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NESTING HABITATS OF BLACK STORK (*CICONIA NIGRA* L.) IN UKRAINIAN FOREST ZONE (POLISSIA) REVEALED BY AN OVERLAY ANALYSIS IN GIS

The study was based on an overlay analysis in GIS. Exact locations of 108 nest and layers representing forest types, prevailing tree species, forest age and productivity (bonitet class) were used. The analysis was performed on the level of individual nests (spatial join to point layer), and on the level of buffers with 500m radius around nests. To find the most preferable forest types for Black Stork we compared the frequency of distribution of forest types on the nesting territories with the frequency of distribution of those types in the study area and in 500m buffers around 108 random points.

According to the results of our research, the spatial distribution of Black Stork nests to a great extant follows the general structure of forests in the region. We found some selectivity in case of wet forest types with prevalence of oak with pine, as well as with black alder, but the result is not statistically significant. The only statistically significant relation was found in case of forest age. Black Storks prefer old and mature forests. The most important trees for nesting were oak (53,3%) and pine (29,9%).

Keywords: *Black Stork, Ciconia nigra, habitats, GIS.*

Introduction

Conservation of any species is usually impossible without protection of habitats important for their breeding, foraging, resting etc. Black Stork is one of most habitat-dependent species of birds in Europe, because it is strongly dependent on the availability of mature forests and trees with a low level of disturbance. There is a large number of papers devoted to Black Stork habitat preferences in Europe. Most of them are based on the studies made in Central and East European countries [1, 4, 7, 11, 12 etc.], mostly Baltic countries, which is reasonable, taking into account the species distribution in Europe and the sizes of national populations [2, 10].

Ukraine possesses a significant part of the European Black Stork population [2, 10] and is interesting as a territory of breeding range margin, where European Forest zone borders with steppes. The Ukrainian population may be underestimated and might actually be much bigger. No detailed studies of Black Stork breeding habitats in Ukraine have been conducted so far. Some generic works [5, 17, 17, 20 etc.] with the topic-related information have been published, yet there is a lack of specialized studies. One study [14] was related to habitats and their changes but was mostly analytical and based on expert opinions without appropriate raw numerical data. Current publication aims to fill some of gaps in this area of Black Stork studies using GIS approach.

Materials and Methods

The analysis of Black Stork spatial distribution in relation to forest habitat types was performed in the territories of eight forestry companies (table 1) in the Rivne region of Ukraine, which overlap with the Polissya nature zone and with the kernel of Black Storks highest population density, as well as with the main part of the breeding range of this species in Ukraine (fig. 1). The territories of other forestry companies in the region and known nesting locations from other parts of Ukrainian Polissya have not been covered by the analysis, because it was not possible to obtain databases of their forest structure so far.

Table 1

Forestries (territories) included to the analysis of Black Stork spatial distribution in Rivne region

Names of forestries	Area, ha
DP "Vysotskyi lisgosp"	29677
DP "Volodymyretskyi lisgosp"	80435
DP "Dubrovtskyi lisgosp"	44746
DP "Klesivskyi lisgosp"	48729
DP "Kostopilskyi lisgosp"	34853
DP "Ostkivskyi lisgosp"	32325
DP "Sarnenskyi lisgosp"	74623
DP "Sosnivskyi lisgosp"	46354
Total	**391742**

In the analysis of Black Stork nests spatial distribution an overlay approach in GIS was used. The analysis was performed on three levels: 1 – level of general analysis of forests structure in the entire study area (forestries level), 2 – level of separate breeding territories (500m buffer zones around individual nests, see fig. 2) and 3 – level of individual nests locations (spatial joining of attributes from forest plots to point layer of nest locations).

