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FACTORS INFLUENCING THE NUMBER OF FEEDING ROOKS
(*CORVUS FRUGILEGUS FRUGILEGUS* L.)
IN VARIOUS FIELD ENVIRONMENTS

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I. INTRODUCTION

The material for this work was obtained from the area situated outside Warsaw, between the Vistula and the fringe of the Kampinos Forest — from Prochownia to the village of Czosnów. Total area covered by this stretch of country was about 50 sq. km. Additional observations were made in the areas on the right bank of the Vistula, and in the Modlin and Wyszogród districts. The area of basic investigations lies in the old valley of the Vistula, on its first terrace (subject to flooding) and second terrace (dunes) (Kobendza and Kobendza 1957), and lies at about 75 m. above sea level (fig. 1).

The soils in this area vary considerably. Loose sands occur in the form of dunes along the banks of the Vistula, and in Czosnów and Górka Dziekanowska, and also on the edge of the Kampinos Forest near Sadowa. Extensive dunelike tracts lie beyond the area examined, on the edge of the Kampinos Forest. Soils containing the largest number of alluvial and pulverous particles — clayey-pulverous sands (light alluvial soils) extend over a large area on terrace II, from Czosnów, past Łomna, and in addition occur in smaller patches over the entire area examined. Within the boundary of Kępa Kielpińska there is a series of belts of silty bog soils. The greatest area is, however, occupied by various sandy-clayey soils (alluvial soils) with indirect quantities of alluvial particles¹.

¹ Map of geological surface formations and soil systems prepared under the guidance of Dr. M. Prószyński of the Warsaw City Area — scale 1 : 25 000, 1948—1954.

The area examined is covered by fields in which cultivation most often takes the form of wide strips about 50—70 m in width. The quantitative observation routes ran vertically to these strips, except in the case of the large area covered by single-crop cultivation, situated between Palmiry, Łomna and Pienków. The wet land lying between the villages of Czosnów and Czastków and the Vistula dikes, and the areas between the villages of Dziekanów Polski, Kielpin and Kępa Kiełpińska are used as pastures. The remainder of the area is occupied by cultivated fields. The wooded patches in the fields, in the form of clumps and belts of trees, on terrace I, are densely grouped (fig. 2), whereas they are absent on terrace II (fig. 3), the fields here being almost entirely treeless (fig. 1). The fields in which few trees grow are chiefly sown with rye or oats. In the fields between Łomna and Czosnów wheat is more frequently grown than rye. There were few fields sown with barley. Potatoes are the most frequently grown root-crop, beetroot being far more infrequently grown. There are practically no meadows or pastures. In the thickly-wooded fields there are frequent clumps and belts of trees composed chiefly of pollarded willows, with groups of tall poplars occurring here and there. This lowlying area is wet and used for root-crops, especially beetroot; there is also more wheat, barley and oats, and less rye, sown here. The cultivated land is dotted with small patches of meadowland and pastures. The land on the Vistula banks between the flood dikes and the river is occupied chiefly by pastures with varying amounts of trees. On the edge of the Kampinos Forest in the vicinity of the fields young pine woods are predominant, only in two places are there stands of fully-grown pine trees (Dziekanów Leśny, Kaliszki).

A bicycle was used during observation work as being a comparatively rapid method of locomotion², in order to include the greatest possible area within the scope of the quantitative investigations. Observations were made while cycling at a speed of 7—10 km per hour, taking in a belt 400 m wide (200 m on each side of the route). The material so obtained was divided into samples (1 sample = observations carried out on a route 600 m long).

² In the post nesting period the area covered by the rook population is extensive. Birds form different colonies which congregate in a common

