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REDUCTION OF THE BREEDING POPULATION OF THE ROOK, *CORVUS FRUGILEGUS* (AVES, CORVIDAE), IN UKRAINE: THE EXAMPLE OF THE EASTERN PART OF THE KYIV REGION

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Reduction of the Breeding Population of the Rook, *Corvus frugilegus* (Aves, Corvidae), in Ukraine: the Example of the Eastern Part of the Kyiv Region. Poluda, A. M., Dupak, V. S. & Markova, A. O. — Since the 1980s, a significant decline in the number of breeding populations of the Rook, *Corvus frugilegus* Linnaeus, 1758, has been observed in many European countries. In Ukraine, this trend has been observed since the late 1990s. In 2021, the conservation status of the Rook in Europe was significantly upgraded — from "LC" (Least Concern) to "VU" (Vulnerable). The analysis of the material of surveys in 1983–1985 and 2021 on the territory of 1850 km² in Kyiv Region showed that during the 35 years, there was a catastrophic decrease in the number of nesting birds, it decreased almost 12 times, from 11,480 pairs in the 1980s to 961 pairs in 2021. In addition, the spatial structure of the distribution of colonies in relation to large arable agricultural land has changed. We suggest that the main reason for these changes is the widespread use of seed treatments with the active ingredient imidacloprid. The use of treated grains for food by birds leads to their death. Since 2018, the countries of the European Union countries have banned the use of insecticides containing imidacloprid outside of permanent greenhouses.
Key words: Rook, breeding population group, decrease in number, insecticidal seed treatment, imidacloprid, Ukraine.

Introduction

Since the middle of the 19th century, when regular ornithological researches on the territory of Ukraine began, it was believed that the Rook, *Corvus frugilegus* Linnaeus, 1758, was one of the most numerous and common bird species. Kessler (1851) showed that this bird occurred in large numbers in the provinces of Volyn, Kyiv, Podillia, Poltava and Chernihiv, but not everywhere, "only in known places". In summer, it inhabited the edges of forests, small groves and villages, but always close to fields. Somov (1897) emphasised that this bird was common in the Kharkiv Region, where it occurred in large numbers and nested in groves and gardens, often forming large colonies. Throughout almost the entire 20th century, the Rook retained the status of one of the most numerous breeding birds of the forest steppe, the southern strip of Polissia (forest zone) and a large part of the steppe zone where there are tree plantations and settlements. This was confirmed by Khranevych (1925), Velykokhatko (1927), Havrylenko (1929), Voinstvenskyi (1960) and Voinstvenskii (1960). The latter paper emphasised that the Rook was a forest-steppe bird that could use small tree plantations, but did not occur in dense forests.

However, already in the late 1990s and early 2000s, a significant decrease in the number of breeding groups of these birds was observed in some regions of Ukraine. In particular, it was observed in the Vinnytsia (Lopariev & Yanish, 2007), Mykolaiv (Redinov & Petrovych, 2011), Lviv (Bokotei, 2008, 2011), Zaporizhzhya, Donetsk (Andryushchenko et al., 2016) Regions. Previously, this trend was observed in several European countries: for some regions of Poland (Czapulak & Betleja, 2002; Kuźniak et al., 2005; Kitowski, 2011; Orłowski & Czapulak, 2016) since the 1980s, in Germany (Krüger et al., 2020) throughout the XX century until 1977, in Sweden (Malmberg, 1973) in 1955–1970, etc.

In 2021, the European Red List of Birds (BirdLife International, 2021) was published and, in light of these trends, the conservation status of the Rook was significantly upgraded from 'LC' (Least Concern) to 'VU' (Vulnerable). This decision was based on the fact that about half of the species' populations are in decline. Some countries explicitly reported a real change in the size of the rook population, including the European part of Russia (which contains almost a third of the European population). Overall, the population size of the Rook in Europe is declining by more than 30 % and the breeding population is now estimated at 5.7–10.65 million nesting pairs (BirdLife International, 2021), compared to between 8.17 and 14.2 million nesting pairs in 2015 (http://datazone.birdlife.org/species/factsheet/rook-corvus-frugilegus/text).

The main objective of the study was to determine the current status of breeding rook populations in one of the optimal regions for this species, the eastern part of the Kyiv Region on the left bank of the Dnipro River, to study changes over almost 40 years, and to analyse possible causes of these changes.

Material, Methods, and Region of Investigation

In 1983–1985 a survey was carried out in the area of Boryspil International Airport as part of the project "Peculiarities of the ornithological situation in the area of Boryspil International Airport and measures to reduce the risk of aircraft collisions with birds" of the Institute of Zoology NAS of Ukraine. The project manager was one of the authors of this publication. The study area included the left bank of the Dnipro River in Kyiv Region (fig. 1) and a significant part of the modern districts of Boryspil and Brovary, the southern and eastern parts of Kyiv that fall within the airport zone. The total area of the airport zone is 1850 km² and includes the city of Kyiv (about 10 % of its territory), the towns of Brovary, Boryspil and Baryshivka and 61 rural settlements.

This part of the Forest-Steppe belongs to the zone of intensive agriculture. More than half of its territory consists of fields, meadows, pastures, gardens, etc. In the 1980s almost every village had livestock complexes, but in the 1990s most of them were destroyed. Forests are located in the south-western, western and north-western parts of our study area, occupying less than 4 % of it.

During this survey, the entire 25 kilometre area around the airport was surveyed by vehicles and helicopters. The rook colonies were usually found in late autumn, winter and early spring when the trees were leafless. All of these rookeries were surveyed during the breeding season to determine the number of nesting birds. Since then, some of the colonies have been visited regularly every 1–3 years, some even 2–3 times during a breeding season. In the spring of 2021 (March–April) a full car survey of the same area was carried out to check the rook colonies known since the 1980s and to identify new breeding colonies.

During the nesting period in 2021 and 2022, additional surveys were conducted to find out the state of nesting groups of rooks in adjacent territories. In particular, 142 settlements of the Poltava, Myrhorod and Lubny Districts of the Poltava Region and Zolotoniskyi District of the Cherkasy Region were surveyed. The total area of the surveyed territory was 3009 km².

