ASSESSMENT OF THE STATE OF NATURAL ENVIRONMENT IN VILNIUS CITY

Raimondas Leopoldas Idzelis1, Audrone Jankaite2, Vytautas Oskinis3, Romas Pakalnis4, Zenonas Venckus5, Tomas Virbickas6

1,2,3,5 Dept of Environmental Protection, Vilnius Gediminas Technical University, Saulėtekio al. 11, LT 10223, Vilnius, Lithuania, E-mail: aak@ap.vgtu.lt, Audrone.Jankaite@ap.vgtu.lt
4Institute of Botany, Žaliųjų ežerų 49, LT- 08406 Vilnius, Lithuania, E-mail: Romas.Pakalnis@botanika.lt
5Institute of Ecology, Akademijos 2, LT- 08412, Vilnius, Lithuania, E-mail: tvirbickas@takas.lt

Abstract. Biological assessment of the state of natural environment in Vilnius city and its environs was carried out. Botanical and zoological criteria were selected to make the ratings of the state of certain aquatic, coastal and terrestrial habitats. Fauna and flora species, which characterize natural state of densely, moderately and sparsely urbanized as well as protected areas, were sorted out. The impact of urban development upon natural state of Vilnius city and its environs was estimated as well as biological criteria and indicator species of flora and fauna, which allow to evaluate these changes, were described.

On the grounds of the performed research work, the assessment of the state of natural environment in the city was made according to botanical and zoological criteria and indicators.

Keywords: urbanization, invasive plants, ruderal plants, urban birds, biological criteria, biological indicators.

1. Introduction

Under the impact of human economic activity, the environment undergoes obvious changes, the habitats of plants and animals on the neighbouring areas become extinct and biological diversity decreases because of fast development of cities. At present, the territory of Vilnius city covers 401 sq km. Forests surround the city on all sides. Forestland makes up 36% of the total city area [1]. The city is rich in surface water bodies (rivers, rivulets, lakes, ponds).

During the last 30 years, the boundaries of Vilnius city have changed intensively. The directions of urban development have been defined in the strategic plan of the city. The process of urban penetration into natural areas is inevitable; therefore, an optimal way of solution of environmental problems is necessary.

Diversity of natural environment (forests, bogs, meadows, rivers, lakes, land use, waste plots of land) in Vilnius city and its environs predetermines the diversity of flora and fauna species [2]. Therefore, different evaluation criteria should be applied for the assessment of the state of natural environment in certain areas of the city.

In the territory of Vilnius city, there are quite a lot of protected areas used for different purposes, in which almost all the main types of ecosystems occur: forests, meadow areas of varying humidity, lakes of diverse eutrophication level, ponds, small bogs and springs [3]. Different flora and fauna communities thriving in these ecosystems and their fragments undergo wide–scale human activity impact because of urban development [4-8]. In different habitats, the impact of urban development upon natural environment is diverse.

The state of natural environment in Vilnius city can be rated according to various biological criteria. Assessment of the state of vegetation (populations and species composition) is one of rather reliable ways of predicting of the state of environment. Another not less important criterion of urbanized environment evaluation is the state of fauna in certain terrestrial and aquatic habitats of the city.

The goal of the paper is to present a system of assessment of the state of natural environment in Vilnius city, which is based on the analysis of flora and fauna species distribution and their habitats in the areas of different urbanization level.
2. Methods

Assessment of the urbanization influence on natural environment is complicated because the ratings can be made applying very different criteria. The state of environment at a particular moment can be characterized by chemical parameters of environment quality.

Living organisms or their parts can be used for the evaluation of environment state, for this goal chemical composition or metabolism of a plant can be observed or recorded. To describe environmental conditions and indicate long–term changes in the state of environment, morphological characteristics of plants can also be used.

The process of urbanization, as a multifactor phenomenon, continues for a long period and modifies all components of a landscape. Floristic and phytocenotic features of flora can present integral parameters of environmental changes [9, 10].

