreational parameters of the transformation of urban parks.

Results

The level of the man-made transformation of the city parks was determined. The studied parks were ranked based on the human impact and the stages of recreational transformation of land from minimum to maximum levels as follows: EP1, EP2, EP3, and EP4. The integral levels of recreational transformation of the city parks were II (EP1), III (EP2), IV (EP3) and V (EP4), accordingly.

Plant community

Tree stand

A detailed description of forestry and morphometric parameters of tree stands (*Quercus robur* L., *Carpinus betulus* L., *Acer platanoides* L., *Tilia cordata* Mill, *Ulmus glabra* Huds., *A. hippocastanum* L.) was given in Appendix 1. A mechanical damage of stands in the EPs was given in our previous work (Blinkova and Ivanenko 2014). The studied tree stands on the EPs of the surveyed parks are weakened. Changes in the composition of the phytosanitary state of the tree stand and vitality composition were detected depending on the level of recreational transformation.

The largest shares of healthy trees were recorded on EP1 and EP2 (32.5% and 37.2%, respectively), and the smallest one was on EP4 (15.7%). The largest share of trees belonging to the III category of tree state was found on EP4 (34.3%), which is due to the proximity of the transport network and residential areas to the park. The share of weakened trees on EP1–EP4 varies almost equally (31.1%–39.7%). The share of drying trees is the lowest on EP3 (5.7%). Given the constant human care for the condition of trees, trees that would belong to the V category, have not been found in the studied parks of Kyiv. The general index of phytosanitary conditions varies for each EP as follows: 1.98; 2.09; 2.23; 2.44, respectively.

The analysis of the tree vitality composition in the parks of Kyiv showed that the trees of the highest Kraft class (I) occur only on EP1 and EP2. The trees of the II and III Kraft classes prevail. WAKC values for EP1–EP4 indicate the development of pathological processes in the system since the drying of trees here is not a natural loss. On EP1 the trees of the II–III Kraft classes were drying. WAKC values were 2.4 and 3.2 for weakened and heavily weakened trees, respectively. WAKC of wilting trees was 4.0, indicating that mainly trees of the IV Kraft class suffer from wilting. The analysis of generalized vitality composition on EP2 indicates a more considerable transformation of the dominant tree species compared to EP1. WAKC for weakened and heavily weakened trees was 2.2 and 2.9, respectively, indicating the wilting trees of the II Kraft class. It should be mentioned that the WAKC of wilting tree species indicates the dying of trees of the III Kraft class. Evaluation of the vitality composition of trees on EP3 and EP4, which have the highest rates of phytocoenosis transformation, showed that the dying of phanerophytes is not a natural process. In particular, the WAKC values for weakened and heavily weakened trees on EP3 indicate the wilting of the high Kraft class trees. On EP4, even the II Kraft class trees are among the dying ones.

Herbaceous layer

The structural changes in the herbaceous layer (systematic, species, ecological, ecomorphological compositions) of the EPs were detected. The projective cover degree of the herbaceous layer of the EPs was within 25.55%–83.01% (Appendix 2). In total, the species composition of herbaceous vegetation of spontaneous flora on the EPs was represented by 55 species of vascular plants belonging to 41 genera and 15 families. The spectrum of leading families of herbaceous plants on the EPs was formed by the following: *Poaceae:* 11–14 species, or 25.6%–36.8% of the total number of species, *Asteraceae*: 6–14 species, or 15.9%–30.4%; *Convallariaceae*: 5 species, or 13.2%; *Scrophulariaceae*: 3 species, or 7.9%; *Rosaceae*: 2–7 species, or 5.3%–15.2%; *Lamiaceae*: 2–4 species, or 5.3%–9.5%; *Fabaceae*: 3 species, or 6.9%; *Plantaginaceae*: 2 species, or 4.8%; *Brassicaceae*: 5 species, or 10.9%; 6 families with 1 species, or 2.2%– 2,6%. The dominating species at the II and III levels of recreational transformation (EP1, EP2) were forest species (*Asarum europaeum* L., *Convallaria majalis* L., *Melampyrum pratense* L., *Pteridium aquilinum* (L.) Kuhn, *Polygonatum odoratum* (Mill.) Druce, *Viola odorata* L., *Stellaria holostea* L., etc.). The dominating species at the IV and V levels of recreational transformation (EP3, EP4) were ruderal and adventitious species which are common along paths and trails (*Ambrosia artemisiifolia* L., *Capsella bursa-pastoris* L., *Chelidonium majus* L*., Dactylis glomerata* L., *Echinocystis lobata* (Michx.) Torr. et A. Gray et al., *Elytrigia repens* L., *Iva xanthiifolia* Nutt., *Malva sylvestris* L.*, Plantago major* L.*, Solidago Canadensis* L., *Stenactis annua* L.*, Urtica dioica* L. *Xanthium strumarium* L., etc.). The adventivization index varies more broadly: 41.3; 48.8; 84.2; 89.6 (EP1– EP4, respectively).

Analysis of the distribution of ecomorphs based on water availability has shown that mesophytes were dominated in herbaceous layers on all EPs. Evaluation of the ecological strategy of the species showed that species with a secondary type of ecological strategy are the most represented on all EPs (Appendix 3). Species with CSR strategy were mostly represented (35.5%–54.5%). Among the species with the primary strategy, C- and S-species predominate at the II and III levels of recreational transformation (EP1, EP2). R-species are the most represented at the IV and V levels of recreational transformation (EP3, EP4). The contribution of SR-species is minimal on EP4, but on EP2 and EP3 the shares of species with this ecological strategy are approximately the same (6.2%–6.9%).

Soil surface

The total indicator of the state of soil surface on the EPs ranged from the II to V stage of digression (Appendix 4). The damaged areas occupied 9.1%–45.5% of the total area of soil surface. The maximum values of indicators of the damaged soil surface were found at the V level of recreational transformation.