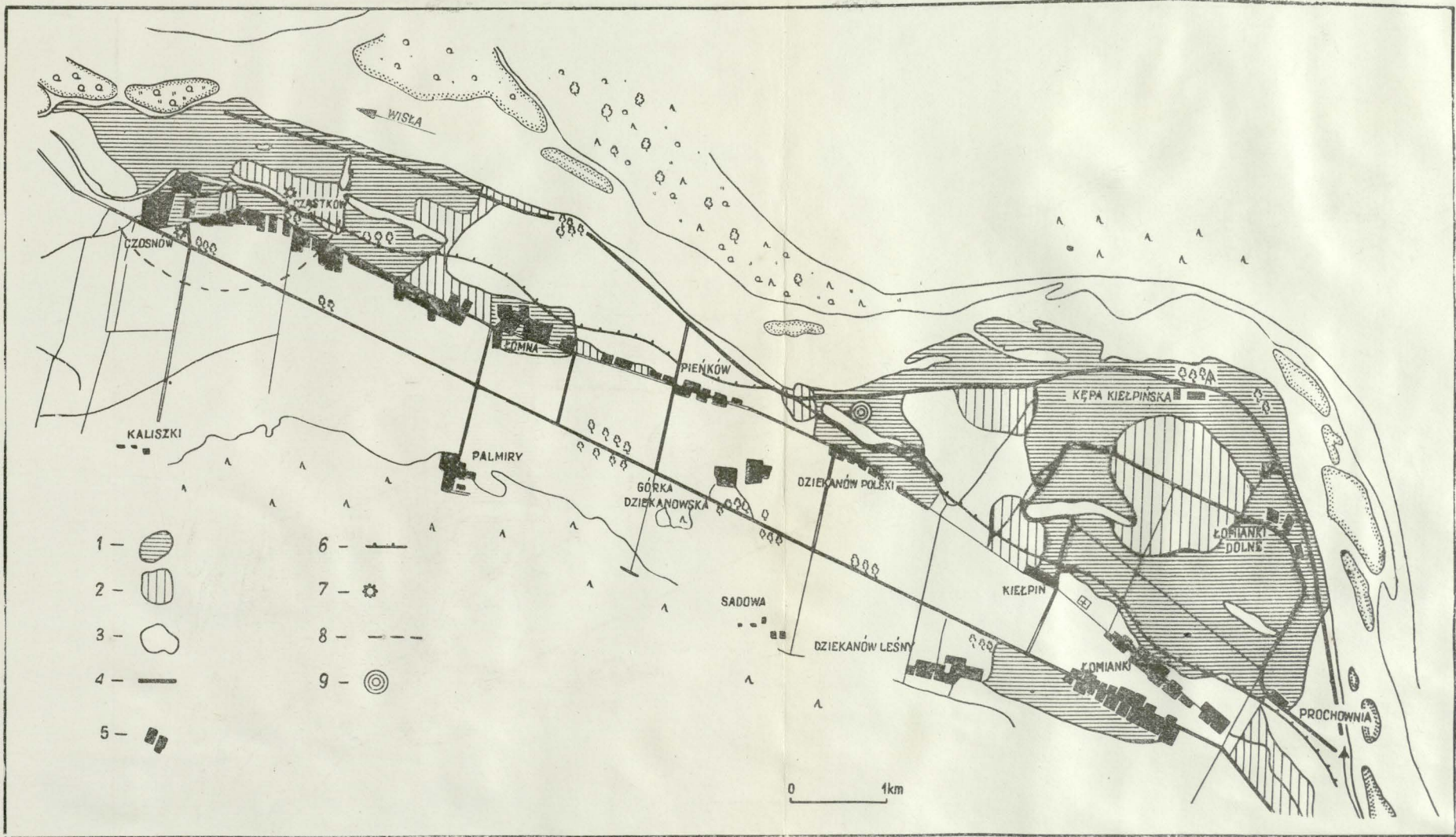


Fig. 1. Map of area investigated

1 — Trees growing more densely than every 500 m; 2 — Trees growing within limits of every 500–1000 m; 3 — Trees growing more sparsely than every 1000 m; 4 — Quantitative observation route; 5 — Buildings; 6 — Edge of terrace II; 7 — Nesting colonies of rooks; 8 — Feeding ground of colony; 9 — Nocturnal resting place of members of *Corvidae* family

Mapa badanego terenu

1 — Zadrzewienia rozmieszczone gęściej, niż co 500 m; 2 — Zadrzewienia rozmieszczone w granicach 500–1000 m; 3 — Zadrzewienia rozmieszczone rzadziej, niż co 1000 m; 4 — Trasa obserwacji ilościowych; 5 — Zabudowania; 6 — Krawędź tarasu II; 7 — Kolonie lęgowe gawronów; 8 — Areał żerowania kolonii; 9 — Miejsce noclegu ptaków krukowatych

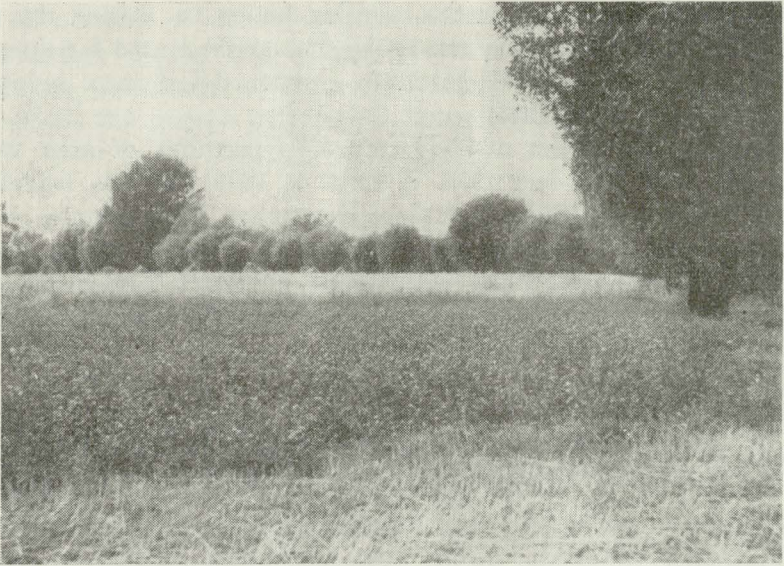


Photo. B. Siemaszko

Fig. 2. Densely wooded fields. Pola gęsto zadrzewione

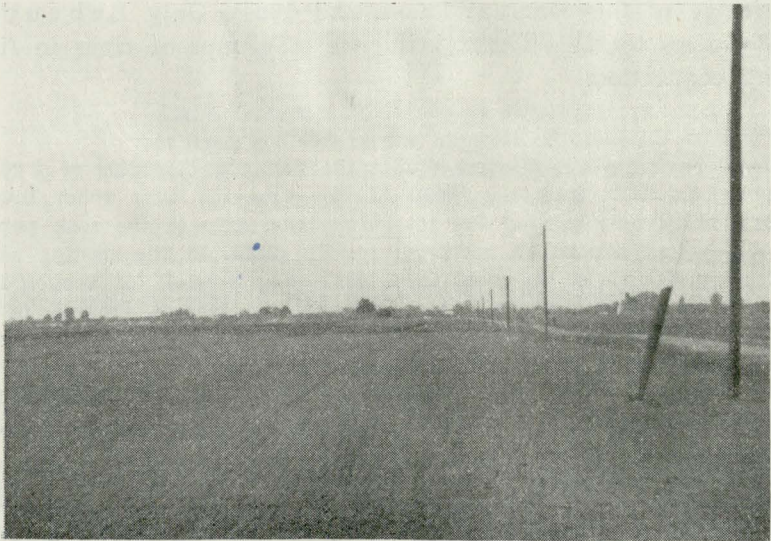


Photo. B. Siemaszko

Fig. 3. Sparsely wooded fields. Pola rzadko zadrzewione

Observations were made in the morning hours, i.e. during the period of intensive feeding by the rooks. The method used for quantitative investigations is described in greater detail in a separate article (Pinowski 1955).

Observations of the numbers of rooks per unit of area were carried out in 1954 and 1955. A total of 1600 km was travelled during these investigations in these two years, 2667 samples were taken and 9980 specimens of rooks observed. In addition, from 1954 to 1957 investigations were made of the behaviour of the flocks of rooks during their search for food, in the nesting colonies and in their nocturnal resting places³.

II. QUANTITATIVE DYNAMICS OF ROOKS IN THE AREA INVESTIGATED⁴

1. INFLUENCE OF GROUPS OF TREES IN FIELDS ON THE NUMBERS OF THE ROOKS

Very little is known of the influence of the extent to which the area is wooded on the numbers of feeding rooks. It is, however, well known that rooks only exceptionally feed within forests, and then only during the gradation of insects (Haber 1952, Koehler 1957 and others). While feeding the rooks avoid the fields on the fringe of the forest (Pinowski 1954). Only Lebeurier (1953) refers to the adverse influence of groups of trees in fields in this connection.

nocturnal resting place, disperse during the day over a radius of ± 20 km (Philipson 1933; Šedivý 1949). At this time the area under investigation covered only part of the total dispersion area of the rook population which had a common nocturnal resting place. In the nesting season the feeding grounds of the rooks from one colony is small (cf. Section II. 2). The area examined included a large part of the feeding grounds of two rook colonies situated at Czastków and Czosnow, and only a small part of the feeding grounds of the rook colonies at Bielany.

³ My colleague A. Wasilewski took part in collecting the material for this work, and in its preliminary analysis, and I have pleasure in here tendering him my sincere thanks.

I am greatly indebted to Dr. J. D. Lockie (Edinburgh), Prof. Z. Raabe (Warszawa), Dr. F. J. Turček (Banská Štiavnica ČSR), Prof. K. Szarski (Wrocław) for reading the manuscript and giving valuable criticism.