For the determination of the degree of nesting density of rooks in the study area, we used the technique of nuclear density estimation (Kernel Density Estimation) in the Quantum GIS 3.10.10 software (QGIS.org 2021). Vector layers for the boundaries of Districts of the Kyiv Region (before the administrative and territorial reform in 2020) were downloaded from the site https://www.diva-gis.org/Data. Spatial trends in the number of rooks were determined by calculating the ellipse of standard deviations (Standard Deviational Ellipse) in the same software.

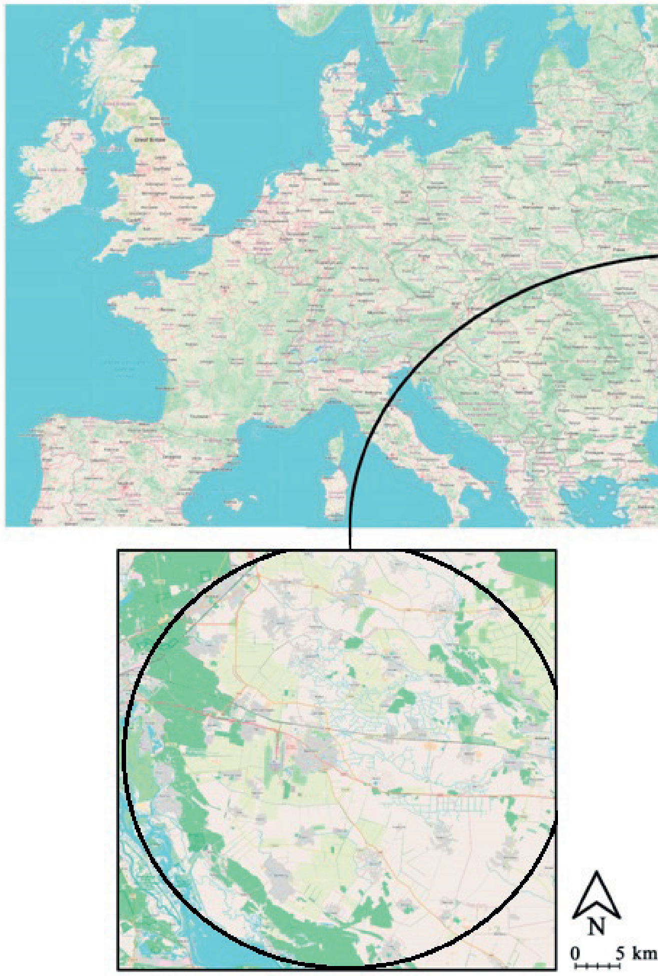

Fig. 1. Geographical location of the study area. The circle is a research territory with an area of 1850 km².

Results

As a result of surveys of the territory of Boryspil Airport in 1983–1985, 35 colonies of rooks with a total number of 11,480 pairs in an area of 1850 km² were found (table 1, fig. 2, A); the density of breeding birds in this area was 6.21 ± 0.17 pairs/km². The largest number of breeding rooks were found in Boryspil and in its surroundings (80 km², including the territory of the airport) where 6630 pairs in 13 colonies (57.75 % of the total number in the study area) were observed. The density of breeding pairs was more than an order of magnitude higher than the average for the study area — 82.87 ± 3.91 pairs/km².

In the central part of the airport, 860 pairs of rooks bred; that had a negative impact on the safety of civil aviation. The three colonies (No. 1–3, fig. 2, A) were located between the two runways and, in most cases, the fodder routes of rooks crossed the courses of takeoffs or landings of planes. The situation was particularly complicated by the chicks leaving their nests and spreading over the aerodrome area, often concentrating near the runways where low-grass plots are optimal for their feeding.

One of the practical tasks of the project mentioned above was to stop breeding rooks in the central part of the airport, i. e. in the colonies No. 1–3. For this purpose, from 1983 to 1985, at the beginning of the breeding season, a set of measures was taken to prevent the

Table 1. Results of surveys of rooks' colonies in the research area in 1983–1985 and 2021 (total area 1 850 км²)

No colony on maps	Location (coordinates)	Number of rooks in colony (in pairs)	
		1983–1985	2021
1	Airport "Boryspil" (50.344° N 30.893° E)	90	125
2	Airport "Boryspil" (50.347° N 30.895° E)	390	0
3	Airport "Boryspil" (50.370° N 30.896° E)	380	0
4	City of Boryspil (50.373° N 30.913° E)	850	0
5	City of Boryspil (50.363° N 30.924° E)	450	58
6	City of Boryspil (50.361° N 30.929° E)	250	17
7	City of Boryspil (50.357° N 30.929° E)	700	63
8	City of Boryspil (50.384° N 30.919° E)	120	0
9	City of Boryspil (50.388° N 30.941° E)	260	0
10	City of Boryspil (50.383° N 30.967° E)	370	0
11	City of Boryspil (50.374° N 30.956° E)	680	18
12	City of Boryspil (50.334° N 30.988° E)	1100	0
13	City of Boryspil (50.331° N 30. 976° E)	990	0
14	Velyka Olexandrivka (50.395° N 30.881° E)	11	0
15	Prolisky (50.392° N 30.775° E)	55	0
16	Petropavlivske (50.322° N 30.822° E)	1100	0
17	Zatyshne (50.283° N 30.870° E)	600	0
18	Kyiliv (50.162° N 30.875° E)	100	0
19	Hlyboke-1 (50.272° N 30.946° E)	60	0
20	Hlyboke-2 (50.253° N 30.953° E)	100	0
21	Rohoziv (50.257° N 31.028° E)	39	0
22	Stare (50.156° N 31.072° E)	45	0
23	Myrne-1 (50.175° N 31.169° E)	140	0
24	Myrne-2 (50.183° N 31.177° E)	110	0
25	Liubartsi (50.259° N 31.176° E)	250	0
26	Kuchakiv (50.369° N 31.107° E)	200	0
27	Baryshivka (50.358° N 31.300° E)	130	50
28	Peremoha (50.498° N 31.253° E)	90	0
29	Rusaniv-1 (50.495° N 31.140° E)	70	75
30	Rusaniv-2 (50.485° N 31.155° E)	50	0
31	Hoholiv-1 (50.540° N 31.044° E)	730	0
32	Hoholiv-2 (50.498° N 31.036° E)	110	0
33	Hoholiv-3 (50.511° N 31.002° E)	0	63
34	Hoholiv-4 (50.511° N 31.013° E)	0	45
35	Hoholiv-5 (50.520° N 31.020° E)	0	70
36	Trebukhiv (50.489° N 30.873° E)	390	116
37	Dudarkiv (50.430° N 30.935° E)	190	73
38	Velyka Starytsia (50.449° N 31.073° E)	280	0
39	Kyiv: Kharkiv Square (50.403° N 30.681° E)	0	25
40	Ivankiv (50.319° N 31.061° E)	0	138
41	Krasylivka (50.517° N 30.904° E)	0	25
	Total	11480	961
	Mean ± SD	328.0 ± 314.7	64.07 ± 36.61
	Density of rooks (pairs/km²): Mean ± SD	6.21 ± 0.17	0.52 ± 0.02

