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SPATIAL PATTERNS OF BIRD COMMUNITIES OF THE LOWER DNIEPER SANDS DURING THE BREEDING SEASON: DIFFERENTIATION FACTORS

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Spatial Patterns of Bird Communities of the Lower Dnieper Sands During the Breeding Season: Differentiation Factors. Moskalenko, Yu. O. — Using hierarchical cluster analysis there were distinguished six spatial patterns of bird communities during the breeding season in the Lower Dnieper Sands. The differentiation of these patterns is based on a spatial heterogeneity in the area ratio of different habitats. The sites with natural and sub-natural landscapes hold three types of bird communities. Another type of the bird community is relatively similar to the previous three, but characterized by a poor quantitative and qualitative bird composition; it is associated with open landscapes with destroyed natural vegetation. Bird communities of artificial pine plantations (the most transformed landscapes of the Lower Dnieper Sands) are very different from those in the natural and sub-natural landscapes. The spectra of ecological groups of different bird communities match the spectra of different habitat types obtained using a supervised classification of remote sensing data. It makes it possible to use a topological model of the habitat types (based on remote sensing data) as a predictor for GIS modelling of spatial distribution of different birds communities throughout the Lower Dnieper Sands.

Key words: bird communities, habitats, spatial patterns, GIS.

Пространственные варианты населения птиц Нижнеднепровских песчаных массивов в гнездовой период: факторы дифференциации. Москаленко Ю. А. — С помощью иерархического кластерного анализа среди населения птиц Нижнеднепровских песчаных массивов в гнездовой период удалось выделить 6 пространственных вариантов. Их дифференциация обусловлена пространственной неоднородностью соотношения площадей различных местообитаний. При этом для участков с сохранившимися естественными или малотрансформированными ландшафтами характерны три типа орнитокомплексов. Относительно близкий к ним орнитокомплекс, который, однако, характеризуется бедным количественным и качественным составом птиц, приурочен к открытым участкам со сведённой естественной растительностью. На трансформированных вследствие создания искусственных сосновых насаждений участках сформировались орнитокомплексы, резко отличающиеся от таковых в естественных и полуестественных ландшафтах. Спектры экологических групп различных орнитокомплексов хорошо согласуются со спектрами местообитаний различных типов, выделенных в ходе контролированной классификации данных дистанционного зондирования. Это даёт возможность использовать полученную с помощью данных дистанционного зондирования топологическую модель узора типов местообитаний в качестве предиктора для ГИС-моделирования распространения разных орнитокомплексов на всей территории Нижнеднепровских песчаных массивов.

Ключевые слова: население птиц, местообитания, пространственные варианты, ГИС.

Introduction

The knowledge of spatial distribution patterns of individual species or communities of animals allows for solving a wide range of tasks related to the monitoring, protection and sustainable use of wildlife. An example can be the survey that indentified the potential breeding grounds of the Black Stork (*Ciconia nigra*) (Augustis, Sinkevičius, 2005; Fesenko et al., 2012), Golden Eagle (*Aquila chrysaetos*) (Karyakin et al., 2006) and the Stone Curlew (*Burhinus oedicnemus*) basing on these patterns knowledge (Thompson et al., 2004) and thereby providing an opportunity for the essential improvement of monitoring activities focused at the status and protection of the above-mentioned species populations.

The practice of zooecological research has developed two major approaches in studying territorial distribution of animals. In the first approach the distribution is studied on the basis of geobotanical, landscape, forest typology maps, etc. However, critics of this approach argue that it does not analyze the territorial distribution of animals but more likely characterizes some pre-selected plot of land by a set of species within a classification unit of any other non-relevant typology (Ravkin, Lukyanova, 1976; Shishkin, 1991; Panteleev, 1999). Instead, given the ecological individuality of species and stochastic nature of the ecosystem organization, these authors consider as more effective the second approach which proposes to identify spatial patterns of distribution of individual species or communities by a successive topological analysis of variability in their territorial distribution with the following search of key factors determining this variability. In addition to the well developed apparatus of multivariate statistics, the wide implementation of this approach is currently promoted by a relatively simple, quick and cheap assess to the data on spatial dynamics of many environmental variables with a help of remote sensing data (RSD). Not the least role in this plays the development and distribution of desktop geographic information systems (GIS), which are shared under a free license (Dubinin, Rykov, 2009), and which, according to researchers, are a worthy alternative to commercial packages, including their application to environmental studies (Steiniger, Hay, 2009; Tytar, 2011).