Nesting bird communities

Altogether, 52 bird species of 19 families and 8 genera have been observed on the EPs, 47 of them (90.38%) are subject to protection by the Berne, Bonn and Washington Conventions. In total, there were 49 nesting species in all the EPs, with an average density of 1.19 ± 0.62 pairs/ha. In all bird communities, the Great Tit, *Parus major,* is the most numerous. The list of dominants is supplemented by the Common Chaffinch, *Fringilla coelebs*, the Blackbird, *Turdus merula*, the European Starling, *Sturnus vulgaris*, the Fieldfare, *Turdus pilaris,* House Sparrow, *Passer domesticus*, Field Sparrow, *Passer montanus,* and Rock Dove, *Columba livia* (Appendix 5). Alien species, such as Collared Dove, *Streptopelia decaocto,* and European Serin, *Serinus serinus,* were registered only on EP1.

In general, the avifauna of the surveyed area was divided into relevant ecological groups, among which the group of bird which living in tree plantations was represented by 39 species (79.60%, $n = 49$). Of these, by 14 species, or 35.90% ($n = 39$) each, nested both in hollows and tree canopies were observed, 5 species (12.82%) nested on the ground, and 6 species (15.38%) nested in the undergrowth. Obligatory synanthropes such as the House Sparrow, Rock Dove, Collared Dove and European Serin have been registered in each EP, except PP3. The synanthropization index for EP1–EP4 was 0.76, 0.87, 0.57 and 0.71, respectively. In total on the EPs, 3 species of woodpeckers made hollows: Gray-headed Woodpecker, *Dendropicos spodocephalus*, Great-spotted Woodpecker, *Dendrocopos major*, and Middle-Spotted Woodpecker, *Leiopicus medius*. In total, 12 bird species were registered that use ready-made hollows for nesting.

The most numerous among forest birds were entomophagous (22 species), which feed mainly on invertebrates. Bird species, which were characterized by a mixed type of foraging, rank second in number (8 phytoentomophagous species and 3 polyphagous ones), viz. the Eurasian Jay, *Garrulus glandarius*, Eurasian Magpie, *Pica pica*, Hooded Crow, *Corvus cornix*. The share of predatory birds (European Sparrowhawk, *Accipiter nisus,* and Long-eared Owl, *Asio otus*) was the smallest (5.13%, $n = 49$). Phytophages were represented by a small group of purely grain-eating birds (Wood Pigeon, *Columba palumbus*, and Eurasian Collared Dove, *Streptopelia decaocto*). In general, the proportion of entomophagous and phytophages can be considered as stable. In general, they are dominated by species that feed on tree canopies, or equally in canopies and on the ground: 10 species, or 25.64%, and 12 species, or 30.77%, respectively, $n = 49$). The least represented polystacial birds were the polyphages described above and the birds that forage in the canopy and branches (7.69% each). On the gradient of recreational transformation of city parks, the proportion of birds foraging in tree canopies (4.76%–14.81%) and those who forage on the ground (4.76%–7.41%) increases in bird communities. The proportion of birds foraging in canopy in combination with ropes (14.29%–11.11%), tree trunks (23.81%–18.52%) and on the ground (42.86–37.04%) is declining.

Wood-decaying fungi composition

Altogether 20 species (111 findings) of macromycetes were found at the EPs, the fruiting of which occurs in autumn. These fungi species represented by 12 genera, 12 families, 5 orders of Agaricomycetes, division Basidiomycota. The species composition of communities of wood-decaying fungi in city parks depends on the level of recreational transformation. The maximum number of species and findings of wood-decaying fungi were detected on EP4 (14 spp., 51 find.). However, the minimum number of species and findings were noted on EP1 (3 spp., 12 find.). The most signifucant number of findings of wood-decaying fungi was detected on living trees of *Quercus robur* L. corresponding to the I–IV categories of tree state.

The first-order eurytrophs among the detected wood-decaying macromycetes were not registered. Most fungi (15 species, 83.6% of the number detected) belonged to the second-order eurytrophs growing on deciduous trees, viz. *Hypholoma fasciculare* (Huds. Fr.) P. Kumm., *Phlebia radiata* Fr., *Schizophyllum commune* Fr., *Cylindrobasidium evolvens* (Fr.) Jülich, *Stereum hirsutum* (Willd.) Pers., *Schizopora paradoxa* (Schrad.) Donk., *Basidioradulum radula* (Fr.) Nobles, *Corticium roseum* Pers., *Ganoderma lucidum* (Curtis) P. Karst., *Hyphodontia sambuci* (Pers.) J. Erikss., *Phellinus ferruginosus* (Schad.) Pat., *Radulomyces molaris* (Chaillet ex Fr.) Christ., *Trichaptum biforme* (Fr.) Ryvarden, *Armillaria mellea* (Vahl) P. Kumm. and *Pholiota squarrosa* (Vahl) P. Kumm. Stenotrophs were represented by only 5 species (16.4%): *Dendrothele acerina* (Pers.) P.A. Lemke, *Peniophora quercina* (Pers.) Cooke, *P. rufomarginata* (Pers.) Bourdot et Galzin, *Phellinus robustus* (P. Karst.) Bourdot et Galzin and *Vuilleminia comedens* (Nees) Maire. The analysis of the spatial structure of wood-decaying fungi communities in the parks of Kyiv showed that the ground (31.5% of detected ones) and canopy (45.091% of detected ones) myco-horizons were the most populated (Appendix 6). The smallest number of species and detected fungi was recorded in the root myco-horizon. The developing of 2 species (15 find.) of *P. quercina* and *V. comedens* was detected on fallen wood debries (branches, *Q. robur*). The wood debris was not detected in the studied city parks. The minimum number of findings were assigned to stumps (only 2 find.). Detailed information on the links between the species, functional compositions of wood-decaying fungi and vitality, age, sanitary compositions of the tree stand has been given in our previous work (Blinkova and Ivanenko 2014).