reproduction of rooks: the destruction of old and newly built nests, using acoustic devices (both day and night), scaring with light rockets, pruning trees and using of trained Goshawk, *Accipiter gentilis* (Linnaeus, 1758) and Saker Falcon, *Falco cherrug* Gray, 1834. As a result, in 1986 the number of birds in these three colonies decreased several times and over the next 2–3 years they completely stopped breeding there. The restoration of the colony started only 30 years later and only in one site (No. 1). In 2021, we found 125 pairs of rooks nesting there (table 1). Such measures were not applied to other colonies, even those located at the airport (No. 5 and No. 7).

In the spring of 2021, only 15 colonies with a total number of 961 pairs of nesting rooks were found (table 1, fig. 2, B). In comparison with the previous period, 26 rookeries disappeared, 9 remained and 6 new ones were founded. The nesting density was 0.52 ± 0.02 pairs/km^2 which is almost 12 times less compared to the 1980s. The Fisher's exact test confirmed a significant decrease in the number and the density of nesting rooks: $\varphi = 54.342$ and $\varphi = 11.946$, respectively; in these two cases $p < 0.01$. Mann-Whitney U test also confirms the change in the number of birds in the selected study areas ($U = 257.5$; $p < 0.001$).

In 2021, there were 5 colonies on the territory of Boryspil (including the airport) on the area of 80 km^2, counting of 281 breeding pairs (29.4 % of the total number in the study area). The density in this area was 3.51 ± 0.49 pairs/km^2, which is 23.6 times less than in the mid-1980s.

The GIS analysis also confirmed significant changes in the state of breeding groups of rooks in the 1980s and 2021 (fig. 3). Two distinct kernels with a high density of breeding birds are drawn based on the data of 1983–1985. One of them covered the city of Boryspil

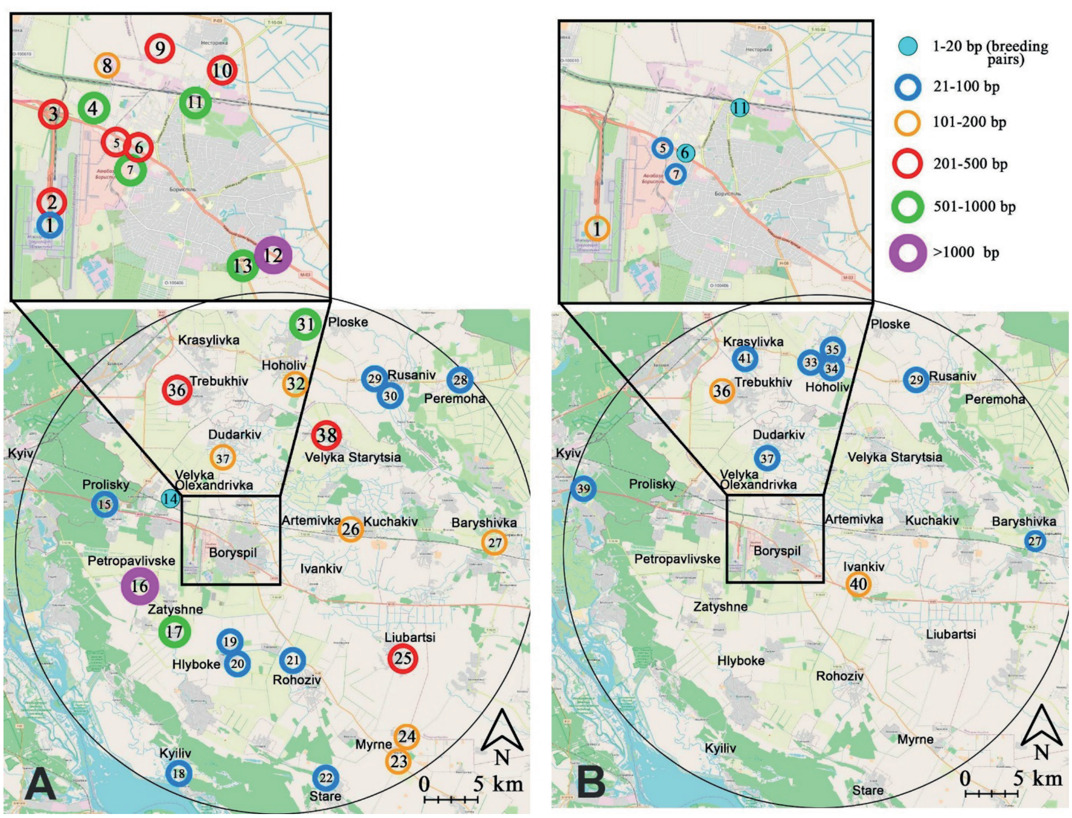

Fig. 2. The location of Rook colonies and their number in the research area in 1983–1985 (A), and in 2021 (B).