Abundance of species is a very significant feature that allows indicating the state of environment, however, ecological characteristics of certain species are known to be different. Consequently, estimation of the abundance of species individuals (as well as spread and extinction tendencies) is differentiated.

To ascertain the level of landscape and natural environment urbanization, in addition to specific characteristics of plant species and communities, ecologically closely related animal species and populations are used.

Assessment of natural environment according to zoological criteria and indicators of fauna has specific features. It depends on animal habitats: some of them live on land (forests, open areas), others – in bogs or water (rivers, lakes). Animal mobility is also very important: some species constantly live in the same place or small area, others, on the contrary, are mobile, migrate from one place to another due to various reasons.

Due to flora and fauna species composition as well as habitat diversity, different criteria for environment assessment are necessary. In addition, urban impact upon natural environment varies in the Old Town, the centre of the city or its environs.

3. Results

Plant species and communities are very closely related to habitat conditions, depend upon its changes; therefore, perfectly reflect both the state of environment and landscape, and the impact of urbanization processes [8, 11-15]. On the other hand, botanical criteria even better than certain chemical parameters integrally reflect the state of environment and its fitness for the existence of living organisms (humans included). The following botanical criteria characterize the state of environment: plant communities, green plantations, and plant species (alien, ruderal, segetal, red–listed species).

Habitat diversity impacts the variety and abundance of fauna species. Species of animals are closely related to ecological conditions of habitats, depend upon their changes and, therefore, indicate both ecological state of natural environment as well as landscape and the development of urbanization processes [16].

Zoological criteria as compared to chemical parameters more effectively reflect the state of environment and show how animals adapt to it.

Rare and endangered species included into the Red Data Book of Lithuania [17] as well as the Annex of the EU Habitat Directive are the most important zoological criteria. Zoological criteria for the most part depend upon plant species composition and diversity of communities in a specific habitat. Zoological criteria are reasonably considered to be the principal elements of both the assessment of the state of landscape as well as the level of natural environment urbanization, and the prognosis of its future development and possible alternatives.

In Vilnius city and its environs, approximately 100 species of birds live during reproduction period, about 50 species stay for winter, and in certain years almost 200 species of birds fly by the city and its environs in the period of seasonal migrations [18-19]. Birds of certain ecological groups occupy typical habitats, where they find enough food, and favourable conditions of reproduction.

A long–term experience in observation of ornithocomplexes formation allows us to confirm that in new residential areas, bird communities have been forming for decades. For example, the construction of Viršuliškės residential area was completed in 1976, but, eventually, the structure of ornithofauna in that area has changed. The number of bird species characteristic to open landscape has decreased because of smaller areas of open spaces. In eight years the number of synanthropic bird species has stabilized. In larger and older green plantations, the number of dendrophilous species of birds has intensively increased (Fig. 1).

Bird species characterize the natural state of differently urbanized territories. Prevalence of certain bird species (abundance is higher than 15–20%) in a habitat (or ornithocenosis) favourable for its living is considered to be one of the indices of natural environment quality. The list includes protected species of the Red Data Book of Lithuania and the Annex of the EU Bird Directive. In total 52 rare and dominating bird species were registered (Fig. 2).

Recently much attention has been paid to the inventory of fauna and flora, establishment of their living conditions as well as investigations on biological diversity and the impact of urban development. To make the ratings of the state of biological diversity, the inventory of flora and fauna in Vilnius city and its environs was carried out,
changes in biological diversity and prognoses of
tendencies were reviewed [3]. Recently, 46 species of
mammalia (7 species of bats included) [2], 11 species
of amphibia, 5 species of reptilia, over 3000 species
of insects and other invertebrates have been
registered. Being rare and dominating in certain areas
of the city, they form the basic structure of
zoocomplexes (Fig. 3).

In water bodies of Vilnius city and its environs, 33 native fish species and 2 lamprey species live or
spawn [20, 21].