Material and methods

1. Study area

The Lower Dnieper Sands (LDS) consist of seven major arenas (with a total area of about 161,000 ha), stretching from Kakhovka along the downstream of the Dnieper and Dniprovskyi Liman (Gordienko, 1969). Their natural landscape, remained relatively untouched only within sandy arenas of the Black Sea Biosphere Reserve (BSR), is defined by researchers as the intrazonal hilly sandy forest-steppe (Tkachenko, 1999). A major part of the Lower Dnieper Sands have large tracts of artificial plantations of pine trees interspersed with occasional spots of deciduous trees (mainly robinia) which were planted to mitigate the deflation caused by destruction of natural vegetation due to overgrazing and felling of natural forests. The remaining areas of the LDS that were not forested or lost their artificial pine plantations due to forest fires are mostly represented by an open terrain with vegetation at various stages of recovery succession.

2. Collection and processing of field data

To investigate the territorial heterogeneity of the breeding bird community in the Lower Dnieper Sands we used the data of bird transect counts carried out along the routes laid in different LDS areas. The count data were collected per 1 kilometre sections, each of them in subsequent processing and analysis was considered as one sample. A total of 86 samples were analyzed. In 2005 (the main year of data collection) we succeeded in covering only 71 samples, and for the remaining samples there were used the count data collected in 2002 (8 samples) and 2006 (7 samples). A brief description and location of test plots are presented in table 1 and figure 1.

As a quantitative indicator for the bird population analysis it was used the total number of all registered individuals of each species within 1 kilometre section of the route (samples). Singing males or broods were counted as one breeding pair, while transit birds flying across the transect were ignored as those that had no ecological relations with this transect section. Since at the large distances it is difficult to detect small bird species, we ignored bird encounters further than 300 m to the transect line to avoid significant bias in favour of large species in the quantitative data.

The classification of bird species by ecological groups used in this study is generally similar to that given by V. P. Belik (2000), except that a number of xerophilous species, which in the LDS breed in planted forest stands (the Common Kestrel, *Falco tinnunculus*; the Roller, *Coracias garrulous*, and the Hoopoe, *Upupa epops*), we considered in the analysis as a composite part of the dendrophilous group.

3. Statistical analysis and GIS software support

Spatial differentiation of bird communities was studied through hierarchical cluster analysis. Euclidean distance was used to calculate similarity between individual samples. A dendrogram was built by the algorithm of group dispersion minimization or so-called Ward's method (Pesenko, 1982). Probability of difference between samples was evaluated by statistical criteria: for nonparametric data (number of individuals) by the Wilcoxon-Mann-Whitney test, for parametric data (area of habitats) by Student's t-test. In all cases, the null hypothesis was rejected, if probability of statistical error (p-value) was less than 0.05. The analysis was made in the environment of a statistical package R (R Core…, 2012), including cluster analysis by using a specialized vegan module (Oksanen et al., 2013).

To interpret the groups of samples obtained in the output of cluster analysis, these groups were visualized in the environment of desktop GIS QGIS 1.8 (QGIS…, 2012) and the possible factors determining spatial heterogeneity of bird communities were revealed by a visual overlay analysis along with statistical analysis of the area ratio of different habitat types. As the basis, a vector map of habitat types was used created by vectorizing the outputs of supervised classification of remote sensing data (RSD) Landsat 8 (sensor OLI, date of image — August 24, 2013, combination of RGB channels — 764, spatial resolution — 30 m/pixel) using a method of support vector machines (SVM) (Mather, Koch, 2011). The classification procedure of RGB-composite was made