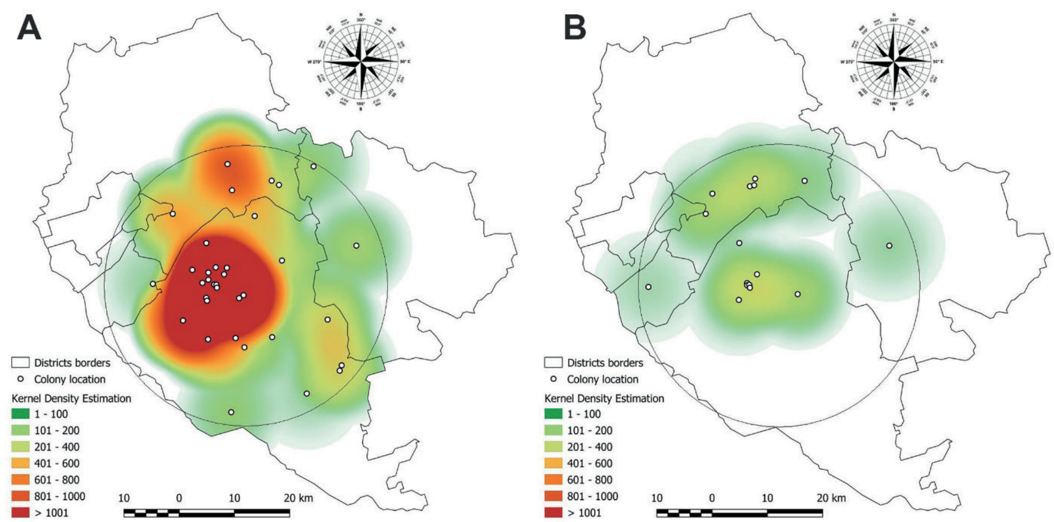

Fig. 3. Kernel Density Estimation of number of the rook breeding group in the research area in 1983–1985 (A), and in 2021 (B). The highest density areas are highlighted in red; the lowest density areas are green.

(including the airport) and neighboring areas. The area is approximately 300 km², where 19 colonies were located with a total number of 8691 pairs. The mean density of breeding pairs was 28.96 ± 1.16 per km². The second kernel was in the northern part of the study area, which has been outlined due to two colonies with a total of 840 pairs. Its approximate area is 120 km², and the density is 7.0 ± 2.58 pairs per km². In 2021, the picture of the location of the colonies and the number of rooks that nested there has changed dramatically. There were still two approximately equal kernels of 170 and 160 km². The first of them covered the city of Boryspil with surrounding areas and the second one was located in the northern part of the study area, same as 35 years before. The density of rooks in these kernels was almost the same, comprising 2.46 ± 0.28 and 2.46 ± 0.17 pairs/km², respectively.

The standard deviation ellipse method of the spatial location of rookeries also showed significant changes that have occurred over more than 35 years (fig. 4). In the 1980s, the colonies were grouped along the NNW-SSE conditional line; moreover, the most numerous groups were located close enough to this line. This determined that the ellipse had a rather elongated form. The point of mean coordinates was located on the territory of Boryspil almost in the center of our research area. Already in 2021, due to the absence (disappearance) of colonies to the south of Boryspil, the point of mean coordinates of the placement of nesting groups shifted to the north for about 7 km. Spatial placement of colonies changed and the number of birds that nest there decreased significantly as well. All of these factors caused the more uniform distribution and the ellipse of standard deviations to take the form of a circle. A comparison of the spatial location of colonies and the number of birds in them (using an ellipse of standard deviations) shows that in the northern part of the studied territory the conditions for the presence of rooks are more favorable than in the southern part. Thus, the influence of negative factors (or factor) that caused the disappearance of nesting groups to the south of Boryspil was not that strong in the northern part of this territory.

In addition to the extremely sharp reduction in the number of nesting birds and the associated density of rooks, there have been significant changes in the number of individuals that form colonies. In the 1980s, the dominant part of rooks nested in large groups, for example, 18 out of 35 known rookeries had from 200 to 1100 pairs, which totaled in 9970 pairs (86.8 % of the total group). The smallest colonies consisted of 11, 39, and 45 pairs. The average number of nests in the colonies at that time was 328.0 ± 314.7 (n = 35) (table 1). In 2021, the number of nesting pairs in the colonies ranged from 17 to 138. The average number of pairs in these colonies was 64.07 ± 36.61 (n = 15). Compared to the previous period, this number decreased more than 5 times ($p < 0.001$).

In 1983–1985, the vast majority of rooks bred either among agrocenoses or near them (from 0.1 to 0.7 km); they composed 77.2 % of the total number of breeding groups. Twenty-three colonies with a total number of 7705 pairs (67.1 % of breeding group) located among fields have disappeared and only four colonies (780 pairs) remained. Six colonies (2560 pairs) were located at distances from 1.2 to 1.9 km from large fields (this does not apply to small agricultural plots in settlements). In particular, these were four rookeries on the territory of the airport (No. 1, No. 2, No. 5, No. 7) and two ones in Boryspil (No. 6 and No. 11). Five of them still exist, and one (No. 2) has disappeared. To some extent, this also applies to colony No. 1, but it has recovered in recent years. It should be noted that colonies No. 1, No. 2 (airport), and No. 3 (also airport, but close to the agrocenose) were artificially removed due to measures for preventing nesting rooks close to the airfield.

One colony (No. 15) disappeared, although it was located at a distance of more than 3 km from agricultural land. However, it was located on the periphery of a large forest. It is