In contrast to terrestrial fauna and flora, the
impact of urbanization upon aquatic fauna in most
cases is indirect, i.e. under increasing density of
constructions and smaller areas of green plantations
the habitats of aquatic fauna physically are not
disturbed. However, straightening of riverbeds,
artificially fortifying their banks, constructing the
dams, destroys some riparian habitats of natural
vegetation. Significant impact on water quality has
direct (domestic or from waste water treatment
facilities) as well as accidental pollution (e.g.
pollutants get into water bodies together with
rainfall). Therefore, the state of water bodies in
Vilnius city depends not so much upon the level of
urbanization, but more on the quality of riparian
management as well as efficiency of pollution
prevention. Taking into consideration direct and
indirect impact of urbanization on fish fauna,
indicator species were selected to evaluate the
ecological state of water bodies in Vilnius city.

According to urbanization level, 4 zones were
marked out in the territory of Vilnius city (in each of
them, characteristic areas, evaluated by botanical and
zoological criteria as well as indicators, were
selected):

1. Sparsely urbanized areas:
Nemenčinė Highroad (forests and sparsely built up
areas of the communities of gardeners: 5 km–
width area on the right side of Nemenčinė
Highroad from Smėlynė to Antaviliai settlements,
in which recreational forests dominate);
Vingis Park (a fragment of natural environment
within the city limits isolated from densely built
up areas);
The environs of Lake Salotė.

2. Moderately urbanized areas:
Communities of gardeners in Balsiai settlement;
Rokantiškės cemetery and its environs (dominate memorial green plantations); Viršuliškės residential area (densely built up area with the fragments of natural environment); Lazdynai residential area (densely built up residential area with the fragments of natural environment).

3. Densely urbanized areas

Centre of the city (the Old Town and centre of the city on the left banks of the rivers Neris and Vilnia).

4. Protected areas:

Verkiai Regional Park; Pavilniai Regional Park;

Karoliniškės Landscape Reserve; Tapeliai Landscape Reserve. Lake Tapeliai is an overcrowded recreational area.

3.1. Assessment of the state of natural environment in the city

The state of natural environment in the city was evaluated according to the peculiarities of flora (plant species) and fauna (birds, fish, mammalia and other species of animals) distribution depending on the level of urbanization in the area. These species of flora and fauna are presented on Tables 1-4.

Table 1. Plants. Plant species characterizing the urbanization level of natural areas

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of species</th>
<th>State of natural areas</th>
<th>Protected areas</th>
<th>Status of species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Urbanization level</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sparse</td>
<td>moderate</td>
<td>dense</td>
</tr>
<tr>
<td>1.</td>
<td>Alien plant species</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Acer negundo L.</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3.</td>
<td>Robinia pseudoacacia L.</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4.</td>
<td>Pinus banksiana Lamb.</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>5.</td>
<td>Sarothamnus scoparius (L.) Wimm. et Koh</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>7.</td>
<td>Echinocystis lobata (Michx.)Torr. et A.Gray</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>9.</td>
<td>Impatiens glandulifera Royle</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>10.</td>
<td>Impatiens parviflora DC.</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>11.</td>
<td>Galinsoga parviflora Cav.</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2.</td>
<td>Ruderal plant species</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Artemisia campestris L.s</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>14.</td>
<td>Cirsium arvense (L.) Scop.</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>15.</td>
<td>Urtica dioica L.</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>16.</td>
<td>Chenopodium album L.ir kitos balandų genties rūsys</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3.</td>
<td>In established green plantations dominate introduced plant species</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>In established green plantations dominate native flora species</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Single individuals of species included into the Red Data Book of Lithuania</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Red–listed species</td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Cypripedium calceolus L.</td>
<td>LRDB, EUHD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Liparis loeselli (L.) Rich.</td>
<td>LRDB, EUHD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Pulsatilla patens (L.) Mill.</td>
<td>LRDB, EUHD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) LRDB – species included into the Red Data Book of Lithuania; EUHD – species protected by the EU Habitat Directive