⁴ Part of the material contained in this section was read at the IV International Congress of Crop Protection, Hamburg 1957.

As a result of the investigations described in this work it was found that during the nesting period (29.III—22.VI.1955) there were no detectable differences in the number of rooks in areas in which the groups of trees in fields were densely and sparsely

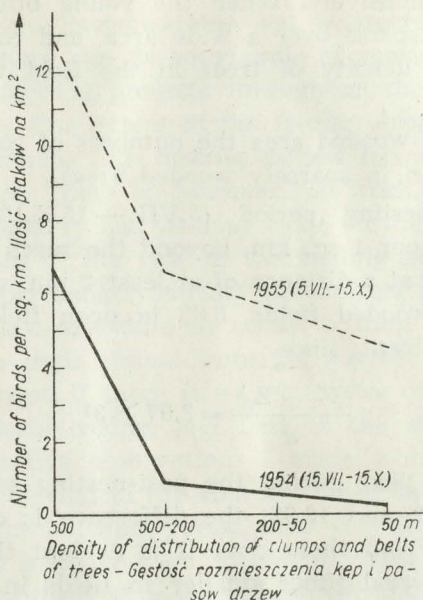


Fig. 4. Influence of density of distribution of trees in fields on the numbers of rooks
Wpływ gęstości rozmieszczenia zadrzewień na polach na liczebność gawronów

situated, and at least 2 km away from the nesting colonies. For the purposes of this work, areas were considered as sparsely wooded where the clumps or belts of trees grow at over 500 m apart, and as densely wooded, where the groups of trees are closer together than 500 m. For purposes of analysis of the behaviour of birds in densely wooded areas, a division was made into fairly densely wooded section, in which the clumps and belts of trees were distributed at from 500 to 200 m intervals, and very densely wooded sections, with clumps and belts of trees distributed at closer intervals than every 200 m. In the nesting period, apart from the

colony feeding area, the rooks occurred in very small numbers (densely wooded fields — 1.05 bird per sq. km, open fields 1.85 per sq. km).

During the post-nesting period, the colony exerts a far smaller influence on the distribution of the rooks in the morning when the birds feed intensively. When the young birds have left the nest, the rooks disperse over a wide area, and then the influence of the degree of density of trees in the field was shown more clearly.

In the densely wooded area the numbers of rooks were several times smaller than in sparsely wooded areas.

In the post-nesting period (5.VII. — 15.X.1954) the average number of rooks per 1 sq. km, beyond the reach of the influence of the colony, i.e. at a distance of at least 2 km, was as follows — 0.54 in densely wooded fields, 6.82 in open fields (difference is statistically significant, since

$$\frac{|Z_1 - Z_2|}{\sigma} = 3.07 > 3^5$$

The following year during the post-nesting season comparable figures were: 4.52 and 12.92, the difference is only statistically probable (2.50). From these data it is evident that the numbers of rooks were several times smaller in fields in densely wooded areas than in those in sparsely wooded areas (fig. 4).

On the banks of the Vistula there was no real difference between the numbers of rooks in sparsely or densely wooded terrain (during nesting period in densely wooded terrain, 4.61 birds per

⁵ The difference between 2 averages is estimated as true if $\frac{|Z_1 - Z_2|}{\sigma} \geq 3$,

where Z_1 = number of birds per sq. km in sparsely wooded area, Z_2 = number of birds per sq. km in densely wooded area, n_1 — number of samples from sparsely wooded area, n_2 = number of samples from densely wooded area, σ = is the standard of difference $Z_1 - Z_2$, K = number of sample and

$$\sigma = \sqrt{\frac{\sum_{K=1}^{n_1} (Z_K - Z_1)^2 + \sum_{K=1}^{n_2} (Z_K - Z_2)^2}{n_1 + n_2 - 2}} \cdot \sqrt{\frac{n_1 + n_2}{n_1 \cdot n_2}}$$

According to: Romanowski, W. 1951 — Zastosowanie statystyki matematycznej w doświadczalnictwie — Warszawa.

sq. km and in sparsely wooded terrain, 4.93; ^{nest -} nesting period 6.02 and 10.58 respectively; neither of these differences are statistically significant).

2. INFLUENCE OF THE ROOKERY AND 24-HOUR CYCLE ON THE DISTRIBUTION AND BEHAVIOUR OF ROOKS

The object of the investigations was to ascertain the influence of the nesting colony and 24-hour cycle of rooks on the numbers of rooks in the feeding grounds throughout the annual cycle of vegetation growth. The extent of the feeding grounds of the rooks of one rookery during the nesting period has been investigated by several authors. There is, however, no work dealing with the influence of the rookery and 24-hour cycle on the number of rooks at different seasons of the year in the feeding grounds.

The rookery, particularly during the nesting season, is a decisive factor in the distribution of rooks in their feeding grounds. Immediately after their arrival from the warmer regions in which the winter was spent, if there is no recurrence of frosts, the rooks form, and live as, a colony, and feed in the areas adjoining it. From the quantitative observations I made while cycling it will be seen (fig. 1, 5, 6), that in the area examined the feeding grounds of the colony in the hatching period were very limited in extent — within a radius of scarcely 2 km. Flights of rooks from the rookery to the other side of the Vistula were, however, observed, but scarcely any investigations were made here. The area round the rookeries in which the rooks belonging to them were encountered have been marked on the map with a broken line (fig. 1). The rookeries examined contained approximately 30 nests. Diagrams (fig. 5, 6) show the fall in the numbers of birds according to the increase in distance from these colonies. It should however be emphasised that the route along which observations were made ran through fields at Czosnów at about 100 m from colony and in Czastków about 600 m from the colony. The route following the banks of the Vistula on the opposite side of the colony lay at a distance of 800 m from both the first and second colony.

At Bielany, at a distance of about 6 km from the area where quantitative observations were carried out, there was a very large colony (several hundred nests). The pastures on the bank of the Vistula on the side near the colony described above formed, during the hatching season, the feeding grounds of a large number of

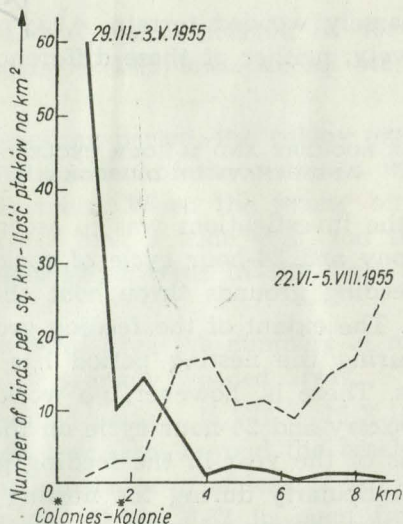


Fig. 5. Distribution of rooks along the observation route: Czosnów — Dziekanów Leśny; sparsely wooded fields.
Rozmieszczenie gawronów wzdłuż trasy obserwacji Czosnów — Dziekanów Leśny; pola rzadko zadrzewione

