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Source: Acta Ornithologica, 42(2) : 145-155

Published By: Museum and Institute of Zoology, Polish Academy of Sciences

URL: https://doi.org/10.3161/068.042.0209

ACTA ORNITHOLOGICA
Vol. 42 (2007) No. 2

Different extinction risks of the breeding colonies of Rooks *Corvus frugilegus* in rural and urban areas of SW Poland

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Orłowski G., Czapulak A. 2007. Different extinction risks of the breeding colonies of Rooks *Corvus frugilegus* in rural and urban areas of SW Poland. Acta Ornithol. 42: 145–155.

Abstract. In 1983–1999 in SW Poland (40 540 km^2, 13% of the total area of Poland) the Rook was reported to nest in at least 270 colonies with a combined total of from ca. 18 to > 20 thousand breeding pairs. Between 1983–1988 and 1992–1999, 105 (39%) colonies were abandoned, i.e., 16–20% of the population as recorded in earlier periods. The largest drop in numbers (34%) occurred in rural populations. The median for abandoned colonies was 16 nests, which was nearly six times lower than that for active rookeries (median = 99). General linear models (GLM) indicate that the abandonment of colonies depends on their location (village, small town, city), the size and number of nests, and the presence of other rookeries in the vicinity of those studied. The best-fit model describing rookery extinction invoked the number of nests and other colonies within a radius of < 10 km from the colony studied. In each of three analyzed radii (10, 20 and 30 km) the numbers of nests and other colonies were decidedly higher around extinct rookeries. Active Rook colonies were farther away from the nearest rookery, and also from large colonies consisting of 50, 100 and 150 nests. The probability that a rookery would be abandoned was strongly negatively correlated with its size.

Key words: extinction risk, population decline, population distribution, Rook, *Corvus frugilegus*, concentric analysis

Received — May 2007, accepted — Nov. 2007

INTRODUCTION

In the past the Rook was acknowledged as a pest to agriculture, which gave rise to the negative attitude of people towards this species, often resulting in birds being killed and the breeding colonies destroyed (e.g. Feare 1969, Juillard 1990). The pattern of distribution of rookeries and that of local breeding densities of Rooks in Europe are highly diversified. Nowadays, the occurrence of rookeries is connected to a significantly larger extent with presence of used meadows and pastures rather than farmland (Griffin & Thomas 2000, Atkinson et al. 2002, Mason & MacDonald 2004, Schoppers 2004, Gimona & Brewer 2006). In Central Europe, however, including Poland, a large proportion of rookeries are situated in arable landscapes as well as in urbanized areas (Czapulak & Betleja 2002, Ptaszyk & Winiecki 2005).

The stable, locally even increasing populations recorded in Western Europe (Marchant & Gregory 1999, Bengtsson 2000, Schoppers 2004, Donald et al. 2006) are showing trends opposite to those observed in Poland, where a gradual decrease in numbers has been noted lately, especially in the agricultural regions of the western part of the country (Czapulak & Betleja 2002, Kuźniak et al. 2005), and most recently also in the east (Kasprzykowski 2005). In Poland the Rook density increases eastwards, which is a pattern described as early as the 1960s and still clearly visible (Dyrcz 1966, Józefik 1976, Jakubiec 2005a).

When foraging during the breeding season (especially during the young rearing stage, April–May), Rooks clearly avoid fields of winter cereals and oil-seed rape (Kasprzykowski 2003, Mason & MacDonald 2004). In the period of late spring these crops are inaccessible to the feeding birds due to the plant cover being too high (Kasprzykowski 2003, Mason & MacDonald 2004, Jakubiec 2005b, Stillman & Simmons 2006). Recently conducted studies in eastern Poland have revealed that the breeding success of the Rook depended positively on the area of spring cereals and meadows and pastures, and seemed to decrease with the area of winter cereals and root crops (Kasprzykowski 2007).

In all likelihood, the opposite trends in the Rook population in the Western and Eastern Europe result from the separation in time of the changes in land-use and crop structure of sown fields in these two parts of the continent. In Poland, between 1985 and 1996 the area of fields occupied by winter cultivars of cereals and of the rape increased from 11% to 28% of the whole cropped area. Throughout the 1990s a large part of meadows and pastures was excluded from agricultural use (in 1990 meadows and pastures covered ca. 4 million hectares), which indirectly confirms also the nearly two-fold decrease in the cattle stock in this period (data compiled for the Central Statistical Office 2000 and earlier publications). In the late 1990s the area of abandoned fields amounted to over 2 million hectares, which constituted ca. 11% of arable land (Marks & Nowicki 2002).

In Western Europe stable and increasing populations of the Rook usually inhabit regions dominated by meadows and pastures (discussed in Mason & MacDonald 2004, Schoppers 2004). Although Rooks have been used to breed in urban areas of Central Europe since at least the first half of the 19th century, these birds generally forage in ploughed land outside the urban territory, and the constantly expanding towns and the consequent increase in the distance to the foraging grounds are indicated as reasons behind the regression of this species in the centres of big towns and cities (Grodziński 1980, Mazgajski 2001, Tomiałojć & Stawarczyk 2003).

The aim of the present paper is to define the directions of changes and dynamics of the Rook breeding colonies in the span from 1983 to 1998 as well as to recognize the main environmental factors which shape the quantitative trend and the risk of extinction of this species both in rural and urban areas of south-western Poland.

