Reproduction of the rook, *Corvus frugilegus* in relation to the colony size and foraging habitats

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A b s t r a c t . Parameters of breeding were studied in seven rookeries in the agricultural landscape of eastern Poland. Within foraging territories near colonies, proportions of environmental components were defined, and avoided and preferred types of crops were distinguished. The mean clutch size, mean number of hatchlings and mean number of fledglings per successful brood did not differ between colonies and did not depend on colony size. In contrast, total losses at the stage of egg incubation and feeding chicks, the mean number of fledglings calculated per breeding pair and the overall breeding success were different. Foraging territories around each colony usually had different proportions of preferred and avoided crops. Breeding success depended positively on the area of preferred crops: spring cereals and meadows and pastures. Breeding success seemed to decrease with the area covered by avoided crops and winter crops, but the relationship was not significant. The area of spring cereals was positively but not significantly correlated with the mean number of fledglings.

Key words: rookeries, breeding parameters, foraging areas, agricultural landscape

Introduction

Colonial breeding is common among birds (B r o w n et al. 1990). The reasons of formation and the rules of functioning of breeding colonies are still a problematic issue and thus detailed studies on colonial species of birds are needed (B r o w n & B r o w n 2001). In particular, mechanisms that influence variation of the colony size are not fully explored and are still the greatest mystery of colonial breeding. Nesting in colonies brings profits and losses (W i t t e n b e r g e r & H u n t 1985). The main positive effect on breeding parameters in colonial species is the reduction of predation (B r o w n & B r o w n 2001). The influence of colony size on a decrease of losses in broods caused by predators has been found for many bird species (e.g. H o o g l a n d & S h e r m a n 1976, B u t l e r & T r i v e l p i e c e 1981, G o t m a r k & A n d e r s s o n 1984, H u n t et al. 1986, B r o w n & B r o w n 1987, W i k l u n d & A n d e r s o n 1994). The second main benefit of breeding in colonies is an increased efficiency of group foraging. Colonial nesting results in common foraging of individuals which are predators themselves, more than of a reduction of predation only (A n d e r s o n & H o d u m 1993). Development of breeding colonies can be also explained on the assumption that during selection of the nesting place birds imitate individuals that reach higher reproductive success (D a n c h i n et al. 1998). As a consequence, the relationship between the average reproductive success and colony size can affect the optimal size of a breeding colony (B r o w n et al. 1990, B r o w n & B r o w n 2001). However, analyses of the reproductive success in many species of colonial birds did not bring unambiguous results (B r o w n & B r o w n 2001).

The object of the present study is the rook *Corvus frugilegus*, a species breeding in colonies of different size. Studies describing the relation between reproduction and colony size in this species are lacking. Aspects of the breeding biology of the rook have been studied in Scandinavia (R ø s k a f t et al. 1983, R ø s k a f t 1985, R y t k ö n e n et al. 1993), Great Britain (O w e n 1959, C o o m b s 1960, H o l y o a k 1967, F e a r e 1974, P a t t e r s o n & G r a c e 1984), New Zealand (C o l e m a n 1972, P u r c h a s 1979) and Poland (K a s p r z y k o w s k i 2002). Studies considering the aspect of coloniality referred mainly to the influence of environmental components on the number of nests in colonies (G r i f f i n & T h o m a s 2000, M a s o n & M a c d o n a l d 2004). Habitat preferences of the rook during the breeding period was analysed in the area of eastern Poland, where avoided and preferred type of crops were defined (K a s p r z y k o w s k i 2003).

The aim of this paper is to define parameters of reproduction of the rook in breeding colonies in a mosaic agricultural landscape and to relate them to colony size and various habitats in the foraging range.