Table 2. Birds. Rare bird species characterizing the urbanization level of natural area

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of species</th>
<th>State of natural areas</th>
<th>Protected areas</th>
<th>Status of species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Urbanization level</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>low</td>
<td>average</td>
<td>high</td>
</tr>
<tr>
<td>1.</td>
<td>Picus viridis</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Falco tinnunculus</td>
<td>+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 3. Mammalia and other animals

Mammalia and other species of animals characterizing the urbanization level of natural areas

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of species</th>
<th>State of natural areas</th>
<th>Protected areas</th>
<th>Status of species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Urbanization level</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>low</td>
<td>average</td>
<td>high</td>
</tr>
<tr>
<td>1</td>
<td>Chiroptera</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Martes foina</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Lepus europaicus</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>Sciurus vulgaris</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>Mustela nivalis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>Mustela putorius</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>Amphibia</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>Reptilia</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td>Helix pomatia</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>10</td>
<td>Sorex minutus</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>11</td>
<td>Neomys fodiens</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>12</td>
<td>Castor fiber</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>13</td>
<td>Lithra lutra</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>14</td>
<td>Martes martes</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>15</td>
<td>Capreolus capreolus</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>16</td>
<td>Alces alces</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>17</td>
<td>Micrurus avellanarius</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>18</td>
<td>Mustela erminea</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>19</td>
<td>Meles meles</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>20</td>
<td>Osmotherodon rexina</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>21</td>
<td>Ophiogomphus cecilia</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>22</td>
<td>Leucorhinia pectoralis</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>23</td>
<td>Unio crassus</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

(1) LRDB – species included into the Red Data Book of Lithuania; EUHD – species protected by the EU Habitat Directive; BC – species protected by the Bern Convention.

### Table 4. Fishes

Fish species characterizing the urbanization level of natural areas

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of species</th>
<th>Alteration of water ecosystems:</th>
<th>Species dominating in protected areas</th>
<th>Status of species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>low</td>
<td>average</td>
<td>high</td>
</tr>
<tr>
<td>1</td>
<td>Extremely sensitive species</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Lampetra fluviatilii</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Lampetra planeri</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>Salmo salar</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

(1) LRDB – species included into the Red Data Book of Lithuania; EUHD – species protected by the EU Habitat Directive; BC – species protected by the Bern Convention.
On Table 4 fish species are presented by the order of general resistance to the impact of human activity [22, 23].

First (I) group includes species, living in water bodies of Vilnius city, which are extremely sensitive to environment alterations (both physical quality of a habitat and water quality). All of them (except *Rhodeus sericeus*) live exclusively in rivers, spawn only on clean, gravelled or stony ground. In this group occur all representatives of Salmonidae (*Salmo salar, Salmo trutta trutta, Salmo trutta fario*) and Petromyzontidae (*Lamptera fluviatilis, Lampetra planeri*) families, and also almost all fish found in the rivers of Vilnius city, the reproduction cycle of which is subject to particularly distant migrations (rivers – sea).

Second (II) group consists of average sensitivity species. Four of them (*Esox lucius, Gymnocephalus cernuus, Scardinius erythrophthalmus, Lota lota*) live in the lakes occurring within the city limits. All the fish are rather resistant to moderate organic pollution, however, quite sensitive to physical changes in their habitats (reinforcement and straightening of the banks, removal of vegetation and wind-fallen trees on the coasts, bottom sedimentation, decline of aquatic vegetation, etc.).

Third (III) group contains fish species, which are the most resistant to the impact of human activity. All of them are omnivorous (except *Perca fluviatilis*), undemanding to spawning substrate, feed on different food objects.