MATERIAL AND METHODS

The research covered breeding colonies of the Rook located within the region of Silesia (south-western Poland). The study area occupies 40 540 km^2, which constitutes 13% of the Polish territory (Fig 1). The predominating form of land-use here is farmland, which accounts for over 55% of the area (data for the provinces Dolnośląskie and Opolskie). A particularly high degree of deforestation is characteristic of the Wrocław Plain (1 251 km^2), situated in the central part of the region investigated, where the proportion of arable land exceeds 90%. In the whole studied region secondary forest plots cover jointly ca. 29% of the area, the largest forest complexes remaining in the western (Bory Dolnośląskie Forest Complex), eastern (Stobrawa Forest) and southern (Sudetes Mountains) part of Silesia (Fig. 1).

The paper is based on data about breeding colonies of the Rook which were compiled for the Silesian Avifauna Scheme by the Department of Avian Ecology (DAE) at Wrocław University. These data had been collected since 1983, and till 1988 information on 160 rookeries had been acquired. In the periods 1990–1992 and 1998–1999 the DAE along with the institute's collaborators pursued a census study of the Rook in the whole region. During the two actions each particular participant was requested to control given rookeries, and special emphasis was placed on collecting information about extinct colonies. As required in the instruction disseminated among the participants, the controls were performed on the turn of March. In spite of the action having been planned, it was not possible to obtain information on the number of nests in all rookeries in Silesia (see Table 1). The undertaken action did not take into account all potential nesting sites of the Rook, but the focus was on the rookeries known in a given period. Undoubtedly, such an approach may have resulted in the newly established colonies not being detected. On the other hand, the Rook had been one of the priority species, and data on its breeding sites in Silesia were being constantly collected. Even in the years when no formal actions were organized, the Scheme file got enriched with reports on newly found colonies received from different observers. Besides, in the proper study periods, most of the area where the largest number of rookeries had been found was controlled by the authors themselves, and also numerous potential breeding sites were checked on the way from one locality to another.

In the case of villages and small towns, due to difficulties involved with precise localization of rookeries (e.g. as a consequence of colony transfer), which might have led to erroneous estimation of their size in consecutive years, the total number of nests found in a given locality was regarded as one colony. In cities (mainly in Wrocław), in connection with existence of satellite colonies (single nests or inconspicuous clusters of those on the border of large rookeries), a colony was defined as all nests situated within a distance of ≤ 500 m (after Jakubiec 2005a). Practically, in Wrocław, Opole and Upper Silesian cities this assumption corresponded with the municipal division into districts.

The paper employs a division of rookeries into those located in villages, towns (< 50 000 inhabitants) and cities (> 50 000 inhabitants). The source of data on the area and the size of human population of the studied locations was the Statistical Yearbook of the Republic of Poland (Central Statistical Office 2006). The towns below 50 000 inhabitants (n = 54) totalled 912 000 people and covered jointly 938.6 km^2. The cities over 50 000 (n = 19) were inhabited by a total of 2 850 460 people and their joint area was 1737.6 km^2. In a combined sample of towns and cities the correlation between the human population and area assumed linear dependence (Pearson correlation coefficient, $r = 0.985$, $p < 0.0001$).

Although the overall results of rookery counts in Silesia have already been discussed in a separate publication (Czapulak & Betleja 2002), the present paper analyses the distribution pattern of the Rook in rural and urban areas of the region, applying three categories of colonies: those situated in villages, towns and cities.

Data analysis

Considering the fact that not all data about rookeries collected for the Silesian Avifauna Scheme were as complete as to provide a full insight into the numbers dynamics in consecutive years and to determine the exact time of the abandonment of colonies, only part of this information was selected to model the pattern of extinction. Of the 270 reports on rookeries in Silesia from 1983–1999, 253 (128 village colonies, 56 in towns and 69 in cities) were used in further analysis.

Due to the lack of normal distribution, the differences in the size of rookeries in villages, towns and cities were compared with the application of non-parametric methods (the Kruskall-Wallis and Mann-Whitney and the median tests).

To estimate the risk of extinction of the Rook breeding colonies between the periods 1983–1988 and 1992–1999, the general linear models (GLM) and logistic regression (Hosmer & Lemeshow 1989) were employed. The models were constructed based on combined data obtained during the rookery counting in 1983–1988 and 1990–1992, the period 1998–1999 taken as the final state. The number of nests in 1990–1992 was regarded as an independent variable, and for 18 cases from the previous period these data were replaced with those on the size of rookeries in 1983–1988. Since that was the probability of abandonment of colonies by Rooks which was tested, the dependent variable introduced to the model was defined as extinct (1) or active (0) rookeries. In total, to model the pattern of extinction of rookeries, 18 such cases from 1990–1992 and 82 from 1998–1999 were compiled (see Table 1). The size of an abandoned rookery was determined on the base of number of nests from the previous count.

The extinction of rookeries was tested with the GLM in relation to thirteen environmental variables: location (categorical predictor: village, town or city), size, total number of nests and number of neighbouring Rook colonies within a radius of 10, 20 and 30 km (concentric analysis), distance from and size of the closest active rookery, distance from the nearest rookeries comprising 50, 100 and 150 nests. The selection of extensive zones (radii) around colonies was dictated by large distances between particular colonies, especially those located in small towns (see Results). Due to the strong dependence between the number of nests and number of rookeries ($r_s = 0.69–0.88$) in successive radii (10, 20 and 30 km) (Spearman rank correlation coefficient $r_s = 0.46–0.81$), three separate models (for each of the three analyzed buffers) were constructed.