Study Area

The study was carried out in 2000–2002 near Siedlce (52° 12' N; 22° 07' E) in eastern Poland. This is a typical farmland region, and in 2002 the largest area there was covered by arable land – 49.1%. Meadows and pastures covered 19.2%, woodlands – 17.1%, orchards – 1.0%, built-up areas – 4.4%, and the remaining land – 9.2% of the total area of the region. A characteristic feature of the study area is a mosaic structure of the farmland landscape and distinctly fragmented arable land into small fields. Proportions of each crop type were very similar in the studied years, and the areas they covered changed only slightly during this period (1999–2002) (Statistical Yearbook of the Mazowieckie Voivodship 2002). The data were collected during three breeding seasons from March to June in seven breeding colonies of the rook. All controlled rookeries were located near human settlements, in the typical landscape of this region. In the analysis of the results, symbols derived from names of settlements were used: O – Oleśnica, W – Wiśniew, S – Śnice, Y – Wyszków, I – Iganie, M – Mokobody and P – Podnieśno. The number of nests in selected colonies varied from 69 to 711, which represented the range of colony sizes in the rook population in the region.

Methods

R e p r o d u c t i o n p a r a m e t e r s

In the study period 179 nests in seven colonies were controlled and in each colony 16 to 35 nests ($\bar{x}$=22.4, SD=6.40) were randomly selected. In total, 37 trees were controlled, with one to 16 nests in each. Most common (43%) were trees with 4 and 5 nests, and the mean number of nests was 4.8. In six colonies (O, W, S, I, M and P) during the breeding season 9–10 controls of nests were performed. In one colony (Y) fewer controls were performed in the end of the breeding season, but nevertheless they allowed the determination of the number of fledglings and breeding success. Only eggs from completed clutches were chosen for analysis. The number of hatchlings was determined as the number of chicks from one to four days old, the number of fledglings – the number of chicks about four weeks old. A nest with at least one fledgling able to leave the nest during the last control was considered a successful brood. The mean clutch size and the mean number of hatchlings and fledglings were compared between colonies by the non-parametric Kruskall-Wallis test (S o k a l & R o h l f 2001). The G-test was used to compare proportions of losses at the stage of egg incubation and feeding nestlings and the proportion of successful nests. All statistics were calculated with the Statistica software (Statsoft 2003). No seasonal differences were found in the proportion of broods with losses and successful ones (G-test, $p = 0.355$), in clutch size ($H_{2,136} = 2.40$, $p = 0.301$), the number of hatchlings ($H_{2,111} = 2.99$, $p = 0.224$) and the number of fledglings ($H_{2,82} = 1.17$, $p = 0.557$).

F o r a g i n g h a b i t a t s

The proportion of habitats in the foraging territory was determined for six colonies (O, W, S, Y, M and P). Depending on the colony, a circle of radius from 1.5 to 3 km from the centre of the colony was established (Table 1). The foraging territory involved places which held over 98% of observations of rooks feeding during the breeding period. Other places of foraging rooks (2%) were localized outside the foraging range of colonies and this observation included only single individuals. After elimination of woodlands and built-up areas, this territory was divided into 250 x 250 m squares. For each square a sketch was drawn with marked areas of grassland and pastures, spring cereal, winter cereal, root crops, wasteland and others. Percent coverage of each crop in the foraging territory was calculated based on their areas (with 1 m^2 accuracy) in randomly chosen squares. The number of random squares was connected with the size of the foraging territory and included ca 5% of all squares. Due to a high level of fragmentation arable parcels – from 4 to 25 in a square ($\overline{x}=10.4$, SD=4.77), this sample was sufficient to reflect the coverage of each type of crop around colonies. The total area in which the proportions of crops were defined was, depending on the colony, from 0.27 to 0.97 km^2 (Table 1). Areas covered by each crop in selected squares were measured in mid-June.

Table 1. Size of foraging areas and random squares around rookeries.

Rookeries	Radius of foraging area (km)	Number of squares	Area of squares (km^2)
M	3	15	0,93
S	2,5	11	0,68
W	2	8	0,50
P	2	7	0,43
O	1,5	5	0,31
Y	1,5	4	0,27
Total	12,5	50	3,12

Division into preferred (grassland and pastures, spring cereal) and avoided (winter cereal, root crops) habitats was adopted after K a s p r z y k o w s k i (2003). This division based on the preferences index allowed to determine which types of habitat were frequently (preferred) or rarely (avoided) chosen by foraging rooks. Proportions of avoided or preferred habitats around rookeries were compared using the G-test. The non-parametric Kruskall-Wallis test was used to compare the coverage of crops in squares of foraging territories in each colony. The relationship between the colony size or parameters of reproduction and the coverage of foraging habitats was determined by linear correlation.