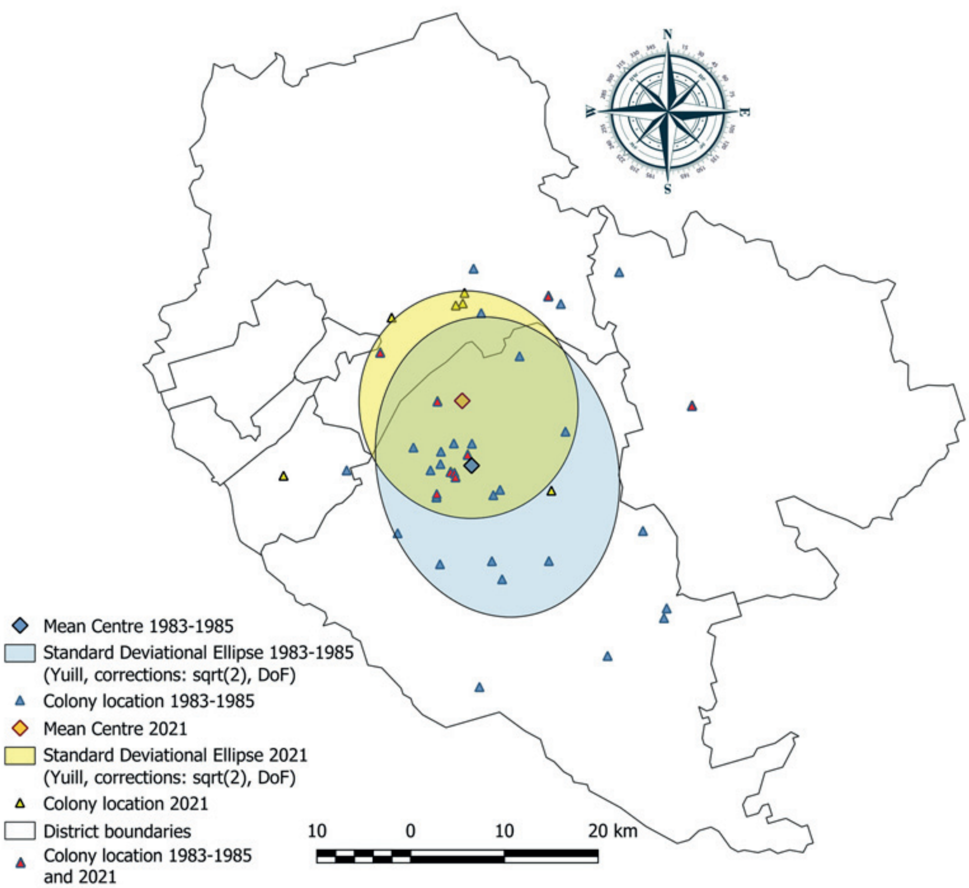

Fig. 4. Standard Deviational Ellipses for the location of rook colonies and their number in the research area in 1983–1985 and 2021.

possible that the rooks stopped nesting there due to the press of the Goshawk which could nest near the colony.

Eight colonies exist from the 1980s to the present; four of them were located at a distance of 0.3–0.5 km from agricultural land, and the number of nesting birds in three of them (No. 27, No. 36, and No. 37) decreased by 61.5, 70.3 and 61.6 %, respertively. However, in one (No. 29) it increased by 6.7 % (from 70 to 75 pairs). Another four colonies (No. 5, No. 6, No. 7, No. 11) were located at distances greater than 1 km (1.3–1.9 km) and the number of birds nesting there decreased by 87.1–97.3 %.

In 2021, in addition to the already mentioned eight colonies, seven new ones appeared. One of them was located in the city of Kyiv, more than 8 km from the nearest fields. The other six rookeries were located at a distance of 1.1 to 2 km away from cultivable agricultural land. No new colony was found in the immediate vicinity of the fields. It is important to emphasize that all colonies in the villages are located in their central parts, usually near schools, medical facilities, churches, and council buildings.

In order to find out the presence of correlations between the decrease or increase in the number of birds in colonies (extreme values: –100 % — the disappearance of a colony and +100 % — the appearance of a new one) and the distances that separated rook's nesting places from large arable fields, a calculation of the Spearman rank correlation coefficient was carried out. It makes $r = 0.719$, ($p < 0.05$) which indicates a strong correlation between these two parameters (according to the Chaddock scale). When conducting these calculations, the disappearance of colonies No. 2 and No. 3 was not taken into account due to the human factor (the preventing nesting of rooks).

Discussion

There has been a fairly long period of 35 years between these two studies. The radical reduction in the number of rooks in the survey area was not gradual and did not take place over a period of decades. The decline and disappearance of three colonies on the airport site (Nos. 1–3) at the end of the 1980s was caused by a series of measures to prevent their nesting. We suspect that the rooks from these colonies did not disappear, but began to breed in neighbouring colonies. Our research confirms this. In particular, in 1985, several neck-tagged rooks that we had captured the previous year in colony 2 at the airport nested in colony 16. The distance between these colonies was 6 km. Throughout the 1990s, the condition of most of the colonies in the study area remained stable. The break occurred in 2001–2010, when the most numerous colonies in the area disappeared extremely quickly within 1–5 years. This was the case for twenty-four colonies (table 1). The total number of rooks nesting only at these colonies was 7,760 pairs — more than two thirds of the total group (67.6 %) present in the 1980s, including the airport colonies. In contrast to the airport colonies, the rooks from these colonies did not change nesting sites, but disappeared and probably died.

The decline in the number of breeding rook groups has also been reported in other regions of Ukraine. Between 1970 and 2006, rook colonies in the Vinnytsia region were monitored over an area of 552 km^2 (Lopariev & Yanish, 2007). In the 1970s, ninety-seven colonies were recorded in this area, and their number remained virtually unchanged until the 2000s, when only five colonies were discovered in 2005 and disappeared the following year.

In the Mykolaiv Region, the highest number of nesting rooks occurred between 1951 and 1990, when the colonies were numerous and spread throughout the region (Redinov &

Petrovych, 2011). The number of birds at that time was about 55.8 thousand pairs. In the next two decades a rapid decline was observed, and in 2009-2010 the number of pairs already changed to about twenty thousand. In the northern part of the region, the nesting groups of the Rook have completely disappeared. The authors emphasise that the remaining colonies were mainly located in settlements.

In the territory of the Azov Highlands (the eastern part of Zaporizhzhya and the south-western part of the Donetsk Region), there was also a catastrophic decrease in the number of rooks (Andryushchenko et al., 2016). In 1991, five large colonies were found in an area of 60 km^2, while in 2014 only two small colonies were found in an area of about 3700 km^2 (one of them in a settlement), and in 2015 none were found. A similar situation was observed in the Odesa Region. According to Prof. Ivan Rusev (personal communication), in the 1980s, in the Bilhorod-Dnistrovskyi District, three rook's colonies were known with more than 1,000 pairs in each and one with 800 pairs. Now one of these colonies has completely disappeared, and three others comprise 80–100 pairs.