Due to the overparametrization of the GLM results, those obtained in a multivariate analysis for villages as well as those for towns and cities were left out. However, considering the potential role of particular parameters in the process of rookery desertion, the above mentioned analysis was limited to providing average values and specifying differences between the studied habitats.

The multivariate analysis was complemented with a simple logistic regression analysis, which served to test the risk of extinction of rookeries in relation to their size and (only for colonies in towns and cities) to the area of a given town or city and its human population. The logistic regression models were tested both based on the actual and transformed data, and the final solution of the regression given is the most fitted model. The variables used in the logistic regression were transformed according to the formula $x = \log (x'+1)$.

Since the results of the tests pertaining to the parameters of inactive vs. active rookeries in a pair-wise comparison were different (which, to a large extent, was caused by high sensitivity of the GLM analysis), both the results of GLM and those of the Mann-Whitney test were included.

Results with the probability of $p \leq 0.05$ were regarded as statistically significant. The statistical analysis of the collected material was performed with the application of the Statistica software (StatSoft 2006).

RESULTS

Quantitative characteristics of colonies in relation to their location

In 1983–1999 at least 270 breeding colonies of the Rook were active in Silesia (Fig. 1). Silesian population of the species could be assessed at ca. 18 000 to over 20 000 pairs (Table 1).

The average size of all the rookeries in three consecutive periods did not differ statistically (Kruskall-Wallis test, $H_{2,487} = 0.54$, $p = 0.76$). Of the thirteen colony parameters analyzed, in eight cases statistically significant differences between the studied habitats were noted (Table 2). In the whole study period the largest rookeries were found in small towns. The average size of rookeries in the three specified habitats differed statistically in each of the study periods. The rookeries in cities were the smallest, and in their neighbourhood there were more other colonies than in the case of rookeries situated in villages and small towns. The largest rookeries were situated in small towns, and, additionally, they were characterized by the highest spatial isolation. In the period preceding the regression (1990–92) the smallest rookeries were in villages. In subsequent periods the mean size of rural rookeries was approximately the same (Kruskall-Wallis test, $H_{2,219} = 4.22$, $p = 0.12$), and only a pair-wise comparison for the periods 1983–1988 and 1990–1992 revealed a difference close to statistical significance (Mann-Whitney test, $U = 2894.5$, $p = 0.053$). The distance from other large Rook colonies was the smallest in the case of rural rookeries as compared with those located in the remaining habitats (Table 2).

Factors affecting extinction risk of colonies

In the periods between 1983–1988 and 1992–1999, 105 (39%) breeding colonies of the Rook got extinct in the whole region of Silesia. In

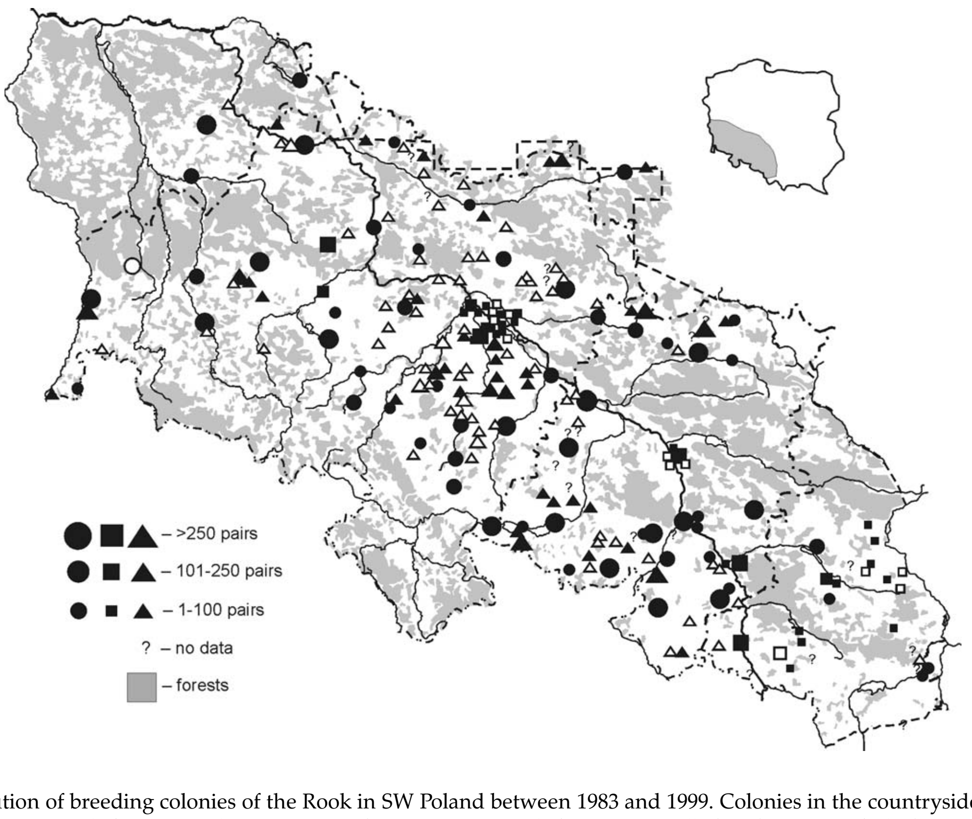

Fig. 1. Distribution of breeding colonies of the Rook in SW Poland between 1983 and 1999. Colonies in the countryside (▲), small towns < 50 000 inhabitants (●) large towns and cities > 50 000 inhabitants (■). Filled and open symbols denote the active and deserted colonies respectively.