Results

Colony size

Variation in the mean clutch size among colonies was rather low (Table 2), apart from one colony (I) where it reached 4.8, but differences between colonies were not significant ($H_{5,136}$ = 6.29, p = 0.278). The clutch size was independent of colony size (r = 0.16, p = 0.794, n = 6). The mean number of hatchlings in studied colonies varied from 2.6 to 3.2 (Table 2) and these values did not differ significantly ($H_{5,111}$ = 4.52, p = 0.476). No relationship between colony size and mean number of hatchlings (r = -0.36, p = 0.484, n = 6) was found. The mean number of fledglings was lowest in large colonies and the relationship was relative large and negative but not significant (r = -0.66, p = 0.102, n = 7). There were no differences between colonies in the number of fledglings ($H_{6,82}$ = 4.55, p = 0.603). However, when the number of fledglings was calculated per breeding pair the differences among colonies became significant ($H_{6,160}$ = 21.31, p = 0.002). Total losses at the stage of egg incubation and feeding nestlings and the breeding success differed between colonies (Fig. 1). Breeding success varied from 33.3 to 66.7% but did not depend on colony size (Pearson's correlation for proportion after arcsin transformation: r = 0.31, p = 0.502, n = 7).

Table 2. Clutch size and number of hatchlings and fledglings in nests of the rook in seven rookeries (mean ± SD, values in parentheses give sample sizes).

Rookeries	Number of nests in colony	Breeding season	Clutch size	Number of hatchlings	Number of fledglings
O	69	2002	4.2±1.00 (18)	2.8±1.53 (12)	2.2±1.17 (6)
W	130	2000	4.2±1.27 (23)	3.2±1.10 (18)	2.4±1.01 (9)
S	199	2001	4.3±1.45 (16)	3.0±1.19 (15)	2.6±1.04 (13)
Y	202	2002	-	-	2.4±1.13 (11)
I	534	2002	4.8±1.07 (23)	2.8±1.37 (21)	2.0±0.87 (9)
M	622	2001	4.2±0.97 (35)	2.6±0.83 (29)	2.3±0.86 (23)
P	711	2000	4.4±0.59 (21)	3.1±1.00 (16)	1.9±0.83 (11)

Foraging habitats

The proportions of six types of crops in foraging territories around colonies are presented in Fig. 2. Due to a lack or low percentage of areas covered by wasteland and other types of land use, the results were analysed based on four main types of crops: spring cereals, grassland and pastures, root crops and winter cereals. The areas covered by avoided and preferred habitats in the foraging territory differed (G-test = 48.14, df = 4, p < 0.001). Comparing the cover of crops in squares of foraging territories, significant differences among the colonies were found for spring cereals ($H_{5,52}$ = 15.22, p = 0.009) and winter cereals ($H_{5,52}$ = 16.52, p = 0.005). No differences in the area of grassland and pastures ($H_{5,52}$ = 7.50, p = 0.186) and root crops ($H_{5,52}$ = 4.62, p = 0.465) were found. The proportions of various habitats were not correlated with colony size, mean clutch size or mean number of hatchlings. However, the cover of preferred crops positively influenced breeding success (Pearson's correlation for proportion after arcsin transformation: r = 0.83, p = 0.040, n = 6). There was a non-significant effect on the breeding success of winter cereals (Pearson's correlation for proportion after arcsin