Biodiversity rate assessment

The values of diversity indices calculated for plant, wood-decaying fungi, and bird communities show man-made pressure in complex ecological conditions in the parks of the metropolis depended on level of recreational transformation. In particular, the assessment of plant diversity indices showed that the highest values of the Margalef, Menchinick and McIntosh indices are characteristic of EP1 (Figure 1, a). The Shannon plant diversity index value was the highest for EP2. The lowest values of these indices were recorded for EP3 and EP4, which have the most characteristics of recreational pressure. Values of the

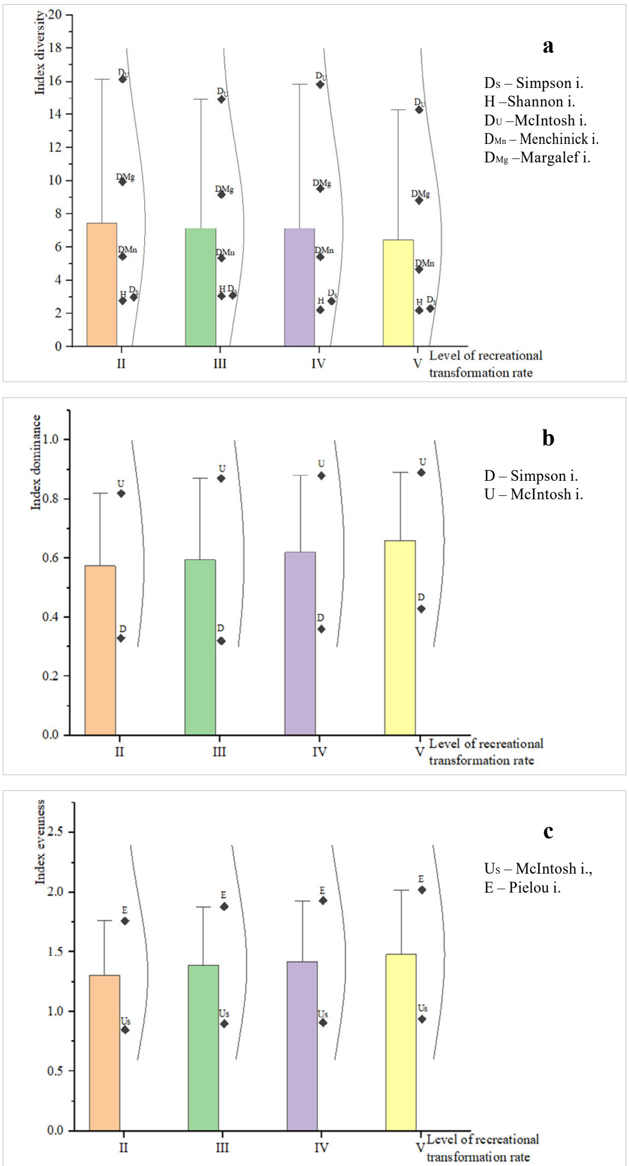

Figure 1. The indices of plant communities in urban parks ($P < 0.05$): a – diversity, b – dominance, c – evenness

Shannon, Margalef and Menchinick diversity indices for bird communities generally decrease along a defined recreational gradient (Figure 2, a). The data of the Simpson's index do not reveal the unity of oscillations, nor any dependence on the level of park recreational transformation. Data for wood-decaying fungi diversity indices show that the highest values for the Margalef, Menchinick and Shannon indices are characteristic of EP3 and EP4 (Figure 3, a). A significant fluctuation of the value of the Simpson index on the gradient of recreational transformation of city parks has not been detected.

Based on the assessment of the dominance indices, it was established that the highest values of the McIntosh and Simpson indices for plant communities were on the most recreationally transformed EP4 (Figure 1, b). This indicates that environmental conditions on this EP with a

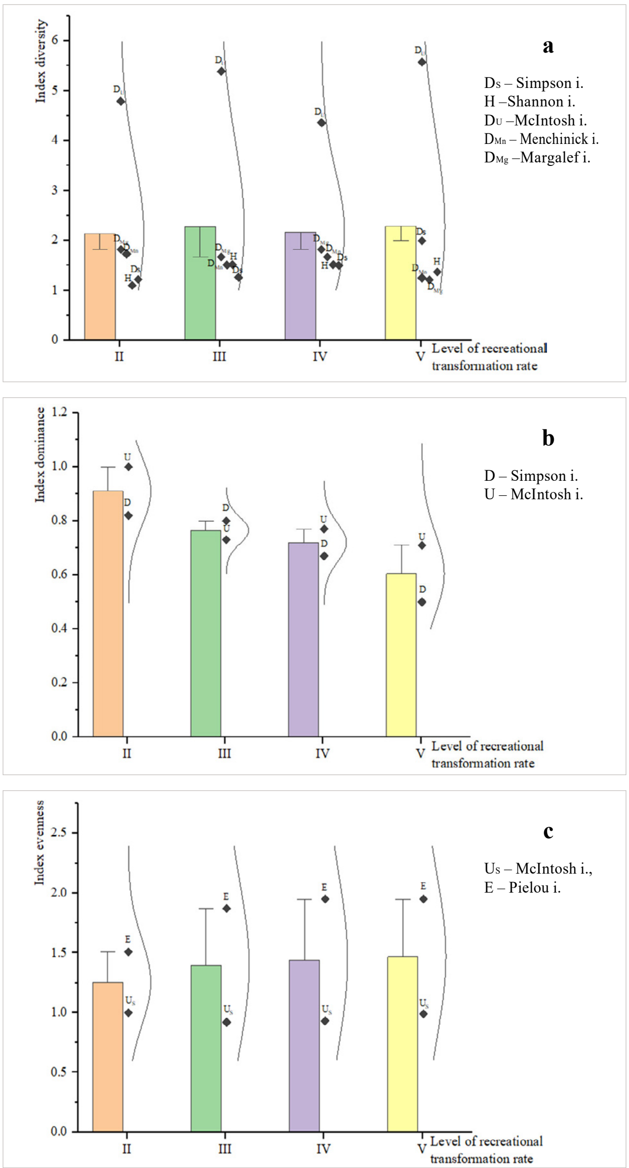

Figure 2. The indices of bird communities in the urban parks ($P < 0.05$): a – diversity, b – dominance, c – evenness