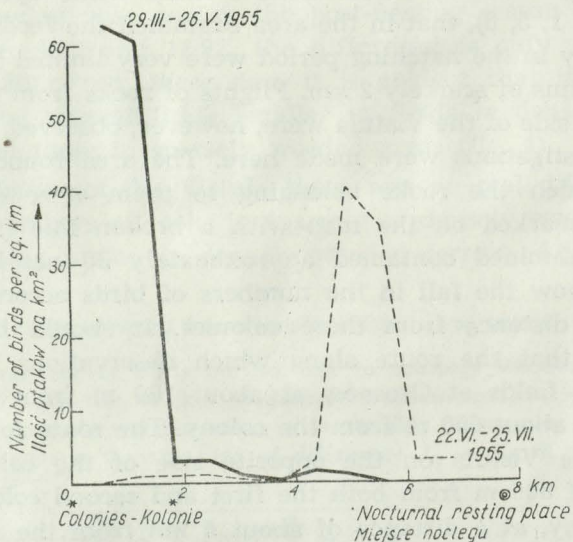


Fig. 6. Distribution of rooks along observation route: Czosnów — Dziekanów Polski; river bank of Vistula.
Rozmieszczenie gawronów wzdłuż trasy obserwacji Czosnów — Dziekanów Polski; brzeg Wisły

rooks which must have been, in some way, connected with this colony. But very few rooks were observed carrying food to the colony, and therefore were either non-breeding birds or those which had lost their eggs or young.

My observations on the feeding grounds of the colony during the nesting period agree with those given by Formozow et al. (1950), Jirsik (1947/48), Šedivý (1949/50) and others. If the colony is situated far from the feeding grounds, e.g. in the centre of a large town, the rooks have to go much further in search of food. Schnurre (1949) states that the rooks he observed nesting in the centre of Berlin probably obtained their food in the fields lying at a distance of 10—12 km from the colony. According to Samorodow (1935) the feeding grounds of the rook colony vary over the course of the day. In the morning hours, to which my material refers, the area of feeding ground is the smallest (0.5—4 km); this increases several times over by mid-day and again decreases in the afternoon. At mid-day the young birds are less frequently fed while the adult rooks fly farther in search of food.

In the post-nesting period and especially in the autumn, rooks often visit the rookery; this behaviour is connected with the renewal of the activity of the sexual glands (Marshall and Coombs 1957) and the 24-hour cycle.

In order to collect material on the 24-hour cycle of the rooks special observations were carried out in their nocturnal resting places and colonies. Investigation of the behaviour of the various flocks of rooks, which it was sometimes possible to observe throughout the day, yielded many interesting data. Material on the 24-hour cycle of this species was also supplied by examination of the forms of communication between the rooks. Although the material collected refers chiefly to the summer months (VII—IX), it was not collected systematically.

According to our observations, the 24-hour cycle was as follows: the rooks spent the night, in the area under observation near the village of Dziekanów Polski, in trees (willows, poplars) between the pond and the Vistula dike, or in trees by the pond on the side near the village (see fig. 1, 7). This area, apart from the fact that the trees were situated near the pond and the Vistula, was not in any way distinguished from any other. There were very many trees in this area. I am unable, however, to supply an answer to the question as to why this site was chosen as their nocturnal resting

place by members of the raven family. Hooded crows passed the night there most regularly. It sometimes happened that crows or jackdaws spent the night there, while rooks were absent (12. VII.1956). Most often, however, all three species were present.

The influence of the nocturnal resting place on the distribution of rooks in the areas examined, during the morning hours,



Photo. B. Siemaszko

Fig. 7. Trees forming nocturnal resting place of members of *Corvidae* family: in foreground lake, trees and on horizon flood protection dike of Vistula
 Drzewa będące miejscem noclegu ptaków krukowatych: na pierwszym planie jezioro, drzewa, a na horyzoncie wał przeciwpowodziowy Wisły

was almost imperceptible (fig. 6, 9), and this is proved by the fact that the rooks did not fly from the nocturnal resting place to the adjacent areas to look for food there, but flew further on. In the autumn the place where they stay in the morning immediately before flying off to the fields and pastures, is the nesting colony. They were encountered at this time both in the colony at Czosnów and that at Czastków. At the end of summer birds of many species, and of the raven family particularly jackdaws, return, with the renewal of the activity of the sexual glands, to the colony where they spend many hours of the day. Šedivý writes that whereas throughout the summer only certain of the birds spent the night in the colony, at the end of September all the rooks in the colony return to it, and pass each night there throughout

the winter. The appearance of rooks in the colony during the autumn period has been noted by Campbell (1936), Garling (1930), Morley (1943), Marshall and Coombs (1957). From the quantitative material (fig. 8, 9) we see that both in the fields adjoining the colony and in the areas in the neighbourhood of the colonies on the Vistula side, there was a far greater number of rooks than in other sections of the observation route. In 1954 from

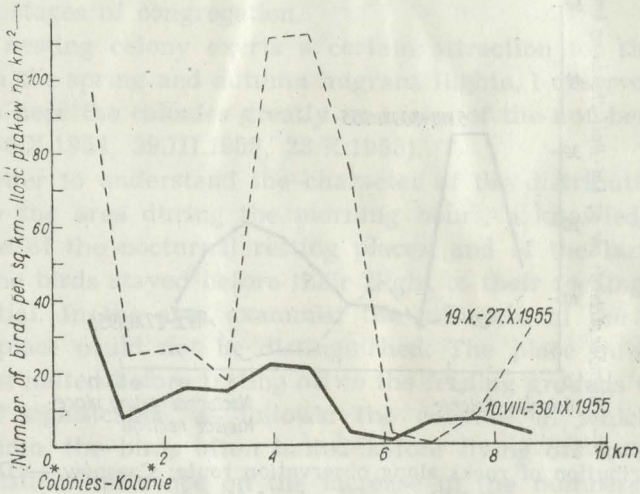


Fig. 8. Distribution of rooks along observation route: Czosnów — Dziekanów Leśny; sparsely wooded fields
Rozmieszczenie gawronów wzdłuż trasy obserwacji: Czosnów — Dziekanów Leśny; pola rzadko zadrzewione

27.IX. to 30.X. and in 1955 from 6.IX. to 6.XI. large quantities of rooks were seen there during every observation period. In the morning hours rooks were encountered in the forest at Dziekanów Leśny (July) before their feeding time. The method of dispersion flight from the nocturnal resting place described does not in principle differ from the mechanism described by Gramet (1956a). According to Gramet the rooks, before they reach the feeding ground, halt two or three times for a short period in trees, and in this way split up into increasingly smaller groups, finally flying to the feeding ground.