Fourth (IV) group involves introduced and alien (*Perccottus glenii*) species. These species are particularly resistant to human activity impact; therefore, they usually prevail in severely polluted waters.
3.2. Characterization of urbanized areas according to flora and fauna indicators

**Sparsely urbanized natural areas**
1. **Plants.** Single individuals of red-listed, alien and ruderal plant species are characteristic (Table 1).
2. **Birds.** In sparsely urbanized city areas with recreational forests and water bodies as well as agrocnoses, up to 24 rare and dominating bird species are recorded in brooding period on certain habitats. Dendrophilous species prevail; three of them are included into the Red Data Book of Lithuania (Table 2).
3. **Mammalia and other animals.** In sparsely urbanized city areas dominate in natural environment prevailing species: *Sciurus vulgaris*, *Lepus europaeus*, *Rana temporaria*, *Bufo bufo*, *Lacerta vivipara*, etc. (Table 3).
4. **Fishes.** Species, characteristic to water bodies of good quality (as well as included in the lists of EU directives and international conventions) occur; moderately sensitive species dominate (Table 4).

**Moderately urbanized natural areas**
1. **Plants.** Alien and ruderal plant species as well as native flora species dominating in established green plantations are characteristic (Table 1).
2. **Birds.** Synanthropic and agrolandscape birds dominate. In residential areas with the fragments of natural vegetation (Šeškinė, Karoliniškės, Lazdynai), the diversity of birds changes in more green and older areas, where hatching conditions are more favourable (Table 2).
3. **Mammalia and other animals.** Dominate indicator species, which are adapted to anthropogenic environment: *Martes foina*, *Bufo bufo*, *Lacerta agilis*, species of bats and some insects as well as other terrestrial invertebrates (Table 3).
4. **Fishes.** Prevail species that are moderately sensitive to the alterations of environment; however, a number of species resistant to the impact of human activity is quite large. Single individuals of species included into the lists of EU Habitat Directive and Bern Convention also occur.

**Densely urbanized natural areas**
1. **Plants.** Very wide-spread species *Acer negundo*, *Heracleum sosnowskyi* and *Galinsoga parviflora* as well as introduced flora species dominating in established green plantations are characteristic (Table 1).
2. **Birds.** Vilnius Old Town is the most densely urbanized part of the city. Almost entire cover of concrete and asphalt dominate. In the streets and courtyards, where single trees grow and small public gardens occur, a stable bird community with dominating synanthropic species has formed (Table 2).
3. **Mammalia and other animals.** In densely urbanized city areas, animal species characteristic to natural ecosystems actually are not found: synanthropic species dominate. Indicator species are *Martes foina* as well as species of bats protected by the international conventions (Table 4).

**Fishes.** In highly altered water ecosystems dominate the most resistant fish species (*Rutilus rutilus*, *Gasterosteus aculeatus*, *Alburnus alburnus*, etc.), introduced and alien fish species occur, too (Table 4).

**Natural state of protected areas**
1. **Plants.** Red-listed, alien and ruderal plant species are characteristic (Table 1).
2. **Birds.** In protected areas of the city – the Verkiai and Pavilniai regional parks, which distinguish in particular relief and other specific natural features, 33 bird species dominate, among which 15 are included into the Red Data Book of Lithuania or the list of EU Bird Directive (Table 2).
3. **Mammalia and other animals.** In protected areas of the city (regional parks, nature reserves, Natura 2000 areas, etc.) optimal indicators of fauna are all animal species included into the Red Data Book of Lithuania as well as protected by the international conventions or EU directives (Table 3).
4. **Fishes.** In water bodies existing in protected areas dominate fish and lamprey species included in the lists of EU directives and international conventions as well as other species extremely sensitive to changes in the environment (Table 4).

To assess the impact of human activity upon landscape and natural environment, other plant species (specific to particular area) or plant communities can be used [12, 14].

The presented plant and animal species are typical to certain areas of Vilnius city and its environs. The whole above-discussed plant and animal species are recommended to use as biological criteria for the assessment of natural environment of the city in sparsely, moderately, densely urbanized and protected areas.