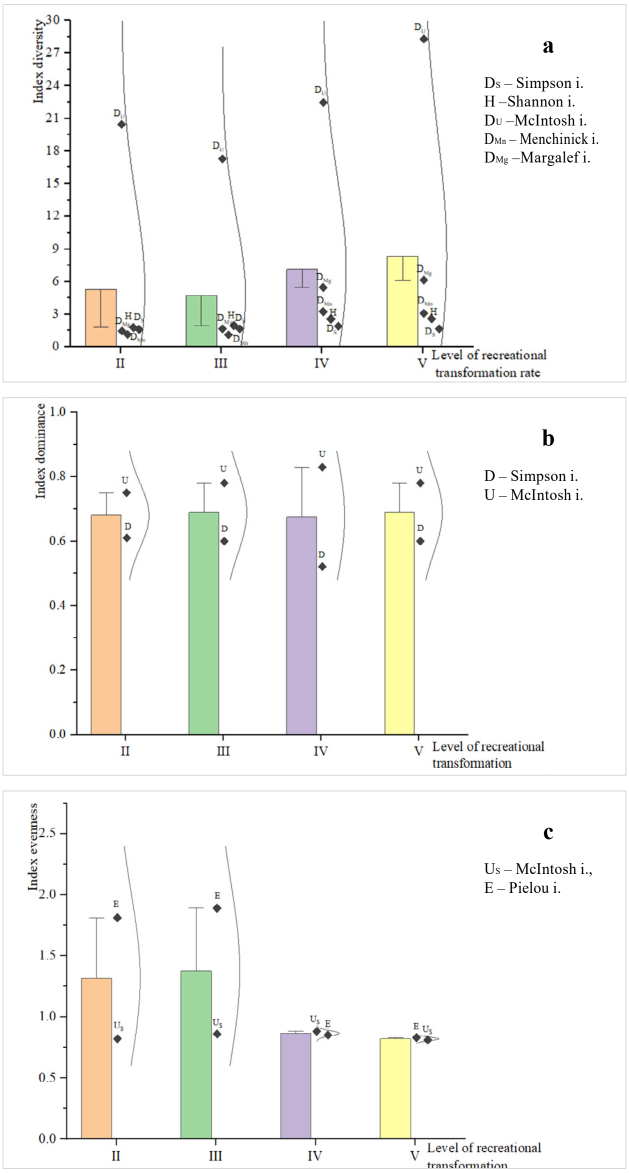

Figure 3. The indices of wood-decaying fungi communities in urban parks ($P < 0.05$): a – diversity, b – dominance, c – evenness

V level of recreational transformation is favourable only for ruderal and adventitious plant species (3.1.2). The values of the dominance indices of the bird communities fluctuate and do not reveal any trend on the transformation gradient (Figure 2, b). The values of the dominance indices of wood-decaying fungi have approximately the same values on the EPs, which indicates the absence of dominance of individual ecological communities of wood-decaying fungi (Figure 3, b). In general, it was found that the values of the Simpson and McIntosh dominance indices of plant communities have less dissimilarity than for bird communities and communities of wood-decaying fungi and are more synchronized by the level of recreational transformation. The evenness indices for the plant communities reveal an increase in their values with the recreational transformation level of the city parks (Figure 1, c). The evenness indicies of birds and wood-decaying fungi in the respective communities fluctuates and does not reveal any tendency toward changes (Figures 2, c and 3, c).

It is important to study the existence of correlations between the relevant diversity, dominance and evenness indices (Figure 4). The evaluation of the correlations between the parameters of the studied biota of the metropolis parks showed the existence of a reliable positive correlation between the IVH and Menchinick plant diversity ($r = 0.90$, $p < 0.005$) and bird diversity ($r = 0.83$, $p < 0.01$) indices, as well as the Simpson plant diversity ($r = 0.81$, $p < 0.01$) and bird diversity ($r = 0.80$, $p < 0.01$) indices. For the Menchinick and Margalef indices of wood-decaying fungi diversity, connections with the IVH were also established, but somewhat weaker: $r = 0.79$, $p < 0.005$ and $r = 0.75$, $p < 0.005$, respectively. The dominance indices for plant diversity were positively correlated with the IVH, in particular for the Simpson index ($r = 0.96$, $p < 0.005$). It is remarkable the close inverse correlation between the Simpson dominance indices for birds and wood-decaying fungi diversities with IVH: $r = –0.94$, $p < 0.005$ and $r = –0.83$, $p < 0.01$, appropriately.

A close positive correlation of the IHH with the Margalef and Menchinick indices was found ($r = 0.95$, $p < 0.005$ and $r = 0.94$, $p < 0.005$, respectively) regarding plant diversity and bird diversity ($r = 0.97$, $p < 0.005$ and $r = 0.98$, $p < 0.005$, correspondingly). Close links were found between indices of plant diversity (Shannon and Simpson ones) and wood-decaying fungi (Menchinick, Margalef and Shannon ones). Close links between the Menchinick and Margalef diversity indices for plants and birds which living in trees were also established ($r = 0.86$, $p < 0.01$; $r = 0.93$, $p < 0.005$; $r = 0.98$, $p < 0.01$; $r = 0.95$, $p < 0.01$). The Simpson dominance index for bird communities revealed a positive correlation with the Simpson floristic diversity index ($r = 0.98$, $p < 0.005$) and a negative correlation with the Simpson floristic dominance index ($r = –0.98$, $p < 0.005$). It is also worth noting the presence of an inverse correlation between the Pielou evenness index for plant communities and the Menchinick and Margalef indices for wood-decaying fungi ($r = –0.85$, $p < 0.01$; $r = –0.84$, $p < 0.01$). Intriguingly, for the first time, we found relationships between the Simpson dominance index for bird communities and the Menchinick ($r = 0.81$, $p < 0.01$) and Margalef ($r = 0.87$, $p < 0.01$) diversity indices for wood-decaying fungi. It is worth noting that a close correlation between the McIntosh dominance index and the corresponding wood-decaying fungi diversity indices was not found.