My observations revealed that the rooks fed intensively in the morning, in hot July days to 8—9 a. m., and in September to

11—12. On cloudy days they spent their afternoon hours chiefly on the feeding grounds, but searched far less intensively for food. On hot days they most often spent these hours in large groups in trees in fields, or by the brink of the riverside pools and in the trees on the bank. I also saw a group of rooks on the ground in the shade of single trees standing in fields. In the late afternoon they again began to feed (in July, August from 4—6 p. m.). Before

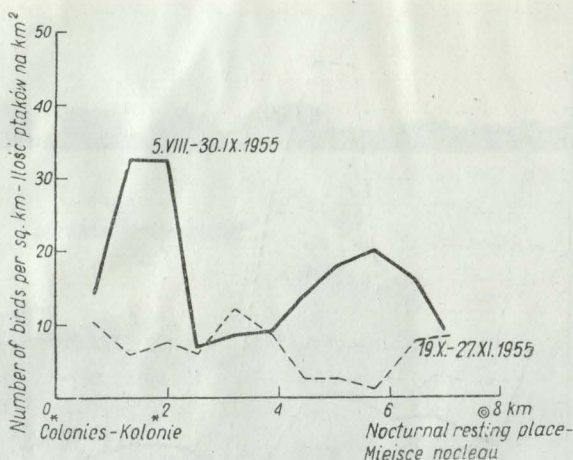


Fig. 9. Distribution of rooks along observation route: Czosnów — Dziekanów Polski; river bank of Vistula

Rozmieszczenie gawronów wzdłuż trasy obserwacji: Czosnów — Dziekanów Polski; brzeg Wisły

evening fell I most often encountered rooks which had gathered, together with jackdaws, in the pastures on the banks of the Vistula, (23.VII.1956 — 6.30 p.m., 9.VIII.1955 — 5.20 p.m., 5.IX.1955 — 5.30 p.m.), whence they flew to a larger group by the riverside pool, later, at dusk, flying down the Vistula or upstream in the direction of their nocturnal resting place at Dziekanów Polski. I also observed (5.IX.1955) the splitting up of such a flock after dividing into two groups flying in opposite directions. In the nocturnal resting place in Dziekanów Polski the rooks, together with jackdaws, usually appeared long after sundown, when it was almost completely dark.

The phenomenon of the congregation of rooks in their nocturnal resting place has engaged the attention of many authors, such as Grimm (1954), Schuster (1954), Šedivý (1949/50), We-

sterfrölke (1954), Zdobnický (1907) and others. Recently Gramet (1956a) described in detail the mechanism of the congregation of rooks. The rooks gradually (in 2—3 stages) gather in increasingly large flocks, in order to fly straight to the nocturnal resting place in the dark. This mechanism is similar to that of the departure from the nocturnal resting place in the morning, but is as a rule more complicated, in the evening the birds remain longer at the gathering points, and also there may be more intermediate stages of congregation.

The nesting colony exerts a certain attraction for the passing birds. In the spring and autumn migrant flights, I observed a group of rooks near the colonies greatly in excess of the numbers of local rooks (16.X.1954, 29.III.1955, 23.X.1955).

In order to understand the character of the distribution of the rooks in the area during the morning hours, a knowledge of the influence of the nocturnal resting places, and of the last place in which the birds stayed before their flight to their feeding grounds, is essential. In the area examined the influence of the nocturnal resting place could not be distinguished. The place in which the birds last halted before flying off to the feeding grounds was, however, of significance, as follows: the colonies in which, during the autumn, the birds often halted before flying off to the fields, had a distinct influence on the increase in the numbers of rooks in their vicinity.

3. SEASONAL VARIATIONS IN NUMBERS OF ROOKS IN VARIOUS ENVIRONMENTS

In this section I have discussed the distribution of rooks during the annual cycle of vegetation growth. I know of no works on this subject except those dealing with the period of autumn migration flights. Many other works contain only the observations that rooks feed in different environments depending on the season of the year, and this is most comprehensively dealt with in the work by Vertse (1943).

The character of the quantitative variation dynamics of this species was different in each of the areas examined.

A. Treeless (open) fields

Rooks occurred in the fields from the spring until the end of April (fig. 10). They then disappeared completely from the fields, not to reappear until harvest time. These areas are covered by winter corn (wheat, rye) and spring corn, and to a lesser degree

by root-crops, chiefly potatoes. There are practically no meadows or pastures. Lovassy (acc. Vertse 1943) writes that the rooks in the late spring change over from fields to meadows and pastures. The reason for this is the growth of the corn, chiefly winter, since this species of birds does not feed in deep vegetation.

I carried out special observations in 1956 in order to ascertain the degree to which the height of the corn crops influences the feeding of the rooks in the fields. In addition to making quantitative observations from my bicycle, I observed the feeding habits of the rooks and measured the height of the corn crops. In 1955 the rooks fed in winter corn (rye) for the last time on 3.V., and the following year on 28.IV., when rye was not more than 10—15 cm high. While investigating, together with B. Siemaszko, the extent to which the fields sown with maize had been plundered by the rooks, I found that the strips of sown field adjoining the wheat, which was than 20—30 cm high, was less plundered than similar cornfields situated further away from these grain crops. Rooks do not feed in tall corn presumably:

- 1) it is difficult for the birds to move over the ground in their search for food in the soil;
- 2) they are more able to see the approach of danger when the vegetation is low;
- 3) higher corn crops made it difficult for the rooks to discover the place where such pest as, for instance, the wire-worm is feeding — the young plants die as a result of damage by this pest, whereas older and larger plants do not necessarily die when part of the plant below ground has been attacked (Csörgy 1926).

The growth of winter, and later spring corn limits the feeding area of the rooks to the root-crop fields, i.e. potatoes and beetroots. In the area in question the only root-crop extensively cultivated was potatoes. In May the freshly-planted potato fields formed a surface free from any vegetation, and it seems probable that because the earth was turned over several times (by plough, cultivator etc.) before the potatoes were planted, the macroentomofauna was very poor here. The lack of easily accessible food was probable the reason for the disappearance of the rooks from treeless fields in the period described.

Rooks left the colony after the young birds became independent at the beginning of June. Their numbers, both in this month and the first half of July showed a minimum increase. The rooks

in small groups consisting of a few birds only, fed on the potatoes and other root-crops, and after the ears formed in the grain crops, on the fringes of the fields of oats and barley. In 1955 a large flock composed of 80 birds was seen for the first time in the area examined on 19.VII.; they fed on a small pasture near the village of Dziekanów Leśny. Reaping began in 1955 on 20.VII., by 24.VII. about 75% of the winter corn (rye) between Dziekanów Leśny and Górka Dziekanowska had been cut, between Łomna and Cząstków about 25%, and between Cząstków and Czosnów reaping had only just begun. The differences in the ripening times of the corns was due to the soil (cf. Section I). Reaping began earlier on sandy soil. Between Cząstków and Czosnów the difference was further increased by the fact that wheat which predominates over rye there, ripens later. This gradual start of reaping made it easier to grasp the relation between the feeding habits of the rooks and reaping of the corn, since the rooks searched for their food in fields from which the corn had recently been reaped.