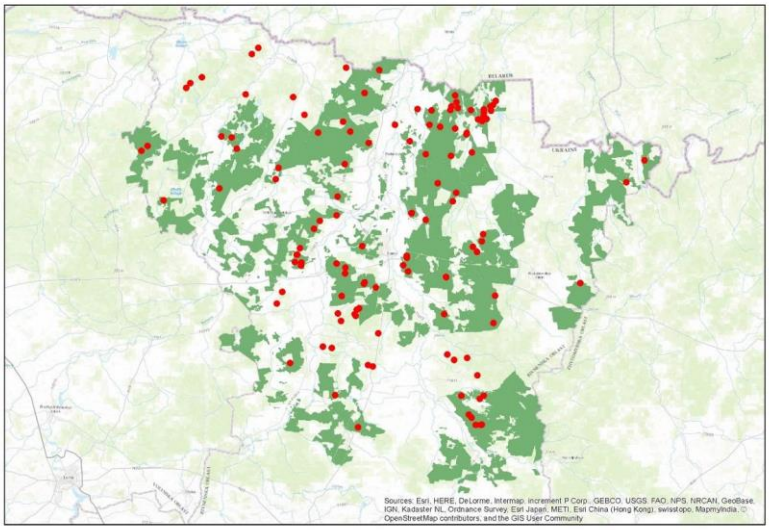

Fig. 1. Territories of forestries in Rivne region considered when performing analysis of the Black Stork nests spatial distribution in relation to forest habitats.
Legend: Red circles – nests of Black Stork in Rivne region.

In some previous studies, other researchers usually used bigger buffer zones around nests (e.g. 2,8 km; [6, 10, 11]) to analyze forest structure there. We decided to use much

smaller buffers because in some parts of the study area the nests are located very close to each other (sometimes less than in 500 m) and we had no possibility to check inhabitance of every nest. Of course, many of those nests are used by the same pairs, but we cannot distinctly separate them. Moreover, in Ukraine 500 m buffers are proposed as a zone of strict protection of the species, so it seemed reasonable for us to use such a distance for the analysis.

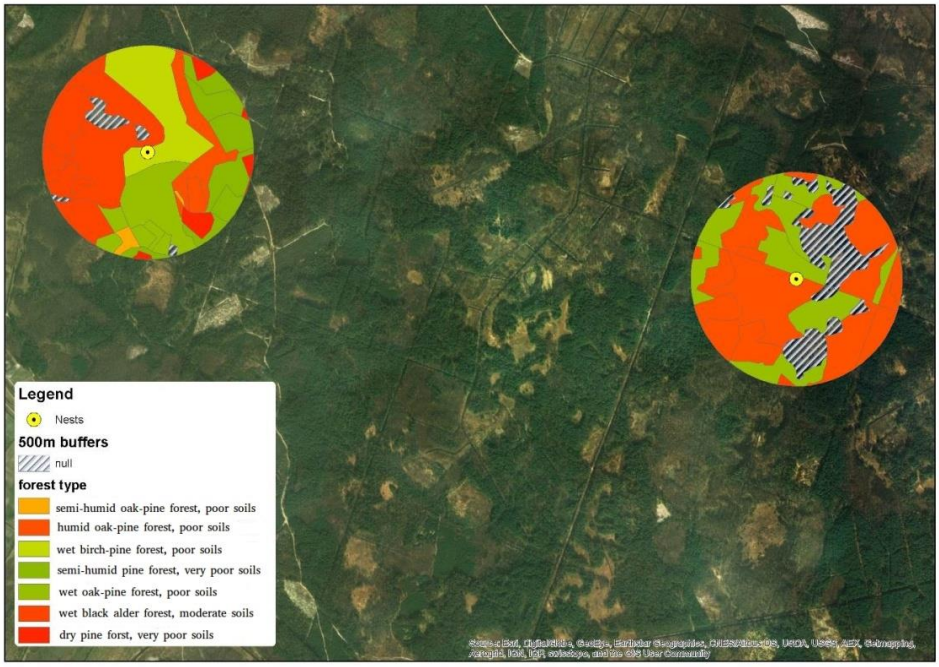

Fig. 2. Example of a forest structure analysis in 500 m buffers around nests (in this particular case – the comparison of areas of different forest types; the areas were calculated in GIS and stored in the attributive table).

In total, in the analysis we have used location information from 100-108 nests and attributive information about the forest age, type, productivity, main tree species and vegetation-humidity types from 148000 forest plots (so-called "vydil" – the smallest forest unit in Ukraine). A large number of forest fragments ("vydil") considered and their comparatively small size allows to estimate forest structure in an appropriate and correct way. On the one hand, a small size of the plots allows to describe local habitats in a detailed way, without major generalization. On the other hand, a big number of such plots provides an excellent sample size. This is crucial to produce robust and precise conclusions about Black Stork habitat preferences on a macro level.

In addition, it should be born in mind that it is easy to make false conclusions if a general forest structure is not considered while analyzing habitat preferences of the species, because distribution of nests in the forests of different types can be predicted by a frequency of occurrence of those forest types. Therefore, when judging about Black Stork habitat preferences we tried to estimate habitat selectivity or avoidance by comparing the frequency of distribution of nests in the forests of different types and the forest types proportional composition (compared by area) in 500 m buffers around nests with the general forest structure (percentage by area) in the region. We have also generated 108 random points in the study area (using ArcGis 10.5 "Create Random Points" tool) and

buffers with 500 m radius around those points to compare additionally the forests structure in 500 m buffers around the nests with random locations.