Our additional surveys during 2021–2022 confirmed a significant reduction in the number of nesting groups in the Poltava Region and Cherkasy Region on the left bank of the Dnipro. Only five colonies with a total number of 336 pairs were found on an area of 3009 km^2. In the 1990s and early 2000s, we were aware of ten or more large colonies with a total of more than 2.5 thousand pairs in the north-western part of Lubensky District (area is approximately 850 km^2), which later disappeared. As an example, in 1984–2010, there was a colony in the village of Lazirky with about 500 pairs nesting; only in this one colony there were more nesting birds than in the currently known five colonies together. In the middle of 2010, this colony disappeared.

The analysis of the modern spatial distribution of colonies and especially the disappearance of a large part of them near large fields shows that there is a certain critical factor related to agricultural production, which has a very strong negative effect on the rook's nesting groups.

In our opinion, such a catastrophic reduction in the number of rooks in the study area and other territories of Ukraine can be explained by the radical reform of agricultural production that took place during the 1990s. The structure of agricultural land has radically changed; the most attractive agrocenoses for rooks, such as dry meadows, pastures, fields of perennial grasses, gardens have been transformed into tall crops of corn, sunflower, rapeseed, soybeans, and cereals. They are unsuitable for these birds to stay there for most of their vegetative period. Since the beginning of the 2000s, almost all arable land has been transferred to the use of powerful agricultural holdings, from hundreds to tens of thousands of hectares of land are in their use. They began to actively use various pesticides to protect plants from pests (insecticides, rodenticides), diseases (fungicides) and to destroy weeds (herbicides). Among them are aggressive preparations that have a negative impact on the environment. As result, in the countries where agricultural production is developed (Ukraine occupies the highest levels in the world), a negative influence on the fauna is recorded. In particular, a significant reduction of many species of mesophaunes (e.g. dirt worms), insect-pollinators (bees, bumblebees, etc.), birds, for example, Grey Partridge, *Perdix perdix* (Linnaeus, 1758), Quail, *Coturnix coturnix* (Linnaeus, 1758), Turtle Dove *Streptopelia turtur* (Linnaeus, 1758), Skylark, *Alauda arvensis* Linnaeus, 1758, etc., and mammals (e. g. shrews, gophers, hedgehogs) has been proven (Bright et al., 2007; Gibbons et al., 2014; Gill et al., 2012).

Various pesticides are widely used in Ukraine, resulting in increased mortality of various animals, including birds. In recent years, cases have been registered where the use of treated seeds has led to mass bird deaths. This happens most often in winter and early spring when rodenticides containing brodifacoum (a toxic anticoagulant compound) have been used (https://dpss.gov.ua/news/ptahi-v-zapovidniku-askaniya-nova-zaginuli-cherez-otrutu-proti-grizuniv-derzhprodspozhivsluzhba). It should be emphasised that all cases of mass poisoning of birds are connected with violations of the technology of using this group of pesticides — when poisoned grains are spread on the surface of the soil. Undoubtedly, the use of this group of rodenticides (poisoned grain) leads to the poisoning of many species of birds, including rooks. However, it is unlikely that these pesticides would lead to the disappearance of entire colonies — they are not used during rook nesting, including in the area of our research. We can also rule out the possibility of rooks leaving their colonies and nesting elsewhere. There is no evidence that the number of breeding rooks has increased significantly in the vicinity of our survey area. At the same time, in other places the number of breeding rooks has fallen many times over. The death of birds in the non-nesting period (as a result of, for example, rodenticides) is also excluded, as all the rooks that form a colony could not die in a relatively short time.

The main work with pesticides is carried out from mid-March to mid-June, which is the nesting period of the Rook in the research area — the northern part of the forest steppe (in more southern regions of Ukraine this work is carried out 1–2 weeks earlier). At this time, herbicides (before sowing or after weeds appear), fungicides and insecticides are actively used. The last two groups of pesticides are usually used when crops have completely covered the soil. Although many of these preparations are quite toxic to birds, including rooks, they do not cause mass mortality. However, there is a group of pesticides that, like rodenticides, enter the bodies of animals by eating insecticide-treated seeds - insecticide seed treatments. They get onto farmland when birds are nesting — in March–April, when the sowing campaign takes place. We are convinced that the consumption of treated seeds by rooks has the greatest negative impact on the condition of their breeding groups. It is well known that when agricultural work such as ploughing, harrowing, sowing etc. is carried out near their colonies, the birds concentrate in large numbers and follow the machinery to gather food. If some of the seed remains on the surface of the soil, it is eaten by the rooks. These birds eat seeds and grains of various crops, but have a particular preference for maize (Holovanova, 1975). They collect lost grain at the time of sowing and when maize sprouts appear on the soil surface. Numerous observations show that rooks often walk along the row of seedlings, pulling out seeds until they fill their stomachs (Khranevych, 1925; Holovanova, 1975).

Since the early 2000s, almost all agricultural producers use only treated seeds in sowing. Systemic seed treatments are now used on the majority of agricultural crops worldwide (Jeschke et al., 2011). For example, in total 78 insecticides for the treatment of seeds were officially registered in Ukraine in 2018 (List of pesticides…, 2018). Among them, the largest number (45 seed treatments, 57.7 % of the total registered) contain the active substance imidacloprid. This substance is highly toxic to birds — the average lethal dose (LD_{50}) for Japanese Quail, *Coturnix japonica* Temminck & Schlegel, 1848, is 31 mg/kg body weight (BW) (CCME, 2007), for Grey Partridge — 13.9 mg/kg BW (Gibbons et al., 2015). The next most ”popular“ are seed dressings with the active substances thiamethoxam and clothianidin (in 2018, 14 and 11 preparations were registered, respectively, see List of pesticides..., 2018) have a much lower level of toxicity for birds — approximately 50–100 times. In particular, LD50 of the first of these is 1552 mg/kg BW for Virginia Quail, *Colinus virginianus* (Linnaeus, 1758) (Turaga et al., 2016), for clothianidin — more than 2000 mg/kg BW (Gibbons et al., 2015). There are two preparations with the active substance fipronil among the insecticide-treatments registered in Ukraine. They are highly toxic to some groups of birds, particularly Galliformes — LD50 for Virginia Quail is 11.3 mg/kg BW (Gibbons et al., 2015).