Table 1. Brief description of the location of samples in the research on spatial differentiation of bird communities in the Lower Dnieper Sands

Таблица 1. Краткая характеристика размещения проб для исследования пространственной дифференциации населения птиц Нижнеднепровских песчаных массивов

Number of location	Number of samples	Year of counts	Location
1	1–18	2005	Ivano-Rybalchanska plot, BSB
2	19–30	2005	Solonoozerna plot, BSB
3	31–36	2005	Pine plantations of Ivanivska arena, LDS
4	37–42	2005	Pine plantations of Kinburn Peninsula (in its bedrock part)
5	43–48	2005	Not forested plot on Kinburn Peninsula to the west of Solonoozerna plot, BSB ('Soleprom' area)
6	49–54	2005	Pine plantations in the central part of Zburivska arena, LDS
7	55–60	2005	Not forested plot on Zburivska arena, LDS
8	61–66	2005	Pine plantations of the distal part of Kinburn Peninsula
9	67–71	2005	Pine plantations of Oleshkivska arena, LDS
10	72–78	2006	Not forested plot in the central part of Kozachelaherska arena, LDS
11	79	2002	Mature robinia plantation in Zburivska arena, LDS
12	80–86	2002	Pine plantations of the eastern part of Zburivska arena, LDS

Note. BSB — the Black Sea Biosphere Reserve; LDS — the Lower Dnieper Sands.

in the Orfeo Tollbox 3.16 using the Montewerdi 1.14 graphical interface. The RSD classification by the method of SVM identified 7 habitat types within the Lower Dnieper Sands (table 2).

The statistical evaluation of ratio of different habitat types among sample groups was performed on standard test plots (STP). The standard test plots are represented by polygons constructed by tools for editing QGIS layers (one for each sample), which in situ correspond to circles 600 m in diameter. Centres of these polygons coincided with the centres of transect lines for corresponding 1 km sections. For the research, these STP rather representatively reflect the ratio of certain types of habitats within the transects, since the area of each STP (27.8 ha) covered at least 46.3 % of the total transect area of the corresponding 1 kilometre section of the route. A polygonal layer with shapes of STP circles were used in the "intersection" tool of QGIS as a mask for trimming the vector map created through vectorization of classified raster. After application of the tool in the output we received a polygonal shapefile with STP circles, split into polygons of individual habitats; the areas of habitats were calculated using an integrated QGIS field calculator.

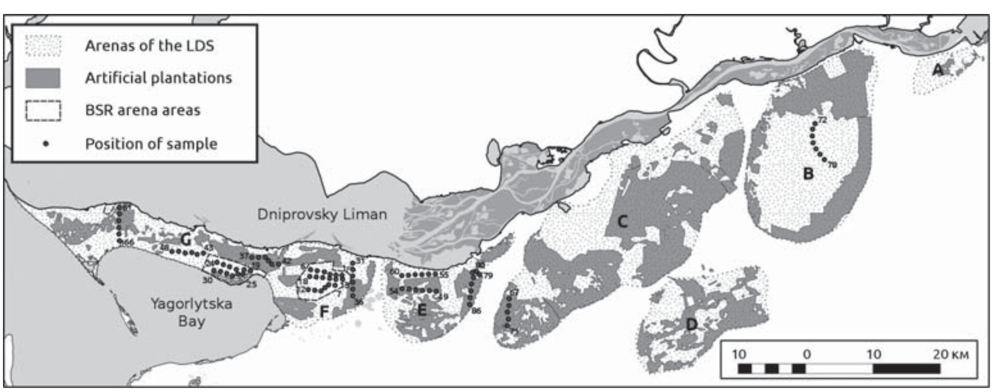

Fig. 1. The scheme of the study area. Arenas of Low-Dnieper Sands: A — Kakhovska; B — Kozachelaherska; C — Oleshkivska; D — Chalbaska; E — Zburivska; F — Ivanivska; G — Kinburn Peninsula.

Note. The first and the last sample of each census route are marked by numbers; the numbering of samples is the same as in table 1.