Table 1. Quantitative characteristics of the Rook breeding population between 1983 and 1999 in rural and urban areas of SW Poland. [1]The number of controlled colonies (known number of nests) and colonies with unknown number of nests given separately in brackets.

Value	Habitat	Spans		
		1983–1988	1990–1992	1998–1999
Number of colonies[1]	villages	144 (73/?)	133 (97/36)	74 (49/25)
	small towns	56 (42/?)	52 (45/7)	47 (43/4)
	large towns and cities	66 (45/?)	66 (56/10)	43 (37/6)
	combined	+160 (160/?)	251 (198/53)	164 (129/35)
Total abundance of the population	villages	6 671	7 498	4 979
	small towns	7 391	10 118	9 533
	large towns and cities	3 705	4 840	4 021
	combined	17 767	22 456	18 533
Number of abandoned colonies	villages	-	11	70
	small towns	-	2	7
	large towns and cities	-	5	28
	combined	-	18	105

the abandoned rookeries a total of 3 565 pairs had bred, which constituted 20% of the population in 1983–1988 and 16% of the 1990–1992 numbers (Table 1); these values, however, should be treated as rough estimates due to lack of precise quantitative data.

Deserted colonies were over three-fold smaller than those which remained active (Table 3). The median (± 0.25 and 0.75 interquarile range) for the abandoned colonies was 16 (± 8–45) nests, which was nearly six-fold lower than that for the active rookeries (99 ± 33.5–218.5 nests) (median test, $\chi^2 = 48.65$, df = 1, $p < 0.0001$). Around the extinct rookeries there were decidedly higher numbers of nests and colonies within each of the three analyzed radii (10, 20 and 30 km). Active rookeries were more distant from the closest colony, and also from large colonies composed of 50, 100 and 150 nests (Table 3). The GLM showed statistically significant differences in each of the analyzed cases. Except for three variables (size of the nearest colony, number of colonies within a radius < 10 km and number of nests within < 30 km), the results obtained with the use of the Mann-Whitney test were also comparable.

A multivariate analysis revealed that the extinction of breeding colonies in Silesia depended on four variables, and the highest values of the *F*-statistics were obtained for the categorical predictor "colony location" (Table 4). The next to follow were the size of the rookery and the number of nests and colonies located around the one studied. The highest GLM statistics was obtained for the model which took into account the number of

Table 2. Comparison of environmental characteristics (average ± SE) of the Rook breeding colonies in three habitat types. Results of the general linear models (GLM) are given as F-statistics (F). * — $p < 0.05$, ** — $p < 0.001$, *** — $p < 0.0001$.

Description (unit)	Habitat			GLM
	small towns	villages	large towns and cities	
Colony size in 1983–1988	168.0 ± 17.2	95.6 ± 11.5	82.4 ± 17.1	F = 4.55*
1990–1992	234.1 ± 21.0	79.6 ± 13.0	83.2 ± 19.0	F = 8.29**
1998–1999	216.6 ± 16.1	93.8 ± 9.9	110.3 ± 14.6	F = 3.67*
Size of the nearest colony	101.2 ± 22.7	148.0 ± 14.0	49.7 ± 20.6	F = 8.06**
Number of colonies within < 10 km	2.0 ± 0.6	3.6 ± 0.4	10.0 ± 0.6	F = 1.71
< 20 km	6.1 ± 1.3	9.9 ± 0.8	19.1 ± 1.2	F = 0.86
< 30 km	8.2 ± 1.1	11.5 ± 0.7	18.2 ± 1.1	F = 4.8*
Number of nests within < 10 km	314.4 ± 41.3	338.5 ± 25.7	329.2 ± 37.1	F = 9.63**
< 20 km	712.2 ± 83.0	959.9 ± 51.6	759.4 ± 74.6	F = 0.15
< 30 km	1338.3 ± 133.6	1744.5 ± 83.1	1557.2 ± 120.0	F = 11.49***
Distance to the nearest colony (km)	9.6 ± 0.5	5.5 ± 0.3	4.1 ± 0.5	F = 26.21***
Distance to the nearest colony ≤ 50 nests (km)	14.1 ± 0.9	8.5 ± 0.6	8.7 ± 0.9	F = 1.15
≤ 100 nests (km)	17.3 ± 1.2	11.0 ± 0.7	17.8 ± 1.4	F = 2.53
≤ 150 nests (km)	19.5 ± 1.6	13.4 ± 0.9	19.8 ± 1.5	F = 14.22***

Table 3. Descriptive statistics (average ± SE) of deserted (n = 86) and active (n = 128) colonies of the Rook in SW Poland. Values are calculated for the period of 1990-1992, supported by the status of a rookery (deserted or active) in 1998–1999. Results of the general linear models (GLM) are given as F-statistics (F). * — p < 0.05, ** — p < 0.001, *** — p < 0.0001.