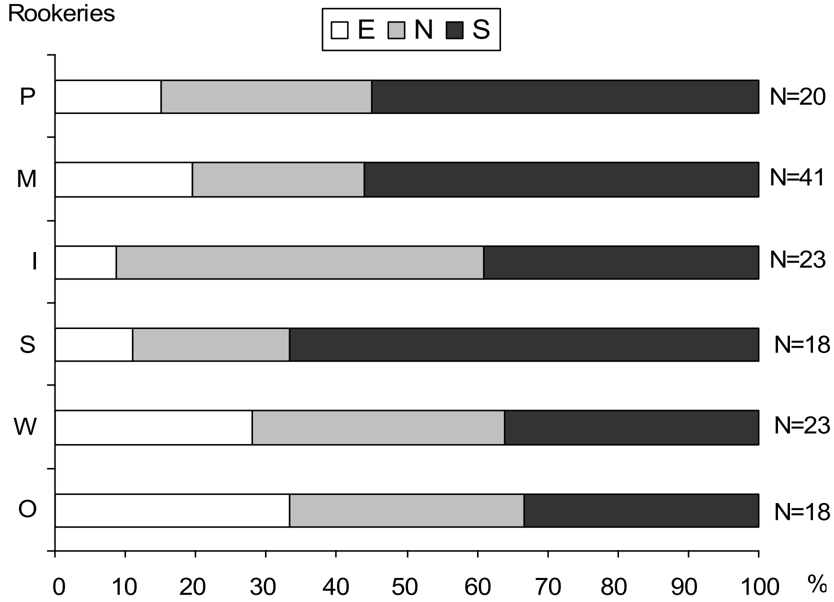

Fig. 1. Percentage of nests with losses in eggs (E), losses in nestlings (N) and nests with success (S) in particular rookeries (P, M, I, S, W and O). Differences among colonies in the nests with losses and successful broods were significant (G-test = 36.59, $p < 0.001$, df = 5).

transformation: r = -0.77, p = 0.073, n = 6) and total cover of avoided crops (Pearson's correlation for proportion after arcsin transformation: r = -0.78, p = 0.068, n = 6). The mean number of fledglings was positively but not significantly correlated with the proportion of spring cereals (Pearson's correlation for proportion after arcsin transformation: r = 0.79, p = 0.061, n = 6).

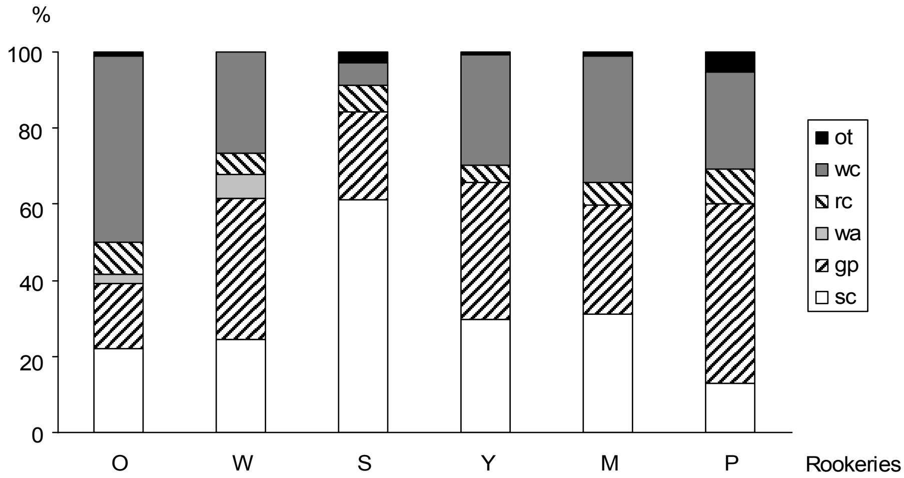

Fig. 2. Percentage of habitats in foraging areas of studied rookeries: sc – spring cereals, gp – grassland and pastures, wa – wasteland, rc – root crops, wc – winter cereals, ot – others.