To analyze frequencies statistically, we used Pearson's chi-squared test in MS Excel 2016. The GIS analysis was performed in ArcGIS for Desktop 10.5.

Apart from habitat analysis, we have also studied locations of individual nests on trees. A total of 375 nests of Black Stork from six regions in Ukraine (Volyn, Rivne, Zhytomyr, Kyiv, Chernihiv and Sumy regions) have been considered.. Tree species, nest location height, and nest position on a tree were described.

Results and discussions

Usage of forest habitats by Black Stork in Rivne region

The results of the analysis show that there is a strong correlation between the Black Stork habitat selection and the general structure of forests in the region, on each of the analysis levels. It is clear from the figure 3 that the percentage of nests located in the given forest types corresponds to the general structure of forests. The difference in distribution does not exceed 5% in any of the cases. The largest difference (selectivity) is observed in the case of humid oak-pine forests and wet black alder forests that seem to be preferable for the species in the studied region. On the contrary, the biggest negative difference in the distribution can be seen in the case of semi-humid oak-pine and semi-humid pure pine forests. Some other studies [1, 4, 8] confirm positive selectivity by the species of mixed humid forests and avoidance of pure coniferous forests. Since we use a more detailed forest classification here, it is quite difficult to compare the results with the literature directly but the tendency seems to be quite similar. However, the frequency of distribution of forests of different types in 500 m buffers around nests does not differ significantly (χ^2=6,29, p=0,85, df=11) from such frequency in similar buffers around random points or from frequency in the entire study area (χ^2=7,24, p=0,78, df=11).

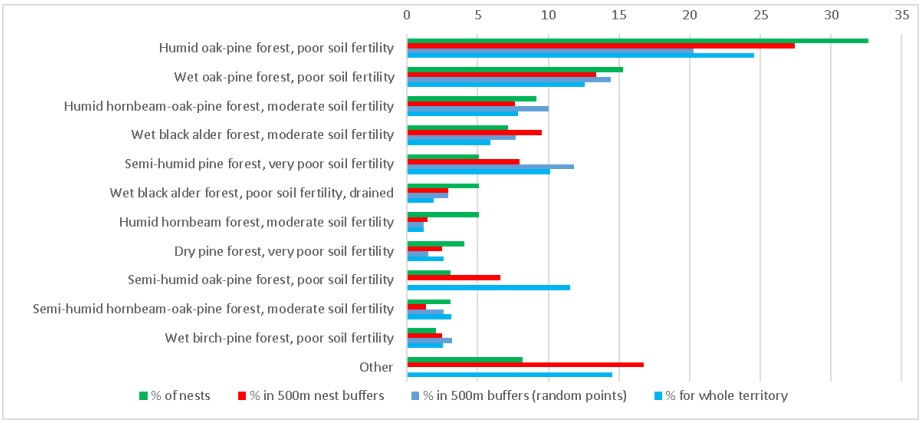

Fig. 3. Distribution (%) of Black Stork nests in the forests of different types in relation to the general frequency distribution of these forest types in the region.

A similar situation can be observed in the case of prevailing tree species in the surrounding forests around the nests (table 2). The difference between inhabitance frequency and general frequency of occurrence in the region is small and insignificant (comparison with random buffers: χ^2=3,85, p=0,57, df=5; comparison with the entire study area: χ^2=5,32, p=0,38, df=5)). There is some positive shift/selectivity in the case of black alder forests (usually very wet forests) and some avoidance of pine (when comparing buffers around nests with random locations and the entire study area).

Table 2

Distribution of Black Stork nests in the forests with different prevailing tree species in relation to the general frequency of distribution of those prevailing species in the region

Prevailing tree species in forest stands	Nests locations		In 500m buffers	In 500 m buffers around random points (n=108)	In the entire study area	
	n	%	%	%	%	ha
Pine	71	65,7	61,4	69,1	68,2	266977
Black alder	19	17,6	14,8	11,5	9,1	35517
Silver birch	11	10,2	16,1	14,2	14,9	58229
Oak	7	6,5	6,6	4,0	4,6	18169
Common aspen	0	0,0	0,4	0,3	0,3	1001
Other	0	0,0	0,6	0,9	2,1	3038
Total	**108**	**100**				**382979**

A somewhat different picture is seen in the case of the Black Storks distribution in relation to the forest age. We found a fairly big positive shift in the inhabitance frequency in the case of old forest fragments. In other words, the forests surrounding nests are usually older than other forests in the region. In general, 54,2% of nests are located in mature forests (pre-mature, mature, and very old combined). The forests of such categories comprise 37,5% of forest in 500 m buffers around nests. In comparison, in the entire study area such forests comprise only 31,8% of all forests. An opposite situation can be found in the case of young and middle-aged forests (fig. 4).