When the corn was reaped the areas which had not been visited by the rooks since April became once again accessible to them and these areas have a rich surface entomofauna in the stubble, swaths, or stooks. It can be seen from Vertse's data (1943) that a large percentage of their food is formed by the field lice of the genera *Eurygaster* and *Aelia*, which occur in large numbers in Poland (Strawiński 1956). Vertse (ibid) suggests that in addition to animal food, vegetable food also attracts the rooks — grains of corn, although my observations do not indicate that the rooks occurred more frequently on wheat stubble, the grains of which they prefer to any other corn (Rörig 1900). It would therefore seem that the decisive factor is the rich entomofauna rendered accessible when the corn is reaped. The majority of the groups of animals undergo a rapid reduction after the corn is reaped (Strawiński 1956, Tischler 1955).

In both these years the harvest was finished about 10.VIII. The rooks fed on the surface left by the ploughs in turning up the stubble, and later inploughing the ground for winter corn. Vertse (ibid) states that in September the rooks fly to the fields in great numbers after rain, and writes that this is caused by the move of the soil macrofauna to the higher layers of the

soil. In the second half of August and first half of September 1954 and 1955 on the study area was practically no rainfall. This drought was responsible for the absence of soil macrofauna in the upper layers of the soil, which was undoubtedly one of the causes of the small numbers of rooks in the fields in this period. The second cause, more important under our circumstances, is the transfer of the rooks to the freshly mown meadows (short cut grass), where they have more accessible, food (insect). An increase in the number of rooks is noticeable with the onset of rain, i.e. about the middle of September (1954 and 1955) (fig. 10).

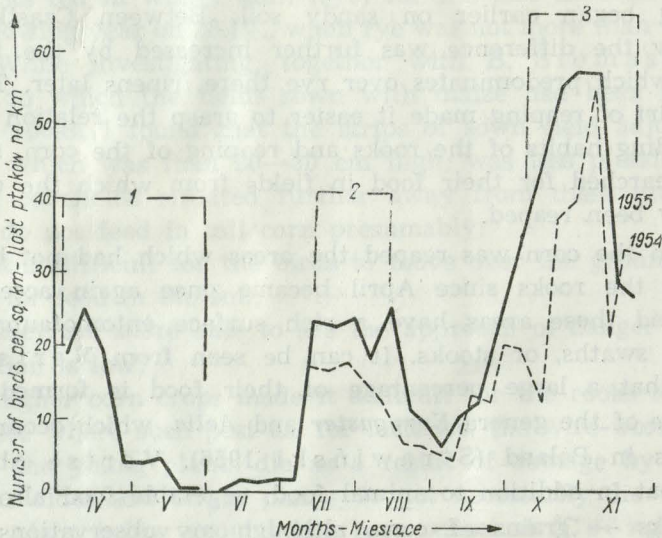


Fig. 10. Variations in numbers of rooks during the annual cycle of vegetation growth; sparsely wooded fields

1 — Nesting period; 2 — Reaping period; 3 — Migration period

Zmiany liczebności gawronów w ciągu okresu wegetacji; pola rzadko zadrzewione

1 — Okres lęgowy; 2 — Okres żniw; 3 — Okres wędrówek

They then fed chiefly on the fields from which potatoes had been lifted, followed the plough, and later fed in the fields sown with winter corn.

In both years in which observations were made (fig. 10) the numbers of rooks increased to a maximum in the second half of October. This was caused by the flight of the migrant rooks.

According to Lechmann (1924), Sutter (1948) and Waterhouse (1949) weather has a deciding influence on the increase of flights and the method of migration. Waterhouse states that on windless days, even when cloudy, members of the *Corvidae* family fly high, whereas on days when the wind is strong they fly just above the ground. For instance on 30.X.1954, when the wind was force 6, Beaufort scale, I saw a large flock of rooks flying low against the wind (on windless days it is easy to overlook birds flying very high). Apart from birds in flight, the majority of the observations refers to birds when feeding. The migrant rooks differ distinctly as to their numbers and size from the rooks observed in the previous periods. The peak period of migrant flights falls in the last days of October and beginning of November. The passage of rooks which I recorded corresponds to the data given by Waterhouse on the increase of flights in Żegań (Sagan) in the Wrocław province in 1943 and 1944.

The maximum number of passage flights took place there several days earlier (15—21.X). According to Tischler's data (1941) the maximum intensification in flights of rooks through former East Prussia also occurred most frequently in the second half of October and beginning of November. In the second half of November the numbers of the rooks decrease. With the onset of frosts the rooks scarcely feed at all in the fields, but gather near ricks and human habitations.

B. Densely wooded fields

During the hatching period III—V in 1955 the rooks occurred in very small numbers (fig. 11) in the area described, and the majority of these were birds passing through this region. The distribution of rooks along the observation route was even. The final section of this route between Łomianki Dolne (tannery) and Prochownia, runs through open fields, frequently visited by rooks through the greater part of the year. It is an interesting fact that although I encountered numerous flocks of rooks in May in the pastures by the Vistula adjoining the above fields, I did not observe these birds feeding here at this time. This again confirms the conclusion that luxuriant vegetation (corn) makes it difficult for the rooks to make use of the fields as feeding grounds in May and June.

Between Dziekanów Polski, Kielpin and the Vistula there is an extensive area of sparsely wooded meadows laid for hay. Adjacent to these are thickly wooded meadows constituting part of the densely wooded section of the area, where quantitative investigations were carried out (see fig. 1). The rooks moved from these meadows to the area investigated during hay-making time, and after its completion, often in very large flocks.

After the harvest the number of rooks increased slightly in the treeless fields between Łomianki Dolne and Prochownia. The numbers of rooks in this section of the observation route in-

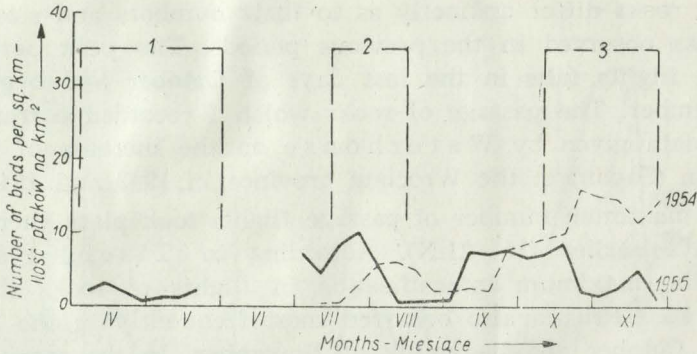


Fig. 11. Variations in numbers of rooks during the annual cycle of vegetation growth; densely wooded fields

For explanation of symbols see Fig. 10

Zmiany liczebności gawronów w ciągu okresu wegetacji; pola gęsto zadrzewione

Objaśnienie patrz Fig. 10

creased steeply in the autumn, in September. Apart from this section, in the period described the rooks seldom occurred in the densely wooded area, and then only in small numbers and mainly as birds of passage. I did not observe any autumn migration of rooks through this area of patchwork cultivation.