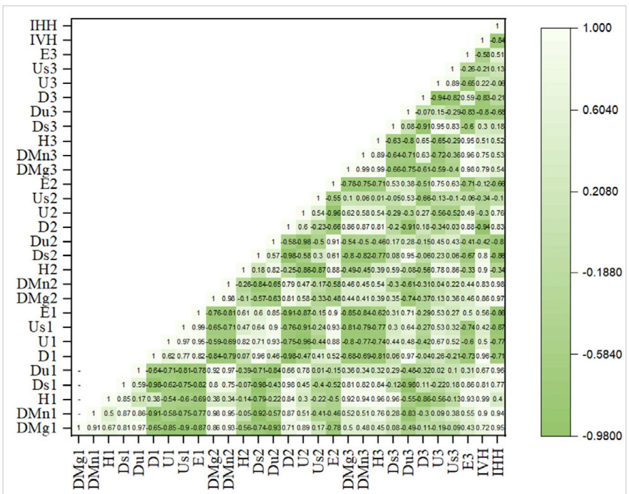

Figure 4. Correlation Matrix Heatmap – diversity, dominance and evenness indices of plant communities (1), bird communities (2), and wood-decaying fungi communities (3)

Rank curves of the relative abundance of species in communities of plants, birds, and fungi

The rank curves of the plant species composition indicate that the highest species diversity and sustainable plant community was on EP1, in contrast to similar data on EP4. On EP2 and EP3, the rank curves of plant community were

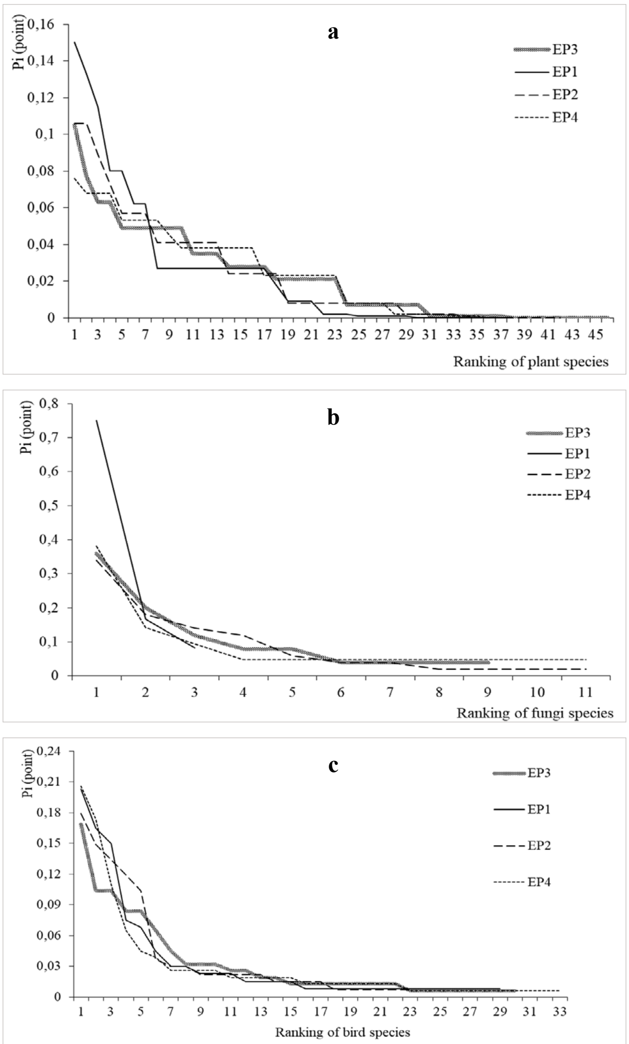

Figure 5. Species evenness in the communities of plants (a), wood-decaying fungi (b) and birds foraging in forest (c) on the EPs

similar, with a slightly higher species diversity on EP3 and a slightly lower pressure of dominants on EP2. On EP1, the greatest pressure of the dominant plant community over the common ruderal species has been found (Figure 5, a). The distribution curves of the fungi species composition according to the partial number of their detections showed similarity for EP1, EP2, and EP4. The curves for community of EP4 was the most balanced (Figure 5, b). The distribution curves of birds by the number rank in the community revealed the equality of the communities in terms of species diversity and showed a slightly better sustainable bird community in terms of number for EP2 (Figure 5, c).

The main driving factors of α-diversity in the urban parks

Multivariate analysis (HCA) was conducted between the generylized diversity indices and the recreational parameters of the transformation of the urban parks (Figure 6).

Application of cluster analysis to the datasets demonstrated excellent separation of parameters of recreational transformation and α-diversity of studied communities into different groups. Levels of similarity between parameters are indicated by a linkage distance. As can be seen from Figure 6, total area of city parks and damaged area of soil surface were well separated from other parameters. The relationship between the damaged area of soil surface and the total area of the parks and the α-diversity of studied communities was not found. The associated relationship between the generalized measure of the diversity of bird and plant communities and the recreational pressure on urban parks / the index of phytosanitary condition was

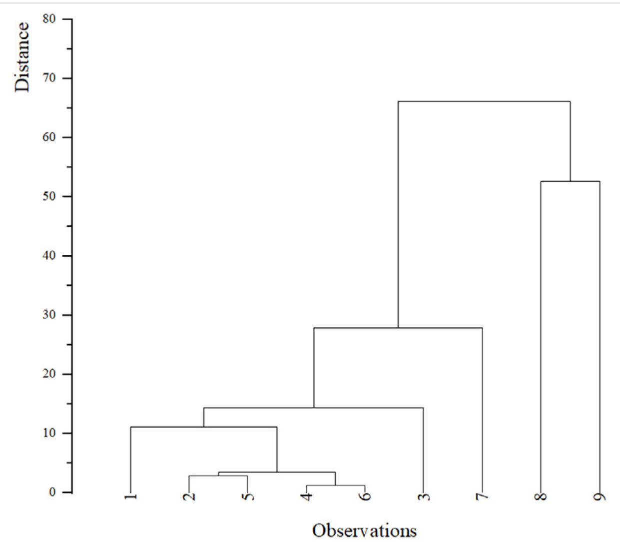

Figure 6. Dendrogram of hierarchical cluster analysis of parameters of levels of recreational transformation of urban parks and α-diversity of herbaceous plants, nesting birds and wood-decaying fungi communities

Observations: 1 – fungal diversity, 2 – IVH, 3 – stand state index, 4 – plant diversity, 5 – bird diversity, 6 – IVH, 7 – recreational pressure, 8 – damaged area of soil surface, 9 – total area of parks.

detected. The associated relationship between the diversity of the fungal community and the stand state index was established.