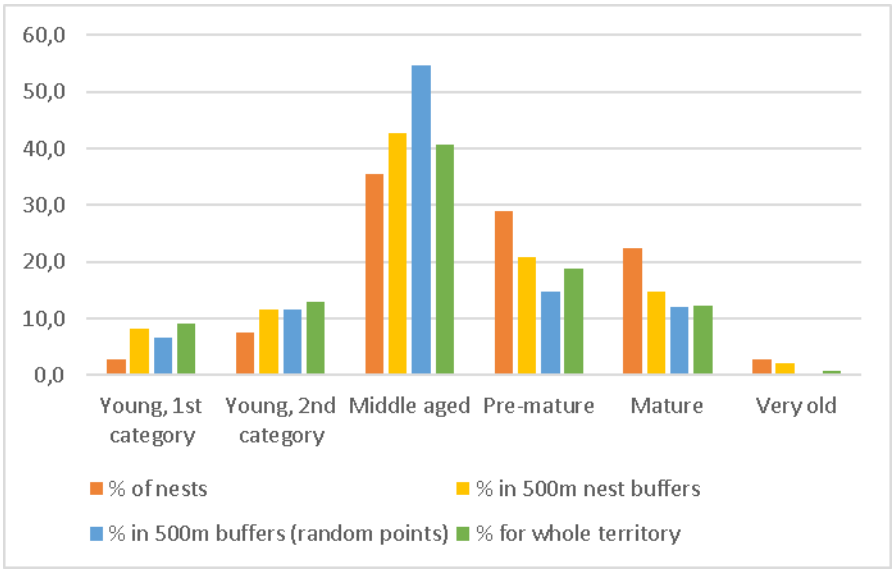

Fig. 4. Distribution (%) of Black Stork nests in forests of different age classes in relation to the general frequency of distribution of those age classes in the region.

Selectivity of Black Storks in the case of old forests of different age categories is statistically significant when comparing forest age structure in 500 m buffers around nests with such in buffers around random points (χ^2=16,59, p=0,005, df=5). In comparison with general forest age structure in the region, the differences in frequencies are not significant (χ^2=3,34, p=0,65, df=5). Many studies report a strong relation between stork nest locations and forest age [12, 13, 14, 15, 19]. In our opinion, forest age is not the crucial factor for storks, but it correlates with the availability of old trees suitable for nest building. The older forest stand is, the bigger a possibility to find old trees there. On several occasions we have found nests in relatively young forest stands with only several old trees or even just one tree (usually old oak or pine).

From the frequency distribution of Black Stork nets in relation to forest soil-humidity types (classification by P.S. Pogrebniak [18]) we can assume that the most preferable types for Black Storks are forests which grow on humid and wet soils (B3, B4, C3, C4; fig. 5). However, the differences are not statistically significant (comp. with rand. points.: χ^2=9,78, p=0,78, df=14 and with the entire area: χ^2=6,73, p=0,94, df=14).

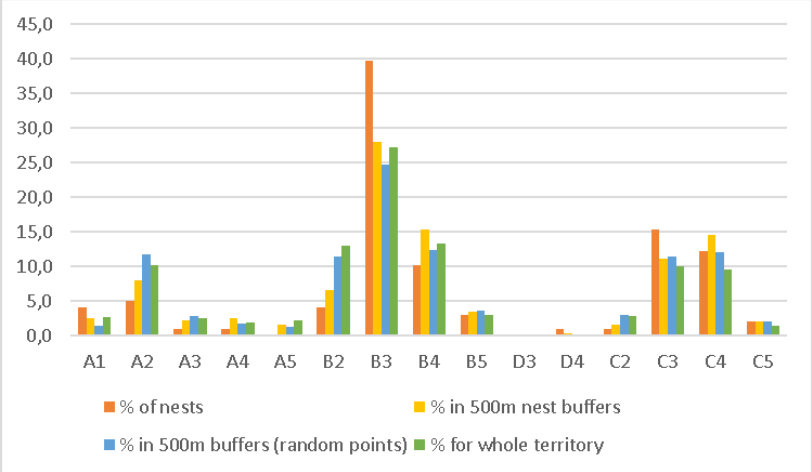

Fig. 5. Distribution (%) of Black Stork nests in forests of different soil-humidity classes in relation to the general frequency distribution of those classes in the region.