Description (unit)	Colonies		GLM	Mann-Whitney test
	deserted	active		
Colony size	48.9 ± 5.3	171.9 ± 17.5	F = 5.44*	z = 6.12***
Size of the nearest colony	106.9 ± 15.9	104.1 ± 12.2	F = 36.66***	z = 0.36
Number of colonies within < 10 km	6.0 ± 0.6	4.1 ± 0.4	F = 84.70***	z = -0.86
< 20 km	13.4 ± 1.1	9.9 ± 0.9	F = 96.65***	z = -2.58**
< 30 km	14.0 ± 0.1	11.8 ± 0.8	F = 72.50***	z = -2.00*
Number of nests within < 10 km	355.8 ± 32.8	332.4 ± 25.1	F = 70.92***	z = -4.12***
< 20 km	921.2 ± 57.3	781.4 ± 52.1	F = 102.20***	z = -3.30**
< 30 km	1743.7 ± 92.8	1508.8 ± 87.8	F = 106.22***	z = -1.88
Distance to the nearest colony (km)	5.2 ± 0.4	6.5 ± 0.4	F = 52.20***	z = 2.36*
Distance to the nearest colony ≤ 50 nests (km)	8.3 ± 0.7	10.9 ± 0.7	F = 47.34***	z = 3.15*
≤ 100 nests (km)	11.7 ± 0.9	15.3 ± 0.8	F = 53.69***	z = 3.11*
≤ 150 nests (km)	13.3 ± 1.0	17.6 ± 1.0	F = 49.87***	z = 3.11*

nests and colonies situated within a radius of < 10 km. With the buffers increasing (20 and 30 km) the goodness-of-fit of the whole model was declining (Table 4).

The probability that Rooks would abandon their breeding colony was negatively related to the rookery size (Fig. 2). The simple logistic regression model was statistically significant for all rookeries in Silesia ($\chi^2 = 63.176$, df = 1, B = 0.607, p < 0.0001, n = 249), for those in cities ($\chi^2 = 8.971$, df = 1, B = 0.345, p = 0.0027, n = 69), towns ($\chi^2 = 23.802$, df = 1, B = 2.974, p < 0.0001, n = 52) and villages ($\chi^2 = 33.356$, df = 1, B = 1.113, p < 0.0001, n = 128). In small towns a colony survival concerned assemblages of > 90 nests, in cities > 320 nests and in villages > 400 nests (Fig. 2).

The risk of rookery desertion depended on the area of the town, the colonies in small towns being most susceptible to extinction (combined model for small towns and cities: $\chi^2 = 4.962$, df = 1, B = -0.502, p = 0.026; Fig. 3A). However, this model was not significant when only colonies in small towns were taken into account (for original data: $\chi^2 = 1.472$, df = 1, B = -0.790, p = 0.224; approximate result was obtained also for transformed data), neither for colonies only in cities (for original data: $\chi^2 = 1.010$, df = 1, B = -1.126, p = 0.315; approximate result also for transformed data).

When testing the effect of another variable, i.e. the number of inhabitants, it was revealed that this factor affected colony extinction negatively only in the case of small towns (model for

Table. 4. Results of the general linear models (GLM) of the extinction of the Rook breeding colonies and their size, and environmental characteristics given as F-statistics (F); in all cases df = 1. [1]Three-level categorical predictor (village, small town and large town or city). [2]Models calculated separately for the number of nests and colonies within a radius of 10, 20 and 30 km. * — p < 0.05, ** — p < 0.001, *** — p < 0.0001.

Effect	Results of the GLM within different radii		
	< 10 km	< 20 km	< 30 km
Colony location[1]	F = 20.11***	F = 11.49***	F = 9.64***
Number of colonies[2]	F = 19.67***	F = 6.51*	F = 0.32
Colony size	F = 11.04**	F = 8.52**	F = 11.15**
Number of nests[2]	F = 7.15**	F = 3.54	F = 6.62*
Distance to the nearest colony ≤ 100 nests	F = 1.55	F = 2.27	F = 3.12
Distance to the nearest colony	F = 1.17	F = 0.47	F = 1.22
Distance to the nearest colony ≤ 50 nests	F = 0.27	F = 0.80	F = 1.13
Distance to the nearest colony ≤ 150 nests	F = 0.01	F = 0.04	F = 0.01
Size of the nearest colony	F = 0.004	F = 0.60	F = 0.47
Goodness-of-fit of the whole model:	$R^2 = 0.278$ $F_{10,160} = 6.123$ p < 0.0001	$R^2 = 0.224$ $F_{10,162} = 4.680$ p < 0.0001	$R^2 = 0.207$ $F_{10,163} = 4.680$ p < 0.0001

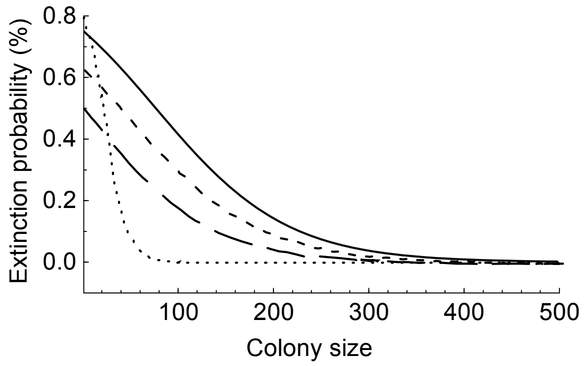

Fig. 2. Probability of extinction (in %) of the Rook breeding colonies between 1983–1992 and 1998–1999 in SW Poland as related to their size. The solid line — all colonies (n = 253), dashed line — rural colonies (n = 128), interrupted line — colonies in cities > 50 000 inhabitants (n = 69), dotted line — colonies in small towns (n = 56).

transformed data: χ^2 = 4.240, df = 1, B = 8.370, p = 0.039; Fig. 3B). The remaining models were not statistically significant: either for cities > 50 000 (χ^2 = 1.171, df = 1, B = -4.58, p = 0.279), or for all towns (χ^2 = 3.489, df = 1, B = -3.621, p = 0.062).