Discussion

The diversity of plant, bird and wood-decaying fungi communities have positive relationships with the parameters and the level of recreational pressure in urban parks. This conclusion has been confirmed in this work, as well as in other our studies. Key ecological theories like the gradient approach and the theory of island biogeography, and fundamental ecological relationships such as the species-area relationship are valid. Most studies surveyed large number of parks and applied "multi-scale" approach intests of confounding variables. The diversity of habitats and microhabitat heterogeneity in urban parks appears as the most decisive factor for the overall species richness. However, a constraint of research to date is the limitation of individual studies to one or a few species groups, rarely bridging between flora and fauna (Nielsen et al 2013). Park area and recreational pressure could play an important role in urban biodiversity (Ewers and Didham 2007). However, the total area of the parks was not significantly correlated with α-diversity (Nielsen et al 2013). The fail of such a correlation link was confirmed in this study. A close relationship between the α-diversity of plant, bird, and fungal communities with the indices of vertical and horizontal heterogeneity was noted.

Variation in plant diversity was largely explained by internal patch characteristics (size, age, level of recreational transformation), which accounted for 27.9% of diversity (Ma et al. 2022). Fluctuations in species and ecological compositions of plant communities were also established in our study. An increase in the level of recreational pressure in parks has also caused an increase in the impact of adventitious species and the transformation of the soil surface. The species composition of representatives of the *Asteraceae* and *Poaceae* family dominate in the parks under recreational transformation. The diversity of plant community depends on the presence of mosaic- and microhabitats and the nature of the vegetation in the surroundings, which is manifested by the participation of socioecological groups of flora. The pace and dynamics of succession depend on the stage of the transformation, the topography, and the nature of the substrate (Antrop 2000, Bjerke et al 2006).

Bird diversity and distribution may be affected by human activities and environmental noise (traffic noise and construction noise) in urban green space (Zhou and Chu 2012, Wang et al. 2013). There is a quantitative relationship among total park area, fragment area and damaged area of soil surface (Beck 2013). The habitat diversity was positively affected bird species richness in urban parks. It was noted that the taxonomic diversity of bird communities is directly related to the size of green spaces and the heterogeneity of habitats in different ecological conditions (Kopij 2019, Koranyi et al. 2021, Zorzal et al. 2021). In our research the list of dominants is quite wide

(Appendix 5), it depends on the level of recreational transformation of the city parks. It is known that in the absence of old trees in the ecosystem, there is a shortage of hollows for closed-nesting birds (Wesołowski 2007, Ranius et al. 2009). We previously showed that the synanthropization of forest bird communities increases depending on their transformation, and obligate synanthropes also nest in the most transformed forests (Blinkova and Shupova 2018). Such a trend in the distribution of birds with varying degrees of adaptation to human presence may be due to the feeding and nesting characteristics of these species, and the urbanization growth can reduce the representation of low-tolerant species (principally forest ones) in bird communities (Fernández-Juricic 2001, 2002). The species that feed in the tree crowns, or equally in the crowns and on the ground were prevailed in our study, so the bird communities of Kyiv parks can be considered sustainable. In the works of other authors, it is indicated that an increase in the share of tree cover had a significant positive effect on species diversity and the presence of large birds, and an increase in the percentage of shrub cover led to a significant increase in the share of hawks, insectivorous and ground-nesters in the bird community (Koranyi et al. 2021). The number of granivorous and granivorous-insectivorous species increases the potential resistance of the community, while the abundance of insectivorous, carnivorous and omnivorous species is negatively correlated with the functional diversity (Morelli et al. 2017, 2020). The group of purely granivorous birds was not numerous in contrast to the proportion of phytoentomophages in our study. The alien species to the ornithofauna of Ukraine preferably nest in the parks of the metropolis compared to natural forests (Blinkova and Shupova 2018, Haichenko and Shupova 2019). The other authors hypothesise that the successful invasion of urban bird species of urban habitats was associated with gradual adaptation to these habitats (Møller et al. 2012). Tree diversity in the long run has a strong impact on communities: increases bird attendance and habitat use (May-Uc et al. 2020). Bird species diversity is positively correlated with the area of parks and tree age (Fernandez-Juricic and Jokimäki 2001, Tryjanowski et al. 2017). The internal habitat qualities of urban parks are more decisive for the richness and composition of birds than both park size and park isolation (Fitzsimons et al 2011). This conclusion is also confirmed in our study.

On the other hand, the links between the health conditions of trees in parks with wood-decaying fungi diversity are also important. An increase in the abundance of dead wood in forests or parks will benefit diversity (Odor et al. 2006). Previous publications have shown that some of the spatial division habitats in parks decrease connectivity among local fungi communities and generally hurt their viability, but it can also have a positive effect on some species, for example, due to released competition pressure (Norden et al. 2013). The colonization rate of wood-decaying fungi on older and weaker trees was much higher than that on the younger and healthy ones (Ding et al. 2020). The relationship between the stand state index and the diversity of wood decay fungi communities was also showed in this study. Previous publications have shown the complexity of the interactions between trees, fungi and the environment on the macro- to the micro-level (Schwarze et al. 2008). The distribution by myco-horizon at the macro-level revealed by us indicates that the wood-decaying macromycetes are more developed in the terrestrial myco-horizon. It has been proven that the composition of fungal fruiting bodies in the studied parks of the metropolis is not stable, since the distribution of wood-decaying fungi in them is limited by the smaller amount of available living and dead rooting substrate, the greater openness of the planting canopy, the lower protective properties of the grass cover, and the transformation of the soil surface layer (Blinkova and Ivanenko 2014). This is in agreement with other studies, in which the compositions of pioneer fungi species in dead branches of park trees were presented (Heaton et al 2012). The importance of different fractions of deadwood for species diversity of wood-inhabiting fungi was investigated in many studies. The category of the substrate (living trees or deadwood) is essential for the development of wood-decaying fungi (Sefidi and Etemad 2015). The results of other studies indicated that the diameter, age and category of dead wood describe the most significant variance in the numbers of species (Juutilainen et al. 2014). Our previous work showed that the type of substrate (living trees or dead substrate) and diameters of deadwood substrate are very important factors affecting fungal community composition. Many scientists were focused on mechanical injury, subsequent infection, and environmental change as facts of life for urban trees (Terho et al. 2007). Our results showed that the stability of communities of tree vegetation and wood-decaying fungi of metropolis park depends on the level of recreational transformation of the territory (Blinkova and Ivanenko 2016, 2018). From our point of view, the absence of correlations between the IHH and diversity, dominance, and evenness indices of wood-decaying fungi communities could be explained by the peculiarities of the species (Appendix 6) compositions of the city parks in this study.