Рис. 1. Схема района исследования. Арены Нижнеднепровских песчаных массивов: A — Каховская; B — Казачьелагерская; C — Олешковская; D — Чалбасская; E — Збурьевская; F — Ивановская; G — Кинбурнский п-ов.

Примечание. Цифрами обозначены номера начальных и конечных проб отдельных маршрутов; нумерация проб соответствует таковой в таблице 1.

Results and discussion

The dendrogram obtained in the cluster analysis is shown in figure 2 in a generalized form. Its generalization means that all clusters, formed by combining samples at the distances smaller than threshold, were ignored. This technique allows us to adjust the scale of the analysis thus not taking into account the groups which formation is determined by too small and insignificant (again — for the certain spatial scale) topographic factors or, moreover, is a result of statistical noise. In choosing a threshold value, which in this case is 60 units, we were guided by an empirical criterion, based on the fact that our long-term experience of analyzing spatial heterogeneity of bird communities in the BSR sandy areas during the breeding season has shown the existence of 3 relatively resistant patterns. Therefore, as a threshold it was chosen the minimum distance above which the samples of sandy areas (N 1–30) were distinguished in no more than three groups (table 3).[1]

As shown in figure 2, the whole set of samples with high degree of dissimilarity is divided into two major groups: A (Clusters I–IV) and B (Clusters V–VI). The main factor that determines their differentiation is the absence or presence of large tracts of artificial pine plantations. According to the statistics of areas of individual habitats, the average area of pine plantations in the STP among samples belonging to Group A is 0.9 ± 0.4 ha and among Group B is 13.4 ± 1.2 ha. The influence of this factor is clearly seen in the ratio of abundance (mean number of individuals per sample) of dendrophilous and campophilous species, whereas these groups do not differ by the abundance calculated for the whole species composition (fig. 3: A — 49.1 ± 3.0 ind/s (hereinafter — individuals per sample), B — 54.0 ± 4.6 ind/s; $p = 0.31$).

Clusters of a lower hierarchical level are also quite significantly distanced from each other, indicating a clear internal heterogeneity of both obtained groups. Thus, samples of Group A in a relatively narrow range of distances (approximately 95 to 145 units) are divided into 4 clusters (I, II, III and IV; fig. 2).

A specific feature of Clusters I and III is that they mostly consist of the samples from arena areas of the Black Sea Reserve. Thus, Cluster I included only 5 samples (33.3 %) from outside the reserve, and Cluster III — only one (Sample 55, 6.3 %). It should also be noted that except for the already mentioned Sample 55 from Zburivska arena, Cluster I and III included only samples taken within the distal arenas of the Lower Dnieper Sands — Ivanivska and Kinburn Peninsula.

The most significant differences in the habitat area ratio in samples of Clusters I and III are due a larger area of lakes in samples of Cluster I (5.2 ± 1.5 ha vs 0.6 ± 0.4 ha; $p = 0.02$) and deciduous forests in samples of Cluster III (6.3 ± 0.8 ha vs 2.2 ± 0.5 ha; $p = 0.0002$) (fig. 4). However, as it can be clearly seen from figure 5, the differentiation of their bird communities lies in dissimilarities between abundances of dendrophiles and campophiles, while the role of limnophiles is obviously vanishingly low. Especially interesting is the dissimilarity between abundances of campophilous bird groups in Clusters I and III, since these clusters do not differ significantly either in the area of sandy steppes or in the area of sparse sandy vegetation (fig. 4). Perhaps a key factor there is a topographic structure of the landscape. In particular, we assume that on the steppe areas which structure is strongly fragmented by large oak and oak-birch groves (typical for samples of Cluster III), and with equal effect of other factors, the breeding density of campophilous birds is lower than on (typical for samples of Cluster I) vast open steppe areas with inclusions of only small groves (mainly birch).

Cluster II was very specific, and included the samples exclusively located within Kinburn Peninsula, namely in the part of the peninsula which is adjacent to Yahorlytska Bay and fragmented by a great number of lakes, most of which, moreover, is connected with the

[1] In the set threshold value of distance, 28 out of 30 samples, taken on the BSR arena areas, are distributed among three groups. The fact that the remaining samples entered the fourth group, we suggest to be an artefact and the explanation of emergence of this artefact is given below.