DISCUSSION

The results of the present paper demonstrate that between 1983 and 1999, 39% rookeries in Silesia got extinct, which was accompanied by a simultaneous 16–20% decline in the population numbers of the Rook. Although data about the number of the species breeding colonies in Silesia are incomplete, especially for the first period (1983–1988), it has been documented that the most intense abandonment of the colonies occurred throughout the 1990s, particularly at the end of that decade. An example of region with substantial extinction of rookeries was the remarkably agricultural (> 90% of arable land) Wrocław Plain (see Fig. 1, central part of the surveyed area), where as much as 61% of colonies had been deserted, although it was not followed by a drastic reduction of the overall abundance of the population (maximum number of nests: 1034 in 1983–1988, 1238 in 1990–1992 and 1174 in 1998–1999).

The results of a multivariate analysis (GLM) show that the colony desertion was most heavily influenced by the rookery size and number of nests and other colonies located around the one studied. Also, lower isolation was conducive to colony extinction, all of which consequently could mean merging of colonies. However, due to the diversification of parameters which characterize the rookeries in the three studied habitats, it is difficult to distinguish and isolate the actual reasons behind the extinction from the "secondary" factors that stem only from different character of the colonies in particular habitats. It is even harder to tell bearing in mind the fact that data about land-use, which constitutes the fundamental factor shaping the rookery size (Griffin & Thomas 2000, Mason & MacDonald 2004) and population density of the species on a large spatial scale (Gimona & Brewer 2006), have not been analyzed (see below). On the other hand, it should be assumed that some of the rookeries' characteristics, such as the rookery size and presence of other colonies, which can have an effect on the dispersal within the breeding grounds, could directly affect the risk of their extinction (Griffin & Thomas 2000). Griffin and Thomas (2000) demonstrate that the rookery size is negatively correlated with the

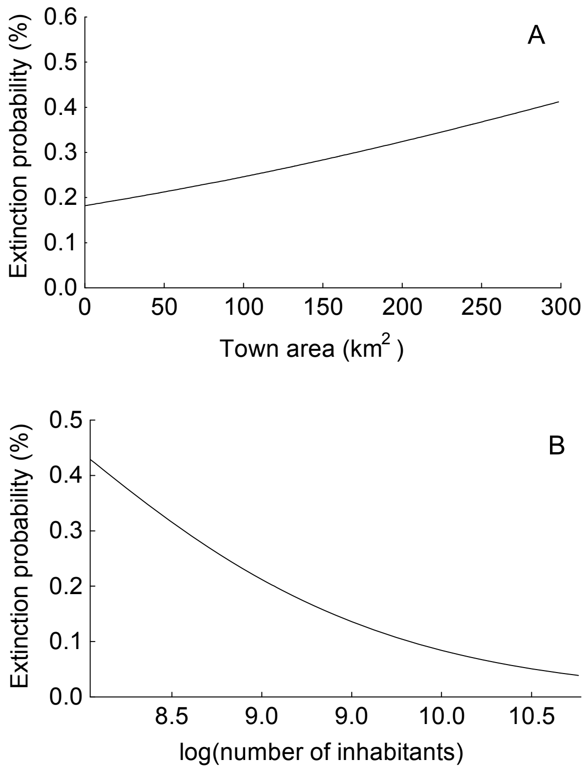

Fig. 3. Probability of extinction (in %) of the Rook breeding colonies between 1983–1988 and 1992–1999 in urban areas of SW Poland as related to: A — the town area (for 125 colonies both in small towns as well as large towns and cities), B — the number of inhabitants in small towns (< 50 000 inhabitants).

number of nests situated within a radius of 1–6 km. Analogously, the results of the present paper show that active rookeries were located at a larger distance from the nearest colony, and also from large colonies grouping 50, 100 and 150 nests. Probably, a small distance between colonies is a factor contributing to dispersal of Rooks to the closest rookeries, which can be evidenced by the increase in their mean size. Additionally, it should be assumed that an array of interactions took place between particular parameters that describe diversification of the rookeries, which could either inhibit or enhance the process of their abandonment by the birds. In cities the desertion of colonies may have been compensated thanks to the presence of numerous other rookeries, which was likely to cause immigration and merging of the neighbouring colonies. Similar interactions might concern rural colonies, which — like the rookeries in cities — expanded, but — unlike in cities — they were more isolated, which simultaneously brought about heavier losses.

In birds living in colonies there is a strong negative correlation between the colony size and the probability of extinction, which was earlier shown for colonies of the Grey Heron *Ardea cinerea* and Purple Heron *A. purpurea* (Barbraud et al. 2003). Józefik (1976) discusses the intrapopulation and environmental mechanisms which determine the size of the Rook breeding colonies in Poland, based on data from questionnaires describing 5867 rookeries. He maintains that small colonies, due to a lack of strong social relationships among individuals, are to a considerably greater extent prone to abandonment than large rookeries. This author has introduced a division into stabilized and sporadic colonies, and based on the log-normal distribution, determined the size of them. The group of sporadic rookeries included merely 1.7% (n = 338) of colonies, and their mean size was 32 nests. The remaining 98.3% (n = 5529) were regular colonies, composed of 146 nests on average (calculated ratio of sizes of sporadic to regular colonies = 1:4.6). The calculations by Józefik (1976) were exclusively theoretical. Yet, comparing them with our results, we arrive at an extraordinarily similar picture — the ratio of the extinct to active colonies equalling 1:4.4 (respectively 37.5:164.5 nests, see Results). However, compared with the theoretical considerations of Józefik (1976), the percentage of rookeries in Silesia that were deserted in the 1990s was 23-fold higher (1.7% vs. 39%). This undoubtedly implies that the extinction of the Rook in Silesia in the mentioned decade was accelerated by strong environmental pressure.