The height and position of rank curves of the relative abundance of species in the communities of plants, fungi, and birds remains a debatable issue. The height and position of the species abundance curve indicate the species diversity in the communities. A high and flat curve demonstrates high α-diversity. The steep slopes of the curve indicate a decrease in the diversity and dominance of individual species in the communities observed in our study.

However, a constraint of research to date is the limitation of individual studies to one or a few species groups, rarely bridging between flora and fauna. Adopting the “multi-species group” approach in future research is needed to further advance the understanding of the overall biodiversity of urban parks and its drivers.

Conclusions

In the plant, bird and fungi communities of the metropolis parks with different levels of recreational transformation, there is a not stability of α-diversity. Among the applied indices of diversity, the Shannon, Margalef and Menchinick diversity indices calculated for the plant, bird and fungi communities had a close relationship with the level of recreational transformation of the city parks. The decrease in the diversity of the plant and bird communities was caused by the increase in recreational pressure on the urban parks. However, the deterioration of the tree stand, and, as a result, the increase in the diversity of wood-decaying fungi communities arisen out of the increasing in recreational pressure in the urban parks. The relationship between the level of recreational transformation and the dominance and evenness assessments was established only for the plant communities (McIntosh and Pielou evenness indices).

The obtained data indicate the existence of a link between the complex tiered vertical structure of the forest (IVH) and the diversity of forest-nesting birds and wood-decaying fungi. The correlations between the complex tiered horizontal structure (IHH) and the diversity, dominance, and evenness indices of wood-decaying fungi have not been confirmed in contrast to the established close links with the plant and bird communities.

Statements and declarations

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

OB, TS and LR contributed to this manuscript equally. OB carried out the observations of plant community compositions and wood-decaying fungi community. TS performed the analysis of the bird community. LR contributed much to the statistical processing of data obtained. OB, TS and LR designed and guided the study and revised the final draft of the manuscript. LR and OB made revision for language, grammar and punctuation of the manuscript. All the co-authors have read and approved the final version of the manuscript.

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Appendices

Appendix 1. Characteristic of dominant woody vegetation

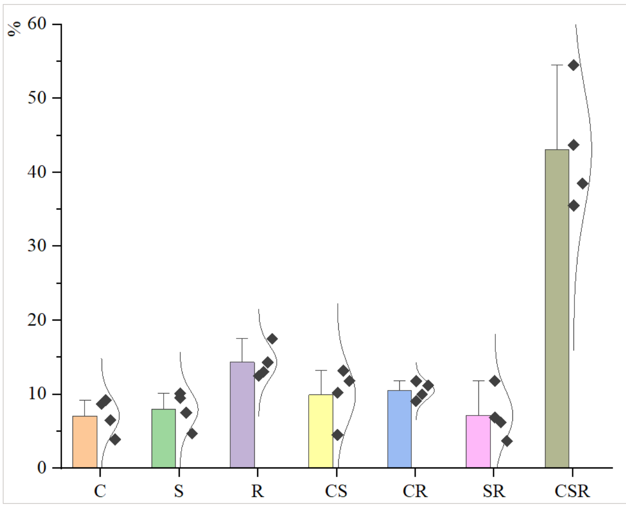
No. EP	Level of recreational transformation	Species	A, y	N, pcs	D_{ave}, cm	D_{min}–D_{max}, *SD*, cm	H_{ave}, m	H_{min}–H_{max}, *SD*, m	G_n, m^2ha^{-1}	AD, *SD*, cm	ADR, *SD*, cm	IHH	IVH
1	II	*Pinus sylvestris* L.	40–60	205	31.5	22.1–38.3, 5.25	17.6	15.7–20.7,1.45	108.1	235.6, 11.8	0.16, 0008	0.84	2.95
		Quercus robur L.	40–60	107	24.2	19.2–28.8, 3.48	15.3	12.2–18.4, 2.08	95.3				
2	III	*Quercus robur* L.	60–80	247	56.1	34.2–89.2, 10.11	17.1	15.1–20.3, 1.92	240.4	209.2, 10.5	0.17, 0.009	0.80	2.87
3	IV	*Quercus robur* L.	60–80	125	71.3	62.5–82.1, 6.23	23.2	21.9–25.7, 1.98	94.4	258.3, 12.9	0.15, 0.008		
		Carpinus betulus L.	60–80	265	36.0	30.1–43.5, 3.89	18.1	16.2–20.3, 1.34	86.5			0.82	3.02
		Acer platanoides L.	40–60	76	19.5	16.3–24.7, 2.51	16.9	13.7–19.2, 1.74	21.8				
		Tilia cordata Mill.	60–80	28	45.3	40.1–52.0, 3.70	19.0	16.4–22.8, 1.92	11.1				
4	V	*Quercus robur* L.	60–80	190	82.8	78.2–95.1, 10.20	26.2	19.5–28.1, 2.87	128.7	301.4, 15.1	0.11, 0.006	0.75	3.14
		Acer platanoides L.	40–60	178	31.1	20.5–46.1, 9.22	16.0	12.4–18.1, 2.56	98.7				

* *Note*: A – age (years), D_{ave} – average weighted diameter (cm), H_{ave} – average weighted height (m), fluctuations range (D_{min}–D_{max}; H_{min}–H_{max}), standard deviation (*SD*), stand density (N), stand basal area as a sum of tree areas (G_n), AD – the average distance between trees (cm), ADR – average density regrowth (thous. pcs./ha), IHH – index of horizontal heterogeneity, IVH – index of vertical heterogeneity.