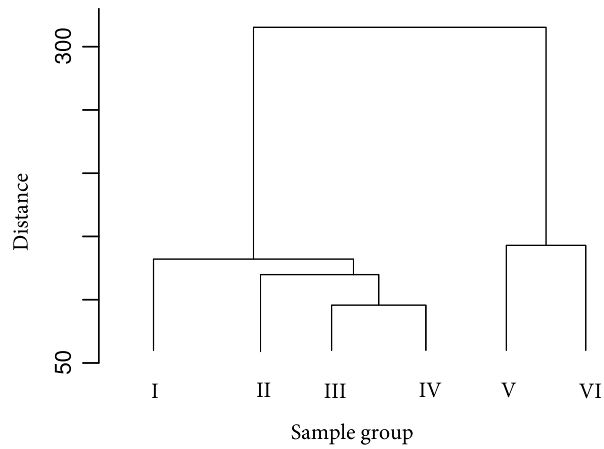

Fig. 2. Dendrogram of hierarchical cluster analysis on a data set.

Рис. 2. Дендрограмма иерархического кластерного анализа совокупности проб.

waters of the bay. Compared to others, samples of this cluster, in addition to the availability of large water areas, are characterized by the largest sizes of depressed and meadow areas (fig. 4). Naturally, a typical bird community in this group of samples is represented by limnophilous birds (fig. 5).

Cluster 4 included the samples mainly located on the most transformed deforested areas of the Lower Dnieper Sands or in clearings on former fire sites in pine plantations. These areas are usually characterized by a combination of almost complete absence of woodlands and significant predominance of loose sand with numerous patches of deflation, or covered by sparse vegetation (fig. 4). Degraded nature of these areas also determines a simplified structure of their bird communities, characterized by poor species diversity (7.4 ± 0.6 species/s) and low abundance (28 ± 1.7 ind/s). It should be separately noted that the entering in Cluster IV two samples of the BSR arena areas (one from Ivano-Rybalchanska and one from Solonoozerna plots) is an artefact, manifestation of which is probably caused by the following conditions. Both of these samples are 1 km sections located in the end of the corresponding count routes,

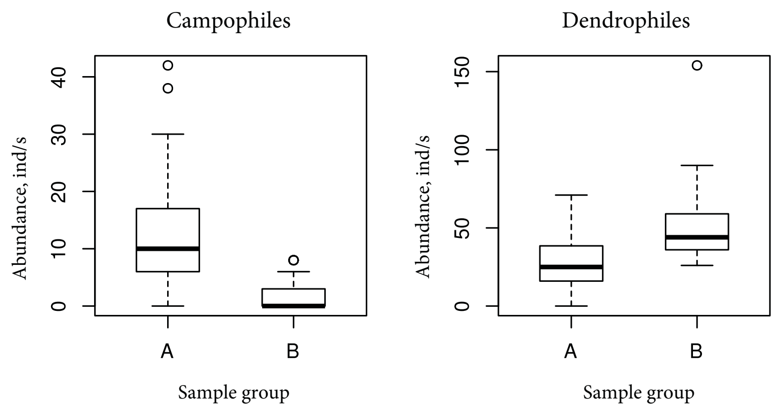

Fig. 3. The abundance (the mean number of individuals per sample) of campophilous and dendrophilous birds in groups of samples A (Clusters I–IV) and B (Clusters V–VI).

Note. The central line represents median, the lower and upper limits of the rectangle — the first and third quartile respectively, "whiskers" — ± 1.5 of interquartile range; circles — outliers.

Рис. 3. Обилие кампофилов и дендрофилов в группах проб A (I–IV кластеры) и B (V–VI кластеры).

Примечание. Средняя черта — медиана; нижняя и верхняя границы прямоугольника — соответственно первая и третья квартили; «усы» — ± 1,5 интерквартильного размаха; круги — значения выбросов.