4. **Conclusion**
1. Vegetation (state, species composition) is one of a reliable means of assessment of the state of environment. Habitat diversity impacts the variety and abundance of animal species. Many birds of agrocnoses, green plantations and those living in water are particularly sensitive to changes in their former habitats. Some species of those ecological bird groups become extinct, whereas the abundance of others badly decreases.
2. Zoological criteria should be considered as principal elements of the assessment of the current state of landscape and biological diversity of Vilnius city as well as the level of urbanization of natural environment, and the prediction of future development tendencies and possible alternatives.
3. Botanical and zoological criteria for the assessment of the quality of areas occurring at different urbanization level were established,
specific indicator species of flora and fauna, characterizing these areas, were selected. On the basis of flora and fauna species distribution as well as their habitats analysis, the assessment of the state of natural environment of Vilnius city and its environs was worked out.

4. **Sparsely urbanized areas** are characterized by:
   a. single individuals of red-listed, alien and ruderal plant species;
   b. dendrophilous bird species, three of them included into the Red Data Books of Lithuania;
   c. indicator animal species distributed in natural environment: *Sciurus vulgaris*, *Lepus europaeus*, *Rana temporaria*, *Bufo bufo*, *Lacerta vivipara*, etc.;
   d. fish and lamprey species typical to good quality water bodies (included into the lists of EU directives and international conventions, too), moderately sensitive species dominate.

5. **Moderately urbanized areas** are characterized by:
   a. alien and ruderal plant species as well as native flora species prevailing in established green plantations;
   b. dominating synanthropic and agrolandscape bird species;
   c. indicator animal species adapted to anthropogenic environment: bats, *Martes foina*, *Bufo bufo*, *Lacerta agilis*, some species of insects and other terrestrial invertebrate animals;
   d. fish species moderately sensitive to changes in the environment, and a large number of species resistant to the impact of human activity.

6. **Densely urbanized areas** are characterized by:
   a. extremely wide–spread plant species – *Acer negundo*, *Heracleum sosnowskyi* and *Galinsoga parviflora* as well as introduced flora species prevailing in the established green plantations;
   b. stable community of synanthropic bird species;
   c. synanthropic animal species: stone marten as well as species of bats protected by the international conventions;
   d. resistant to the impact of human activity as well as introduced and alien fish species.

7. **Protected areas** are characterized by:
   a. redlisted, alien and ruderal plant species;
   b. dendrophilous bird species, among which 15 species are included in the Red Data Book of Lithuania or the Annex of EU Bird Directive.
   c. indicators of fauna are all animal species included into the Red Data Book of Lithuania as well as protected by the international conventions and EU directives.
   d. fish and lamprey species included in the lists of EU directives, international conventions as well as other species particularly sensitive to changes in the environment.

8. Intensive development of the city causes hazardous threat to the existence of protected fish species and the state of water bodies because of alteration of river bed morphology, destruction of natural vegetation on the banks of rivers and lakes, permanent and accidental pollution. Under the impact of these factors, the most sensitive species become extinct, the absolute majority of which are EU protected.

9. Diversity of birds in the city areas of diverse urbanization level depends upon ecological conditions of the environment, their variety and quality (state). Bird diversity and the amount of rare birds, which have special status of protection, is higher in the outlying areas of the city – recreational forests and regional parks.

10. In certain areas of the city, the assessment of natural environment from the point of view of ornithology can be made in a territory of minimal size that is necessary for the existence of certain bird species. Urban development and its impact upon the birds of different areas are diverse. Forest, park and majority of aquatic birds are the most sensitive to landscape alterations.

11. Some terrestrial animal species are very sensitive to urban development: the number of individuals in populations decreases, rather often the populations are separated into two or more parts, i.e. fragmentation and extinction of natural components (habitats) proceed resulting in destruction of the former structures. Different barriers often hinder the usual functioning of natural habitats.

References