Appendix 2. Characteristic of herbaceous vegetation

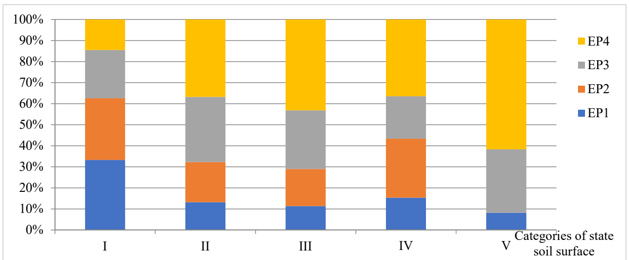
Parameter	*Min*	*Max*	*Mean*	*Median*	*SD*	SEM	*T*-statistic (df = 3, p = 0.01)
Projective cover on EP, area	25.55	83.01	63.53	72.75	26.55	4.27	4.78
Rudearal/adventitious species on EP, pcs.	19	32	25.66	23.52	5.63	4.81	5.15
Species compositon on EP, pcs.	29	55	39.12	40.54	7.43	3.71	7.48
Recreational pressure in park, person × days × ha^{-1}	5.76	21.56	13.95	14.32	7.20	3.60	3.87

Appendix 3. Ecological strategies of herbaceous plants



Note: C – competitor species, S – stress-tolerant species, R – ruderal species, CS – competitor-stress-tolerant species, CR –competitor-ruderal species, SR – stress-tolerant-ruderal species, CSR – competitor-stress-tolerant-ruderal species.

Appedix 4. State of soil surface



Note: Categories of state soil surface: 1 – undisturbed soil; 2 – weakened mulch (single passes); 3 – footpath in mulch; 4 – footpath or road without mulch; 5 – footpath or road with washaways; 6 – deposition and washaways made by recreants descending on steep slopes.

Appendix 5. Characteristic of dominant bird species in the communities

Species	Level of recreational transformation							
	II		III		IV		V	
	Experimental plots							
	1		2		3		4	
	P_i	D_b	P_i	D_b	P_i	D_b	P_i	D_b
Columba livia Gmelin, 1789	-	-	0.104	5.83	-	-	0.019	1.58
Sturnus vulgaris L.,1758	0.077	5.26	0.134	7.50	-	-	0.174	14.21
Turdus pilaris L., 1758	0.169	11.58	-	-	0.032	2.0	0.110	8.95
Turdus merula L., 1758	0.015	1.05	0.022	1.25	0.101	6.40	0.065	5.26
Parus major L., 1758	0.208	14.21	0.179	10.0	0.169	10.40	0.206	16.84
Passer domesticus L., 1758	0.154	10.53	-	-	-	-	-	-
Passer montanus L., 1758	0.069	4.74	0.149	8.33	-	-	0.026	2.11
Fringilla coelebs L., 1758	0.031	2.11	0.119	6.67	0.101	6.40	0.039	3.16

Note: P_i – ratio of species in communities; D_b – bird nesting density (pairs/ha); - – species is absent in this communities; _ – species abundance indicators when the species is dominant.

Appendix 6. Distribution of macromycetes by myco-horizons

No.	Fungi	Trees	Myco-horizons *				
			1	2	3	4	5
1	*Armillaria mellea* (Vahl) P. Kumm.	*A. hippocastanum* (1)	1/	-	-	-	-
2	*Basidioradulum radula* (Fr.) Nobles	*Q. robur* (2)	-	2/	-	-	-
3	*Cylindrobasidium evolvens* (Fr.) Julich	*Q. robur* (2)	-	-	-	-	2/
4	*Corticium roseum* Pers.	*A. platanoides* (2), *Q. robur* (3)	-	3/	-	-	2/
5	*Dendrothele acerina* (Pers.) P. A. Lemke	*A. platanoides* (14)	-	-	8/	6/	-
6	*Ganoderma lucidum* (Curtis) P. Karst	*Q. robur* (1)	-	-	1/	-	-
7	*Hyphodontia sambuci* (Pers.) J. Erikss.	*S. nigra* (1)	-	-	-	1/	-
8	*Hypholoma fascicu-lare* (Huds.:Fr.)	*C. betulus* (1)	-	-	1/	-	-
9	*Phellinus ferruginosus* (Schad.) Pat.	*Q. robur* (9)	-	6/	-	-	3/
10	*Peniophora quercina* (Pers.) Cooke	*Q. robur* (11)	-	4/	-	-	7/
11	*Peniophora rufomarginata* (Pers.) Bourdot et Galzin	*T. cordata* (1)	-	-	-	-	1/
12	*Phlebia radiata* Fr.	*C. betulus* (1)	-	-	-	1/	-
13	*Phellinus robustus* (P. Karst.) Bourdot et Galzin	*Q. robur* (6)	-	-	-	4/	2/
14	*Pholiota squarrosa* (Vahl) P. Kumm.	*Q. robur* (1)	-	-	1/	-	-
15	*Radulomyces molaris* (Chaillet ex Fr.) Christ.	*Q. robur* (10)	-	5/	-	-	5/
16	*Schizophyllum commune* Fr.	*A. platanoides* (1), *Q. robur* (1)	-	2/	-	-	-
17	*Stereum hirsutum* (Willd.) Pers	*C. betulus* (1), *Q. robur* (1)	-	1/	-	1/	-
18	*Schizopora paradoxa* (Schrad.) Donk	*C. betulus* (8), *Q. robur* (2)	-	1/	-	2/	7/
19	*Trichaptum biforme* (Fr.) Ryvarden	*Q. robur* (1)	-	1/	-	-	-
20	*Vuilleminia comedens* (Nees) Maire	*Q. robur* (30)	-	10/	-	-	20/
Total species/discoveries:		6/111	1/1	10/35	4/11	6/15	9/49
% of the total number of species/discoveries:			5/ 0.009	50/ 31.5	20/ 9.9	30/ 13.5	45/ 45.1

Note: pcs./%; 1 – the root; 2 – the ground; 3 – the rod butt; 4 – the stem; 5 – the canopy; "-" – not found.