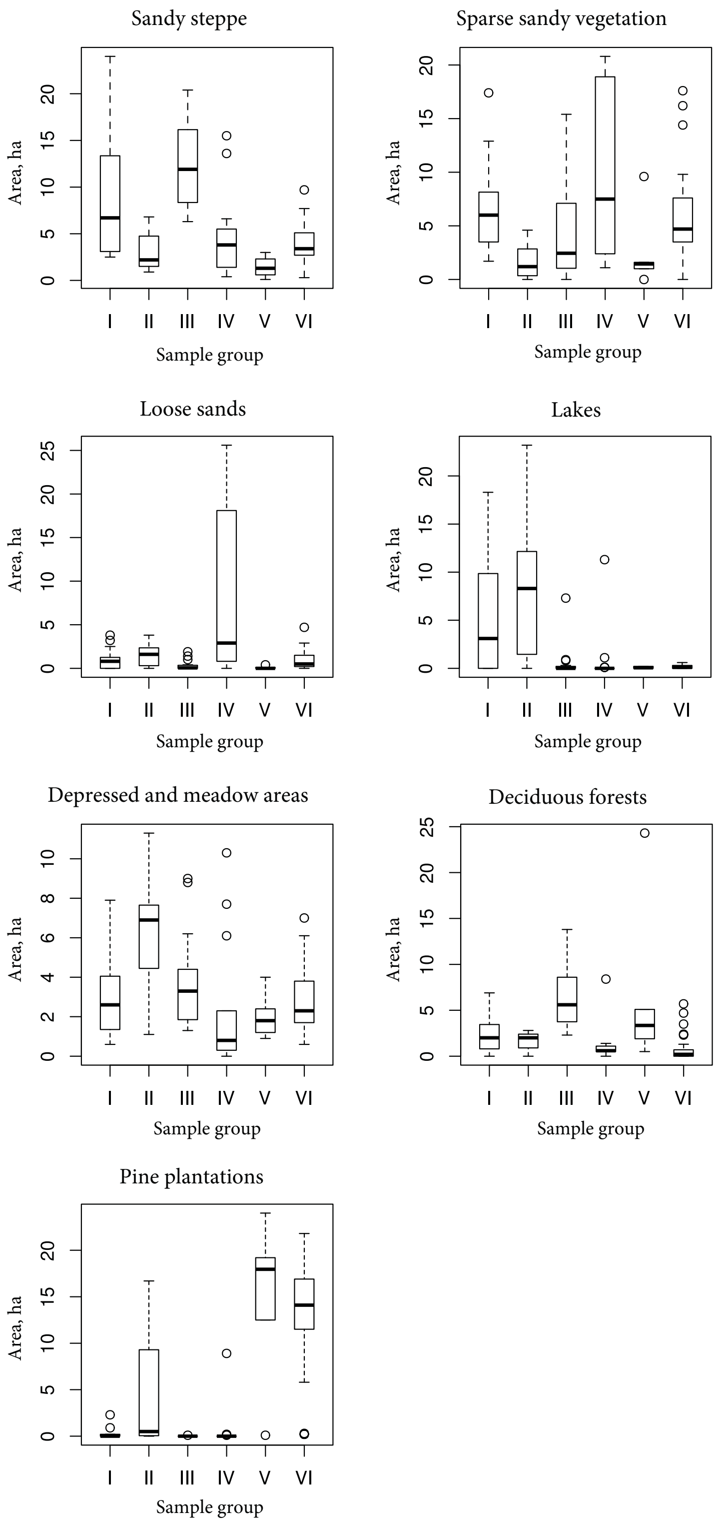

Fig. 4. The area ratio of different types of habitats on standard test plots in the groups of samples.

Рис. 4. Соотношения площадей отдельных типов местообитаний на стандартных пробных площадках по группам проб.