According to the norms of use of seed treatments, which contain the active substance imidacloprid in the most common concentration (600 g/l), 9 liters of this preparation is processed in 1 ton of corn seed, which receives about 5.4 kg of imidacloprid. It is known that the mass of one corn grain, depending on the variety, ranges from 270 to 397 mg, the average 1 kernel weight was 332 mg (Kljak et al., 2020). It is not difficult to calculate that 1 ton of grain consists of approximately 3,000,000 (3,012,048) seeds, i. e. with even distribution, each grain receive an average of 1.8 mg of the active substance. According to Goulson (2013), one corn seed receives approximately 1 mg of imidacloprid, according to their seed treatment technologies. This number fully corresponds to our calculations.The indicator of acute toxicity (LD_{50}) of imidacloprid for the Rook is 14.48 mg/bird (Tassin de Montalgu & Goulson, 2022), that is, approximately 34 mg/kg BW, taking into account the average body weight of the Rook at 430.6 g (the weight of 14 dead rooks found on the roosting place in Poltava ranged between 337 to 503 g; our data).

Usually, the absolute lethal dose (LD_{100}) is 2 times greater than the average lethal one which for the Rook will be 68 mg/kg BW or 29 mg/bird of active substance. Therefore, the lethal amount of imidacloprid for the Rook is contained in 14–18 grains of corn. The weight of such a number of grains is 5–6 g on average. The Rook can eat up to 67.5 g during one day according to data from Tassin de Montalgu & Goulson (2022). In this case, rooks can receive 10–13 lethal doses in one day if they feed only on imidacloprid-treated seeds, meaning that one visit to such a field will result in the bird's guaranteed death.

It should be noted that imidacloprid is extremely stable — the period of its half-life (DT_{50}), depending on soil type, ranges from 80 days to 2 years (CCME, 2007). Corn sprouts usually appear 8–12 days after sowing, and at this time there are high doses of the preparation in the grains. Poisoning of rooks with treated grain takes place in two stages: during the sowing period and when the sprouts appear (usually this happens in May). At this time, there are chicks in rooks' nests. It is clear that the death of adult birds will lead to their death as well.

From literature data it is known, that the majority of rooks feed at a distance of 0.5–1 km from their colony (Kasprzykowski, 2003). During our research we recorded foraging birds at distances of up to 2 km, and therefore we assume that the territories located further from the colonies are basically not used by rooks for foraging. It is clear that if in the zone of intensive foraging around the colony (usually it is a distance of up to 1 km) there is a field that is sown with imidacloprid-treated seeds rooks will all die within one nesting season. If such sowings are on a distance more than of 1 km and only a small percentage of this birds fly to feed there, then the process of disapearing the colony can stretch for several years. And if this distance is several kilometers, then the rookeries may continue to exist. It was shown above that there is a strong correlation between the change of the number of birds in colonies and the distances that separated them from large arable fields.

The active substance imidacloprid belongs to the group of neonicotinoids, which are used in insecticides of systemic action. It is the most toxic in this group — extremely dangerous for insect pollinators and birds. Our calculations on the high risk of feeding by rooks imidacloprid-treated seeds are confirmed by other researchers. Gibbons, Morrissey & Mineau (2015) analyzed almost 150 studies on the effects of neonicotinoids, including imidacloprid, on vertebrates. They concluded that "the use of this active substance to treat the seeds of some crops creates risks for birds, and swallowing even several such seeds may cause death or disturbance of reproductive function sensitive bird species". Another study on the effect of imidacloprid-treated sorghum seeds on Eared Dove, *Zenaida auriculata* (Des Murs, 1847), was conducted by Addy-Orduna, Brodeur & Mateo (2018). They found that to get an average lethal dose (LD_{50}) these doves should consume 1.7 g of treated seeds, and during the day they have eaten an average of 6.4 g. French researchers (Millot et al., 2017) conducted laboratory studies of 734 animals (including 732 birds) that died in fields with imidacloprid-treated seed. It turned out that all of them consumed this active substance in concentrations that caused death. The most numerous were Gray Partridge, pigeons (Rock Dove, *Columba livia* Gmelin, 1789, Woodpigeon, *C. palumbus* Linnaeus, 1758, Stock Dove, *C. oenas* Linnaeus, 1758); among them were even two Common Cranes, *Grus grus* (Linnaeus, 1758).

We assume that the main factor that leads to a significant reduction and often to the disappearance of the rooks' colonies due to the death of birds in most regions of Ukraine is the use of imidacloprid-treated sowing seeds. In the territory of our studies, since the 1980s, out of 35 rookeries at that time, 23 have disappeared due to the influence of seed treatments with imidocloprid. Another 3 colonies disappeared due to the introduction of anti-nesting measures at the airport and one more disappeared due to possible impact of hawks.

On the other hand, it should be emphasized that the general decrease in the number of rooks of the nesting group in Ukraine also occurred as a result of the change in the structure of agricultural land (as mentioned above), which led to a significant reduction in the area of agrocenoses suitable for rooks. There is no doubt that many pesticides — various insecticides, rodenticides, fungicides, as well as the same seed treatmends with imidacloprid — have a strong negative effect on rooks during the non-nesting period. The latters are also widely used when sowing winter crops (wheat, rye, barley, rape), which causes high mortality of many bird species, including rooks (Tassin de Montalgu & Goulson, 2022). However, the overall negative impact of all these factors is much less than the impact of imidacloprid's seed treatments during the rook nesting period, that is, in the spring. During this period, their effect on rooks is much stronger — the reproductive part of the population is destroyed together with this year's generation.

To some extent, our conclusions are consistent with the reasons for the decline of the European Rook population, which are given in the "European Breeding Bird Atlas 2": "The causes for population declines may include the loss of low-intensity pasture as well as the widespread and often massive use of pesticides and potentially poisonous chemical seed treatments" (Keller et al., 2020).