In 1954 from the beginning of July to the end of November the variations in the numbers of rooks were of a different type to those in 1955. Apart from the period of autumn migration, I seldom saw rooks in the densely wooded areas, and then only single birds, or small group of up to 4. The sole exception to this was the section of treeless fields between Łomianki Dolne and Prochownia, where I several times observed large groups of rooks up to 80 specimens in number. In November, that is, the final

period of the migrant flights of the rooks, large flocks (60—80 specimens) of these birds were several times observed feeding on the meadows and among the winter corn by the lake near the village of Kiełpin.

The differences between the variations in the numbers of rooks in the densely wooded area in 1954 and 1955 cannot be attributed to the differing climatic conditions in these two years, nor to any other perceptible variations, but rather prove that this area is not constantly penetrated by rooks. Apart from the river bank areas adjacent to the treeless meadows on the Dziekanów Polski side, and the fields with only small groups of trees between Łomianki Dolne and Prochownia, the rook was seldom encountered in the remaining sections of this patchwork area.

C. Banks of the Vistula (Vistula dike)

Observations were made while cycling along the flood protection dike of the Vistula which stands several metres above the level of the area surrounding it. Approximately half the observation route lay at a distance of at most 200 m from the river bank to the dike, and gave a clear view of the river bank. Throughout the other half the bank was further away, or trees reduced visibility. On the area between the Vistula river bed and the flood protection dikes there were water meadows, with patches of field in three places, and in several other places extensive riverside sand-dunes, either bare or covered with osiers. Some paths of the pasture land were densely wooded by poplars and willows, or dense thickets of blackthorn, wild rose bushes, willows and poplars.

During high water periods (about 2.5 m above level 0 on the water gauge in Warsaw) these pastures are flooded, the water reaching to the dikes themselves. In 1954 when investigations were carried out, the water level was low (apart from the spring period there had been no great rise in water level), but in 1955 the pastures were either partially or wholly flooded five times. High water level was as a rule maintained for only a few days. On the land side of the dike the area is covered by cultivated fields (corn, potatoes). Near Czosnów the fields are intersected by meadows with large numbers of copses. Also, along the line of the dike there is the Kępa Kiełpińska settlement, and several detached farms. The length of the observation route along the flood protection dike was about 14.4 km.

1) Variations in numbers of rooks in 1955. At the beginning of April the rooks fed in large numbers in the meadows and pastures near the colony at Czosnów (fig. 12). Their number was greater than that of both the neighbouring colonies and probably there were many migrant rooks among them. The pastures on the Vistula river banks were flooded at this time by the spring thaw. Rooks were observed by the Vistula for the first time on 16.IV.



Fig. 12. Variations in numbers of rooks during the annual cycle of vegetation growth; bank of Vistula

For explanation of symbols see Fig. 10

Zmiany liczebności gawronów w ciągu okresu wegetacji; brzeg Wisły
Objaśnienie patrz Fig. 10

No large numbers of rooks were observed feeding in the pastures until May; this is certainly connected to a great extent with the decrease in the area of their feeding grounds in the fields. The birds were distributed unevenly along the observation route. Their numbers clearly increased in the sections situated nearest the colonies at Czastków and Czosnów. In the areas lying between Kępa Kiełpińska and Prochownia (with the exception of those densely wooded) the rooks appeared in large numbers in the pastures in May. Flocks composed of 20 individuals were most frequently encountered there, and these were probably birds which had not yet reproduced that year. It should be emphasised that apart from the pastures by the Vistula, practically no flocks of rooks were encountered in the above period. Only three observations were made in June, and these indicate a decrease in the numbers of rooks. It is possible that this is connected with their

move to the haymaking area. In July, until reaping starts, the rooks feed in large numbers in the meadows, but with the start of reaping their numbers decrease (about 20.VII.) and are then maintained at a more or less constant level. Rooks feed chiefly in meadows with few trees. During the migration period no passage of rooks was observed, nor increase in the numbers feeding, except for one warm day, when a great many rooks fed on the late winter corn near the flood protection dike.

2) Variations in numbers of rooks in 1954. Investigations were carried out from the beginning of July to the end of November. There were many more rooks throughout this entire period than in 1955, and the variations in number were different. During the reaping period which in 1954 began before 10.VII., the number of rooks was exceedingly small, and did not increase until after the harvest at the end of August (between 10 and 26.VIII. no observations were made). Rooks were encountered, as in 1955, in the greatest numbers on the meadows between Łomianki Dolne and Prochownia. The frequent inspections made in this year along the dike as far as Młociny revealed a further increase in the numbers of rooks in the riverside pastures situated nearer Warsaw. This was primarily caused by the vicinity of the colony at Bielany, and the circumstance that this was the first large area of pastureland outside the city where the rooks from Warsaw gathered.

In the second half of September the number of rooks increased during the period of migrant flights, to reach a maximum in the last ten days of October and beginning of November. About September 20th I several times saw large numbers of rooks rooting with their beaks in the pastures near the Vistula opposite Pienków. Instances of this sort are recorded in literature (T a c z a n o w s k i 1882) and I have myself several times observed these interesting phenomena in other areas in which there was a mass appearance of beetle grubs. In the instance described, everywhere where the rooks had not already been rooting, there were several grubs in the final stage of development under each tuft of grass, just below the surface of the ground (± 5 cm).

During the migration period I observed on several occasions large flocks of rooks feeding on the winter corn growing by the river dike. I did not see the characteristic migrant flight of rooks. With the onset of frosts, and when ice floes were floating in the mainstream of the Vistula, many of the rooks searched for food

on these floes (21.XI. and 23.XI. and in specially large numbers 27.XI.).