It is quite interesting to note a spatial distribution of Black Stork nests in relation to the distribution of forests with different productivity (bonitet class) and therefore different value for the forestry industry. Storks most frequently inhabit forest plots with the highest productivity – class 1 (1, 1A), which is demonstrated by the occurrence percentage in 500m buffers around nests (42,3% for 1 and 1A combined). It can be concluded that the forests with productivity classes 2 and 3 are most suitable for storks (37,1% and 12,3% respectively, table 3). A very similar situation was observed in the study of R. Treinys and others [12] where they described distribution of 30, 23, 35, 12% for bonitet classes 1A, 1, 2, 3-4 respectively. The same was also indicated by [4]. In the case of our study, the differences with random points and study area are not statistically significant (χ^2=2,25, p=0,99, df=10 and χ^2=1,70, p=0,99, df=10). Therefore, Black Storks inhabit mainly forests of a very high value for forestries producing maximum amount of wood and the highest income. Conflict of interest is obvious and it is one of the main reasons why the species population is declining.

Table 3

Distribution (%) of Black Stork nests in the forests of different productivity classes in relation to general frequency distribution of those classes in the region

Forest productivity classes (bonitet)	Nests locations		In 500m buffers	In buffers around random points (n=108)	In the entire study area	
	n	%	%	%	%	ha
1	40	40,8	33,7	32,4	35,9	140720
1A	11	11,2	8,6	10,8	10,2	39971
1B	0	0,0	0,7	1,0	0,8	3015
1V	0	0,0	0,0	0,3	0,1	239
1G	0	0,0	0,1	0,1	0,1	246
2	30	30,6	37,1	35,9	33,9	132850
3	12	12,2	12,3	12,9	11,4	44573
4	2	2,0	5,1	3,3	4,3	17002
5	2	2,0	1,5	1,8	1,9	7605
5A	1	1,0	0,8	1,4	1,3	4962
5B	0	0,0	0,3	-	0,1	560
Total	**98**	**100**				**391742**

Nesting trees

The majority of studied nests in Ukrainian Polissya are located on oaks (table 4). Other important tree species for storks is pine. All other tree species comprise less than 17% of all the cases. Such proportion is typical for all the studied sub-regions of Polissya and is similar to the findings of other researchers in Ukraine [5, 16, 17, 20] and in some regions of Europe [3, 8, 19]. The proportion of nests on various trees may differ from study to study [6, 8, 15] and might be strongly dependent on the availability of different tree species in the studied areas. At the same time, oak seems to be one of the most preferable trees in all the cases when it is available. Nesting trees were usually very old – older than the surrounding forest stand. Unfortunately, we do not possess any data on the exact tree age to compare it with the published studies, but the same tendency was observed in all the works cited above.

Table 4

Numbers of Black Stork nests located on different tree species in the Ukrainian Forest zone (Polissya)

Tree species	Regions						Total	%
	Volyn	Rivne	Zhytomyr	Kyiv	Chernihiv	Sumy		
Oak	27	69	60	21	16	7	200	**53,3**
Pine	29	35	20	7	15	7	112	**29,9**
Alder	14	9	2	-	2	1	28	**7,5**
Silver birch	4	3	5	-	1	-	13	**3,5**
Common aspen	2	7	7	-	-	-	16	**4,3**
Ash	1	-	-	-	-	-	1	**0,2**
Willow	-	-	-	-	3	2	5	**1,3**
Total	77	123	94	28	37	17	375	**100**

In Ukrainian Polissya, storks usually build nests in the height ranges of 4-25 m (table 5). The average nest height depends on the tree species (ANOVA: F=2,66, p=0,03) but is usually fairly constant (10-15 m).

On the trees, nests were located mostly on side branches near the main trunk (55,7%, n=147). 20,1% of nests (n=53) were built on side branches on some distance from the trunk. Another 20,1% of nests (n=54) were built in the main trunk forks. Six nests (2,3%) were located on the traditional hives in forest ("bort"), while four nests (1,5%) – in the curvatures of the main trunk.