Our focus is on corn, as rooks prefer the grains of this crop, although they like to eat grains and seeds of many other agricultural plants — wheat, rye, barley, oats, sunflower, peas, and soybeans. In the spring, during the appearance of spring crops, they extract the grains of these cultures like corn (Holovanova, 1975). Eating these seeds with imidacloprid will also be fatal for rooks. The areas which are annually sown above listed agricultural cultures, occupy more than ¾ of the arable land fund of Ukraine (76 % in 2019 or 248 thousand km^2 — approximately 41 % of the territory of Ukraine) (Statistical Yearbook…, 2020). The area occupied by corn in 2019 is more than 15 % of all arable land. Therefore, in the case of localization of the rookeries near these lands, there is an extremely high probability that one of these crops will be sown there and if the seeds are be treated (now all sowing material is treated) with the active substance imidacloprid, the fate of these birds will be decided.

In 2018, insecticides containing the active substance imidacloprid were banned for use on open ground (outside of permanent greenhouses) in the European Union due to their high toxicity for bees leading to the destruction of their families (Commission Implementing…, 2018). Ukraine should do the same — it has been proven that, in addition to bees, imidacloprid has an extremely strong negative effect on birds. It is necessary to stop the registration of all insecticides containing this active substance and seed treatments with imidacloprid. All producers of plant agricultural products should use seed dressings with the active substances thiamethoxam and clothianidin, the toxicity of which is ten times lower.

Concluding the discussion of the obtained results, we consider it necessary to make more detailed explanations regarding some aspects of this research.

After completing our research in the area of Boryspil International Airport in 1985 we did not have a complete picture of the state of the rooks breeding group there until 2021. In the mid-2000s, we witnessed the disappearance within 1–2 years of three huge colonies on the outskirts of Boryspil, which were located 100 m from large fields. It could be assumed that these rooks moved to other places, forming colonies there. In the last year of the existence of colony No. 12 (beginning of highway Boryspil–Kharkiv), we saw a significant number of dead rooks on the roadside under trees with nests. We attributed this to natural bird mortality. In 2021, a complete survey of this territory was conducted and it turned out that the colonies did not move anywhere, they simply disappeared, and the rooks probably died.

It was necessary to find out the main reason that led to such a catastrophic reduction of the rook nesting group in the area of our research (and not only). It turned out that there is a strong relationship between the state of colonies (disappeared, new ones appeared, decreased or increased) and the distance to large arable land. It was clear to us that the fatal factor for rooks is related to agricultural production and it is probably some kind of pesticide. It causes mass death of birds during the nesting period, i. e. in April–May. One of the authors of the publication has been professionally engaged in environmental expertise of pesticides and agrochemicals since 2015; in particular, expertise of almost 400 preparations was carried out during this time. Thanks to this experience, it was not a problem to choose the group of pesticides that probably had a critical effect on rooks at this time of the year. There is a very high probability that these are insecticides seed treatments. Among about a hundred disinfectants that currently have registration, more than half contain the active substance imidacloprid. For the past 20 years, agricultural producers have not sown seed that has not been treated with insecticides and fungicides. There is a very high probability that a crop whose seeds have been treated with imidacloprid will be sown near the colony, if it is located next to large arable land. The greatest danger for rooks is corn due to the special attachment of these birds to it. In addition, poisoning occurs in two stages — during sowing and when the sprouts of the crop appear. In our opinion, there is a high probability that Rook's die in our study area as a result of poisoning with imidacloprid's seed treatments. This has already been proven by French and English researchers (Gibbons et al., 2015; Millot et al., 2017; Tassin de Montalgu & Goulson, 2022).

When the article was submitted to the editors of the journal, on April 10, 2023, we conducted a survey of part of the territories of Zolotoniskyi District of Cherkasy Region and Boryspil District of Kyiv Region. In total 15 settlements were surveyed, including Drabiv, Zolotonosha and Pereiaslav. The survey area was approximately 530 km^2. The obtained material can indirectly confirm our point of view regarding the negative impact of seed poisoners on the breeding group of rooks in this region. In particular, an uninhabited colony with 26 nests was discovered on the outskirts of the city of Drabiv (Zolotoniskyi District). The state of the nests showed that 1–2 years ago birds were nesting there. The distance to the nearest large field is 600 m. The second colony was found in the village of Sofiivka (Zolotoniskyi District). According to Dr. M. Gavryliuk, in 2007 it consisted of 150 pairs. We counted 41 nests, of which only 13 were occupied and all of them were located on the same tree at a distance of 350–450 m from other uninhabited nests. It seems that the colony will disappear this year. The distance to the fields that surround the village on all sides is 300–400 m. The third colony was found in the city of Pereiaslav (Boryspil District) — more than 2.5 km to the nearest large arable fields. It consisted of 52 nests — all of them were inhabited. In addition, a new colony was discovered in the center of Boryspil (33 nests) — the distance to agricultural land is more than 2.6 km. This confirms the regularity we discovered — if the colonies are located near large fields, they disappear, and those rookeries remain that are more than 1.5–2 km away from them.

Conclusion

A complete census of breeding groups (colonies) of rooks was made on the basis of surveys carried out in 1983–1985 and 2021 on the area of 1850 km² on the left bank of the Dnipro River in the Kyiv Region. Analysis of the material has shown that the population of rooks has suffered a catastrophic decline over the last 35 years. The number of nesting birds and their density decreased almost 12-fold (from 11,480 pairs in the 1980s to 961 pairs in 2021 and from 6.205 to 0.519 pairs/km² respectively). The average number of nesting pairs in colonies decreased more than fivefold during this period.

The spatial distribution of colonies in the study area has changed over 35 years. The distribution of colonies has changed in relation to large arable fields. Previously, more than 3/4 of all colonies nested in close proximity to these fields, whereas now only 1/3 do so. Twenty-three colonies representing 67.1 % of the breeding population have disappeared; all located between fields at a distance of 0.1 to 0.7 km. Seven new colonies formed by 2021 are located more than 1 km from large agrocenoses. Rooks are most active foraging within 1 km of the colony; with increasing distance, the proportion of birds foraging there decreases sharply, and areas more than 2 km away are hardly used by rookeries during the nesting season. In the 1980s, colonies were more or less evenly distributed across the study area, whereas by 2021 almost all colonies in the southern half of the study area had disappeared. One possible reason for this is that all these colonies were close to agricultural land, where crops were sown, the seeds of which were treated with products containing imidacloprid. This determines the modern spatial distribution of rook colonies — almost all of them are more than 1 km away from the fields. Colonies located several kilometres from fields (often in large settlements) have existed for many years.

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