An essential factor which has not been analyzed in the paper, and which — as the hitherto knowledge about the foraging preferences of the Rook (see references below) indicates — seems to have significantly been responsible for the abandonment of the rookeries by the birds in Silesia (particularly in villages and small towns) were worsening feeding conditions following changes in the structure of the sown area and in the intensity of agricultural production. In the last three decades in Silesia the area occupied by winter crops (winter wheat, winter barley, rye, oil-seed rape and root crops) avoided by Rooks (Mason & MacDonald 2004, Kasprzykowski 2003, 2007) in the breeding season grew by nearly 240%. Simultaneously, in this same period the area of prefered habitats — meadows and pastures decline by ca. 62%, and spring wheat, spring barley and oat increased by ca. 11% (Central Statistical Office 1976–2005). It should be emphasized that the Rooks nesting in villages forage mainly within a radius of < 1 km around the colony, preferring grasslands and spring crops (Macdonald & Whelan 1986, Kasprzykowski 2003, Mason & Macdonald 2004, Jakubiec 2005b). And thus, an inconspicuous change in the policies of land-use and in the structure of sown area around the colonies can drastically reduce food resources, particularly in the late spring season (young rearing, April–May), when advanced winter crops are inaccessible to the foraging Rooks. It should also be stressed that, as indicated by Pinowski (1959) and Jakubiec (2005), the adaptation of the Rook foraging selectivity cycle to the phenology of crops and field work concerned small-scale farming, where crop rotation was a common practice. Nowadays, in large-scale and intensive farming, with winter crops predominating, Rooks cannot find suitable foraging grounds.

Apart from the changes in the sowing structure of the main cultivated plants and the cessation of meadow and pasture use, the process of the Rook extinction is probably also linked to the depletion of the soil fauna resources due to more intensive farming methods. This concerns the usage of invasive tillage equipment (deep ploughing) and abandonment of organic fertilization in favour of chemical fertilizers (Paoletti 1999). Also, massive use of plant protection measures (pesticides, fungicides, insecticides, herbicides) substantially reduces the biomass and fertility of the soil fauna, the latter additionally becoming a vector of the contaminants to the organisms of birds (Paoletti 1999, Robinson & Sutherland 2002).

The definition of a colony applied in the present paper (the number of nests from the whole area of a village or town joined together) might, to some degree, distort the results pertaining to the Rook extinction. In all likelihood, this remark would concern only small towns, in which — owing to a relatively large area (the area of small towns ranged from 4.76 to 59.92 km^2) there may have existed more than one colony (according to the definition, a colony is a cluster of nests within a radius of ≤ 500 m, see Material and methods). It seems, however, that in spite of possible distortion of the results caused by simplification of the nest counting method (i.e. a few colonies treated as one), the pattern of extinction of rookeries in the three distinguished habitats seems to be coherent, especially when we analysed data about rural colonies that are not methodologically biased and compare them with the results obtained for towns and cities.

The results of the present paper reveal that the probability of rookery extinction as analysed jointly for towns and cities is positively correlated with their area whereas in the case of exclusively small towns a negative correlation between the number of inhabitants and the extinction risk has been demonstrated (see Fig. 3). If the linear dependence between the area and the human population of a settlement is taken into account, the results indicate that the abandonment of a colony in cities and towns may have different reasons, which can partly correspond with different foraging habits of the birds breeding in these two types of habitat. The city nesters, beside the possibility to fly out to surrounding farmland, feed also in lawns and other urban habitats (Mazgajski 2001, own data from Wrocław), which can favour the survival of small inner-city colonies. Consequently, Rooks breeding in cities may be less susceptible to the changes in farmland than the birds foraging exclusively in this environment. Many a time, small towns resemble villages in spatial structure, and — due to their small area — they are devoid of habitats which can serve as foraging grounds when suitable crops are lacking.

The opposite population trends of the Rook in Poland (decline) and Western Europe (increase) can reflect changes in the lines and intensity of agricultural activity. Opening of the food market, which took place in Poland after 1989 (following the fall of communism), was connected with intensification of production and rapid changes in the crop structure. In Western Europe analogous transformations had occurred 20–30 years before, bringing about rapid changes in the farmland wildlife as well (Robinson & Sutherland 2002). The West- European intensification of agriculture on the turn of the 1950s caused a clear regression of the Rook abundance during 1970–1980. A visible recovery of the Rook population in Western Europe started in the 1980s and continues until today (Brenchley & Tahon 1997, Marchant & Gregory 1999, Schoppers 2004). And thus, since the situation of the species in Poland in the 1990s corresponds with the scenario of environmental changes observed in Western Europe 20–30 years before, the subsequent restoration of its numbers in our country can be predicted. It cannot be excluded that the extinction of the Silesian rookeries in the 1990s is a temporary phenomenon, whose consequence will be a further increase in the mean colony size (Table 4). An increase in this parameter can be indicative of the birds moving to breeding grounds that are situated in more advantageous regions, this phenomenon being currently recorded both from Western and Eastern Europe (Marchant & Gregory 1999, Kasprzykowski 2005, this paper). Yet, the dynamics of the rookery size in Poland in the last decades was highly diversified, with both increases (Biaduń 2001, Kasprzykowski 2005) and decreases noted (Mazgajski 2001, Kuźniak et al. 2005), and this process was not found dependent on the location of the colonies (rural vs. urban), although in the centres of big towns and cities the colonies get extinct or undergo substantial reduction.