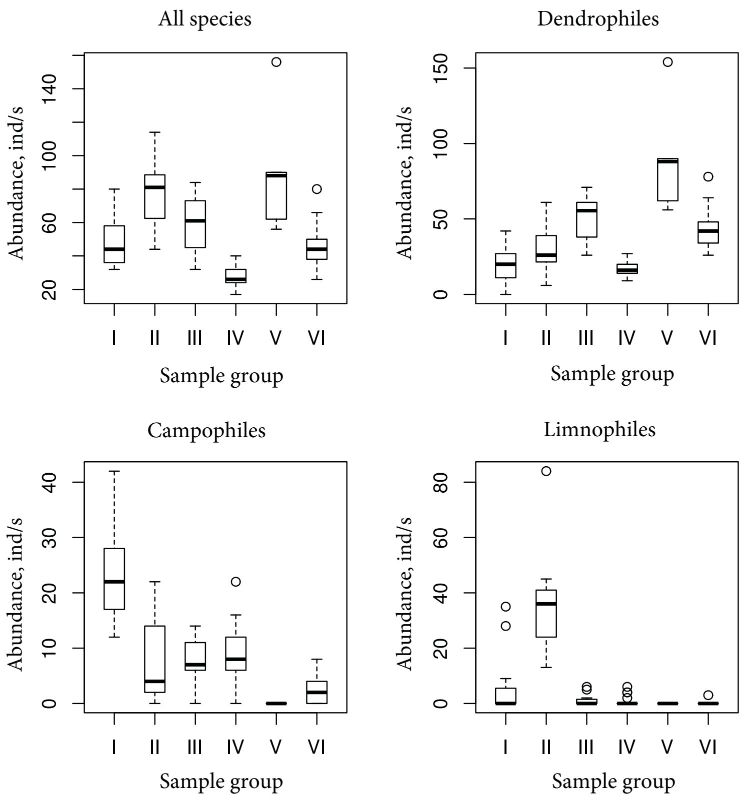

Fig. 5. The bird abundance ratio in the separate groups of samples.

Рис. 5. Соотношение обилия птиц по отдельным группам проб.

and, therefore, the time of the count coincided to the beginning of the heat hours of the day, when the activity of dendrophilous birds sharply declined. That resulted in underestimation and causes the similarity of the obtained quantitative indicators to those, received for the most transformed deforested areas of the Lower Dnieper Sands.

The division of Group B into two separate clusters (V and VI) is determined by a difference in the total forested area, the mean value of which among standard test plots of Cluster V (21.7 ± 1.9 ha) is significantly higher (p = 0.007) than in Cluster VI (13.9 ± ± 1.3 ha). This factor matches with the dissimilarities in relevant bird communities because the abundance of dendrophiles in the whole set of samples of Cluster V almost twice exceeds that in Cluster VI (respectively, 90.0 ± 14.5 ind/s and 45.4 ± 2.3 ind/s; p = 0.0006). We assume that, except for a higher total area of forests, the great role in the dissimilarities between bird communities of Clusters V and VI is also played by a significantly higher proportion of deciduous trees among the samples of Group V (fig. 4). In this context, the only exception was the Sample 80, almost deprived of deciduous trees, but in this case it was apparently the effect of neighbourhood, as it was located in the immediate vicinity to a large mature plantation of robinia.

Thus, as a result of the research there were identified six spatial patterns. Even without a detailed analysis of their composition and structure, which will be a subject for the next report, a preliminary analysis gives the basis to believe that the most powerful factor determining the spatial differentiation of the current bird communities of the Lower Dnieper Sands is the degree of anthropogenic transformation of the study areas. Thus, bird communities of types I, II and III are associated with open areas of the Lower Dnieper Sands with natural or relatively little transformed landscape. Type IV is typical for the LDS open areas with destroyed natural vegetation. The LDS areas with artificial forest plantations hold other, quite different, types of bird communities (V and VI). The ecological structure of allocated bird communities matches the area ratio of certain habitat types that allows considering them as the critical factors for spatial differentiation of the LDS birds. The practical output obtained as a result of supervised classification of remote sensing data, is a topological model of habitat types that can be successfully used as a predictor for GIS modelling of distribution patterns of different types of bird communities throughout the Lower Dnieper Sands.

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