Table 5

Height of nest location on different trees species in the Ukrainian Forest zone (Polissia)

Tree species	M	σ	Min	Max	n
Silver birch	13,2	3,51	6	20	10
Willow	9,0	1,41	7	10	3
Alder	13,3	3,54	7	21	17
Oak	11,3	3,76	4	25	148
Powerline pole	25,0	-	-	-	1
Common aspen	14,1	3,04	10,5	20	10
Pine	12,1	3,73	4,5	22	88
Combined	**11,9**	**3,85**	**4**	**25**	**277**

Conclusions

In the Ukrainian Forest zone (Polissya) within the Rivne region, Black Stork uses for breeding mostly mature forests with old trees located in humid places. In general, the distribution of nests in the forests of different types reflects the structure of forests in the region, although we found some statistically insignificant positive selectivity (shift in occurrence/distribution) in the case of humid oak-pine forests and negative selectivity in the case of semi-humid oak-pine and humid pure pine forests. The most preferable dominant tree species in forest stands is Black Alder *Alnus glutinosa* and the least preferable – Silver Birch *Betula pendula*, yet selectivity in case of prevailing tree species is also statistically insignificant. In Polissia (Volyn, Rivne, Zhytomyr, Kyiv, Chernihiv, and Sumy regions), the majority of nests are located on oaks *Quercus robur* (53,3%) and pines *Pinus silvestris* (29,9%). As to the forest age, Black Storks prefers premature and mature forests (significant) of the highest productivity classes. Our analysis has found very similar results in comparison with other published studies.

Acknowledgments

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Гніздові біотопи чорного лелеки (*Ciconia nigra* L.) в лісовій зоні України (Полісся) за результатами оверлейного аналізу в ГІС

Дослідження базується на оверлейному аналізі в ГІС. Для аналізу використані точні локалізації 108 гнізд чорного лелеки та шари, що містять інформацію про типи лісу, переважаючі лісові породи, лісорослинні умови, вік лісу та бонітет. Аналіз виконано на рівні окремих локацій гнізд та на рівні гніздових територій (буфери розміром 500м) навколо гнізд. Для того, щоб виявити оптимальні для чорних лелек типи лісу, ми порівняли частоту трапляння (представленість) різних категорій лісу на гніздових ділянках з загальною їх частотою трапляння на цілій досліджуваній території та в буферах радіусом 500м навколо 108 випадкових точок..

Згідно з результатами дослідження, просторовий розподіл гнізд чорного лелеки значною мірою повторює загальну структуру лісів досліджуваного регіону. Виявлено деяку тенденцію до вибору вологих типів лісу з переважанням дуба та сосни, а також вільхи чорної, але ці результати статистично не значимі. Статистично значима вибірковість у виборі гніздового біотопу виявлена лише у відношенні до віку лісу, а саме найбільш оптимальними виявились стиглі та перестійні ліси. Найважливішими деревами для побудови гнізд виявились дуб (53,3%) та сосна звичайна (29,9%).

Ключові слова: *чорний лелека, Ciconia nigra, біотопи, ГІС.*

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Гнездовые биотопы черного аиста (*Ciconia nigra* L.) в лесной зоне Украины (Полесье) по результатам оверлейного анализа в ГИС

Исследования базируются на оверлейном анализе в ГИС. Для анализа использовано точные локации 108 гнезд черного аиста и слои, которые содержат информацию о типах леса, преобладающих лесных породах, лесорастительных условиях, возрасте леса и о бонитете. Анализ проведен на уровне отдельных локаций гнезд и на уровне гнездовых территорий (буферы размером 500м) вокруг гнезд. Для того, чтобы определить оптимальные для черных аистов типы леса, мы сравнили частоту встречаемости разных категорий леса на гнездовых участках с общей их частотой встречаемости в целом исследуемом регионе и в буферах радиусом 500м вокруг 108 случайных точек.

Согласно с результатами исследования, пространственное распределение гнезд черного аиста в значительной мере повторяет общую структуру лесов исследуемого региона. Найдена тенденция к выбору влажных типов лесов с преобладанием дуба и сосны, а также черной ольхи, но эти результаты статистически не значимы. Статистически значимая избирательность гнездового биотопа найдена только в отношении к возрасту леса, а конкретно, наиболее оптимальными оказались спелые и перестойные леса. Самыми важными деревьями для строительства гнезд оказались дуб (53,3%) и сосна обыкновенная (29,9%).

Ключевые слова: *черный аист, Ciconia nigra, биотопы, ГИС.*