Discussion

In spite of differences in the size of rookeries, no differences in clutch size, number of hatchlings and fledglings were found in the present study. In contrast, comparison of proportions of nests with complete losses at different stages of brood development showed differences among most of the colonies. In effect, the mean number of fledglings leaving a nest per breeding pair and the breeding success varied. In other colonial birds both the influence of colony size on parameters of reproduction and a lack of such relation have been found (Brown & Brown 2001). In addition, studies showed that the breeding success of some birds could increase with the colony size, while in others it decreased or reached the highest value in the middle range of the colony size. Breeding parameters in relation to coloniality can be influenced by various factors. However, the main factor (related with the colony size) that may influence the efficiency of broods is predation pressure (Brown & Brown 2001). A weaker influence of predators in large colonies is connected with active defence of nests. An increased number of individuals defending nests results in a reduction of losses caused by predators in spite of much higher chances of their locating large colonies (Brown & Brown 2001). Rooks actively defend nests against predators but mainly against other species of birds (Röell & Bossema 1982, Cramp & Perrins 1994). In the study populations, predators were responsible for losses in broods only to a limited extent. The greatest predation pressure occurred during of egg incubation and was probably caused by squirrels (Kasprzykowski 2002). On the other hand, a reason for forming large breeding colonies is to increase the efficiency of group foraging (Clode 1993, Brown & Brown 2001). Social foraging by rooks increases their food-finding efficiency, especially in the case of food hidden shallowly under the ground (Chantrey 1982). Other studies demonstrated that rooks in small flocks (below 10 individuals) reached a lower mean index of foraging success (Höglund 1985). Moreover, a higher number of rooks breeding in a colony is connected with the extension of foraging territory (Kasprzykowski 2003). Types of foraging areas and the location of a water body close by are, according to Korbut (1999), factors that determine colony size in this species. In intensively cultivated farmlands, for example in England, the most important environmental component in foraging territories of rooks which affected the colony size was the proportion of meadows and pastures (Griffin & Thomas 2000, Mason & Macdonald 2004). Also for many other species the colony size reflects local food abundance within the habitat (Danchin & Wagner 1997). A lack of the relationship between the number of breeding pairs and the proportion of preferred crops in the studied population of the rook may be explained by strong social relationships in this species. Large colonies of birds can also be formed according to the rule of common imitation, influencing the individual's choice of their place of settlement (Danchin & Wagner 1997). Young birds or individuals in worse condition, which return later to breeding grounds (Hoi et al. 2002), more often select colonies of this size. This hypothesis is supported by statistically greater variation in the biometry of eggs in large colonies of the studied rook population, which is evidence for a greater diversity of body condition and physiological limitations of the female (Kasprzykowski & Zduniak, in prep.). Moreover, such factors as levels of steroid hormones can influence the choice of colonies, which can also be decisive for differences in the colony size (Brown et al. 2005).

In this study colony size did not depend on the proportion of environmental components in the foraging area. Nevertheless, avoided and preferred types of crops affected some parameters of broods. The mean number of fledglings seemed to positively correlate with the coverage of spring cereals. In some periods of the breeding season, a higher number of foraging rooks was recorded in this type of crop than on meadows and pastures (K a s p r z y k o w s k i 2003). Areas where spring cereals are grown can provide a diverse and abundant food source around the colony, depending on the type of actual cultivation activities. The presence of meadows and pastures, as emphasised by many authors mainly due to the richness of animal food (W a i t e 1984) is necessary. However, in conditions of the landscape of eastern Poland it is the area of spring cereals that is the factor which mainly influences breeding success. In many populations of rooks, food deficiencies cause high mortality of nestlings, especially in the first period of their life (O w e n 1959, H o l y o a k 1967, P u r c h a s 1979, R y t k ö n e n et al. 1993, K a s p r z y k o w s k i 2002). The great importance of spring cereals in the study area was additionally supported by a positive relationship between the density of breeding population of the rook and the area of wheat fields (K a s p r z y k o w s k i 2005). Wheat is the main element of spring cereals and is clearly preferred by rooks for consumption (L u n i a k 1977). In other breeding areas no strong relationship of rook occurrence with areas covered by spring cereals was found. For example, in the agricultural landscape of eastern England winter cereals dominated and the area covered by fields of spring cereals near rookeries was very low (M a s o n & M a c d o n a l d 2004), though they were extensively exploited during germination and early growth in April and May.

In conclusion, the lack of the influence of the colony size on breeding parameters of the population that inhabits eastern Poland can result from a trade off between profits and losses of colonial breeding. Thus, the decisive factor that affected revealed differences in breeding success among studied colonies was the food richness of foraging areas. Apart from meadows and pastures, areas covered by spring cereals played an important role.

A c k n o w l e d g m e n t s

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