In spite of the fact that the European population of the Rook is currently regarded as not endangered (Brenchley & Tahon 1997), the intensification of agriculture in the countries of Central Europe implies a need for continuous monitoring of this species considering its marked population decline in Poland. Undoubtedly, in the nearest future it is advisable to urgently conduct a detailed study on the impact of changes in land-use and the structure of sown area on the condition of rookeries in our country (Kasprzykowski 2003), and also to perform analyses of the food resources of farmland subject to different cultivation methods. This would enable to recognize and better understand the mechanisms and reasons behind the extinction of the populations of the Rook and other birds associated with rural areas of Central Europe.

ACKNOWLEDGEMENTS

We wish to sincerely thank all our colleagues who collaborate with the DAE, Wrocław University, and who have provided us with data about the Rook abundance in Silesia. We are grateful for Z. Kasprzykowski and P. Tryjanowski for their remarks and R. Brasińska and M. Sęk for preparing the English version of this paper.

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STRESZCZENIE

[Zróżnicowane ryzyko wymierania kolonii lęgowych gawrona na obszarach wiejskich i miejskich Śląska]

Pomiędzy rokiem 1983 a 1999 na Śląsku (40 540 km^2, 13% powierzchni Polski) stwierdzono gniazdowanie gawrona *Corvus frugilegus* w co najmniej 270 koloniach lęgowych (Fig. 1), a liczebność populacji kształtowała się od ok. 18 do ponad 20 tysięcy par (Tab. 1). W okresie pomiędzy 1983–1988 a 1992–1999 zanikło 105 (39%) kolonii. W zanikłych koloniach gniazdowało łącznie 3 565 par, co stanowiło 20% stanu populacji z okresu 1983–1988 i 16% z okresu 1990–1992 (Tab. 1). Parametry zanikłych i funkcjonujących kolonii zestawiono w Tab. 2. Ogólny model liniowy (GLM) wykazał, iż zanik kolonii lęgowych gawrona na Śląsku uzależniony był od czterech zmiennych, a najwyższe wartości statystyki F uzyskano dla kategorycznego predyktora lokalizacja kolonii. W dalszej kolejności były to wielkość kolonii oraz liczba gniazd i kolonii zlokalizowanych wokół badanych kolonii. Najwyższą statystykę GLM uzyskano dla modelu uwzględniającego liczbę gniazd i kolonii < 10 km wokół kolonii. W miarę uwzględniania większych buforów (20 i 30 km) dopasowanie kolejnych modeli było coraz mniejsze (Tab. 3).

Spośród trzynastu analizowanych parametrów kolonii, w ośmiu przypadkach zarejestrowano statystycznie istotne różnice pomiędzy badanymi siedliskami (Tab. 4). Kolonie w dużych miastach były najmniejsze, a w ich sąsiedztwie znajdowała się większa liczba kolonii niż w koloniach położonych we wsiach i małych miastach. W małych miastach znajdowały się natomiast największe kolonie, które dodatkowo charakteryzowały się największą izolacją przestrzenną. W okresie poprzedzającym regres (1990–1992) najmniejsze kolonie znajdowały się we wsiach. Dystans jaki dzielił kolonie wiejskie od innych dużych kolonii był najmniejszy w porównaniu z pozostałymi siedliskami (Tab. 4).

Prawdopodobieństwo zaniku kolonii lęgowych gawrona było silnie uzależnione od jej wielkości. W małych miastach przetrwanie kolonii dotyczyło skupisk > 90 gniazd, w dużych miastach > 320 gniazd, a we wsiach > 400 gniazd (Fig. 2).

Przeciwstawne trendy populacyjne gawrona w Polsce (spadek liczebności) i zachodniej Europie (wzrost) najprawdopodobniej związane są z rozdzieleniem w czasie zmian w kierunkach i intensywności działalności rolniczej. Uwolnienie rynku rolnego, jakie nastąpiło w Polsce po 1989 roku związane było ze wzrostem produkcji i gwałtownymi zmianami w strukturze upraw (szczególnie wzrost powierzchni zasiewów ozimych odmian zbóż i rzepaku). W Europie zachodniej analogiczne zmiany miały miejsce 20–30 lat wcześniej wywołując także gwałtowne zmiany wśród fauny związanej z obszarami rolniczymi (np. Robinson & Sutherland 2002). Intensyfikacja rolnictwa w Europie zachodniej na przełomie lat 1950/1960 spowodowała wyraźny regres liczebności gawrona w latach 1970–1980. Zdecydowana odbudowa stanu populacji gawrona w Europie zachodniej rozpoczęła się w latach 1980 i trwa do dzisiaj (Brenchley & Tahon 1997, Schoppers 2004). Sytuacja gawrona Polsce w latach 1990 wpisuje zatem się w scenariusz zmian środowiskowych jaki miał miejsce w Europie zachodniej 20–30 lat wcześniej i na tej podstawie można założyć jednak dalszą odbudowę liczebności tego gatunku w naszym kraju.