During the hatching period the percentage of birds feeding on the banks of the Vistula is very large, greater than in the post-nesting season, whereas the reverse relations obtain in the fields (tab. III). During the nesting season the riverside pastures formed the feeding grounds of great numbers of rooks, both nesting birds and young birds which had not as yet begun to reproduce. This is also indicated by the fact that in the fields, apart from the feeding grounds of the colony, larger groups of rooks (over 20 specimens) were almost never encountered. Groups of feeding rooks, often consisting of as many as 50 individuals, were several times observed on the riverside pastures at a distance from the nesting colonies. Šedivý (1949/50) writes that during the nesting period only, birds which are not nesting fly beyond the feeding grounds of the colony, and in such case form flocks of 20—30 birds. This conclusion is further supported by the fact that in the area adjacent to the banks of the Vistula, adjoining the colony, where the rooks carrying food to the females and young ones feed, the percentage of flying birds is higher.

With the growth of vegetation and consequent decrease in the extent of the feeding grounds accessible to the rooks in the fields, the riverside pastures become an area of attraction to the rooks. In other districts not adjacent to extensive pastures, the rooks do not disappear from the fields during the nesting period, but feed on every scrap of ground where the vegetation is still low.

A very large number of works have been devoted to the variations in the numbers of rooks, but the majority is limited to an examination of the distribution and size of the nesting colonies of this species. Many authors attempt to analyse the causes deciding the distribution of these birds. They discuss the factors governing the distribution of the colony, and not the degree of utilisation of the various field environments by the rooks. Nevertheless this distribution is to a certain extent connected with the accessibility of food to the rooks during the nesting period, and on this account factors governing the distribution of the colony are not without significance to the problem engaging our attention in this work, i.e. the degree of utilisation of various field

environments by the species under investigation, at least during the nesting period.

Among factors deciding, although not always directly, the distribution of the rook colonies, should be included the geological substratum and the soil (Alexander 1933, Csörgy 1904, 1926; Lebeurier 1953, Nicholson 1930, Wynne 1932 and others). For example — in New Zealand rooks occur almost exclusively on the yellowgrey earth areas, since these are formed in a climate suitable for the growth of corn and other cultivated crops. A real connection exists therefore rather between the rook and the use to which the earth is put, than directly between the rook and the soil (Bull 1957). Csörgy (1926) points out the direct connection of the type of soil with the abundance of its invertebrate fauna forming the rooks food. In sandy soil the invertebrate fauna is poorer, and the forms common there, such as groups of may-bugs and wireworms, are only accessible to the rooks at certain periods e.g. during ploughing or when the crops are still low (not yet grown). In compact, clayey soils the basic food easily accessible to the rook, are the caterpillars of *Agrotis* sp. Csörgy concludes that clayey soils are capable of feeding far more rooks than sandy soils. Catuneanu (1953) writes that the rooks avoid soils which become very hard in the summer, such as in southern countries. If, in accordance with Csörgy's data, the type of soil influences the numbers of rooks, the quality of the soil, through the entomofauna specific to it, should also influence the degree of penetration by the rooks of the various field environments over the course of the year.

Comparison of types of soil with the distribution of the rooks in the area examined during the hours of intensive feeding (morning), at various times of the year, revealed no correlation either in the densely wooded fields, or the areas situated close to the Vistula (observations made from flood protection dikes). It was even found that the sandier areas such as the treeless stretch of fields between Prochownia and Łomianki Dolne, were often visited by rooks. In the open fields during the nesting period the feeding grounds of the colonies at Czoznów and Cząstków correspond to the area of most fertile soils in the district examined — clayey-pulverous sands. Possibly, therefore, in accordance with Csörgy's data, the most fertile, clayey soils provide better feeding conditions for the rooks, or possibly this is merely the

effect of the vicinity of the colonies, the location of which may in turn be the result of the character of the soil surrounding it. In this same period the rooks from these colonies feeding in the fields or pastures near the Vistula do not exhibit a dependence on the type of soil. The soil often has a distinct influence on the distribution of rooks in an indirect way, i.e. through the vegetation mantle. The composition of the crops under cultivation and their vegetation period varies according to the type of soil, e.g. in the area examined reaping of crops on sandier soil began almost two weeks earlier than in the case of more clayey soils, which had a decisive influence on the distribution of rooks in this period.

The majority of authors analysing the distribution of nesting colonies, emphasise their large degree of dependence on the proximity of rivers, or rather on river valleys with riverside meadows and pastures (Cramp and Ward 1936; Vertse 1943; Wynne 1932). Certain authors, such as Cramp and Ward (1936) who examined the distribution of colonies in the Manchester district (England) state most distinctly that river valleys without extensive riverside meadows do not bring about concentration of rook colonies. The attraction is therefore not the proximity of water, but of suitable feeding grounds. The situation is different, however, in Hungary, where during a period of drought river valleys ensure constant accessibility of food. According to Vertse, during the summer period, especially after the harvest, the soil entomofauna retires deeper into the soil on account of drought and so becomes inaccessible to the rooks. The birds then feed in the river valleys or move to higher-lying ground where rains are more numerous.

The same probably happened in the study area in the second half of the summer (VIII.—IX.) in 1954 and 1955, when the numbers of rooks in open fields decreased during the period of drought. As can be seen from the description of subsoil water distribution in this area, the open fields, and especially those sections through which the observation route ran, were distinguished by the lowest level of subsoil water (3 m)⁶. Apart from this no more distinct correlation was found between the degree of soil moisture content in the area and the distribution of the rooks. Meteorological conditions during the warm period of the year had a distinct effect

⁶. Material for maps of subsoil water within the Warsaw City Area, collected by the Physiographic Town Planning Office. Warsaw 1957.

on the 24-hour cycle of the rooks (on cloudy days they remained longer on their feeding grounds) but they were not found to exert a basic influence on the distribution of the rooks in the morning hours. In early spring (III), and especially late autumn (XI), a greater degree of frost causes fundamental changes in the distribution of the rooks. They cease to feed in the fields, and gather round stacks of corn, buildings or river banks.

The most important factor governing the degree of utilisation of various environments over the period of a year, at least as far as the area examined is concerned, is the state of the plant vegetation mantle. The rook obtains $\frac{4}{5}$ of its food from below the surface of the ground (Lockie 1955, 1956 and Vertse 1943), and on this account luxuriant plant growth makes it difficult for them to obtain food. I have described this in detail in the preceding section. Technical agrarian operations such haymaking and reaping cause the rooks to move from one area to another over the period of a year.

III. GROUP PHENOMENA IN ROOK POPULATIONS

1. MEANS OF COMMUNICATION BETWEEN ROOKS AND JACKDAWS RESPECTIVELY

The biological significance of various kinds of sounds made by jackdaws is already comparatively well known (Lorenz 1931) but far less is known of the sounds made by rooks (Gramet 1956b, Strauss 1939). I know of no investigations on the frequency of sounds made by these species while feeding.

In this work I have endeavoured to investigate numerically the role of sounds in the contacts between rooks and between jackdaws when feeding. In an attempt to solve this problem Raszewski and I carried out special observations in July and August 1956. We observed the groups of members of the *Corvidae* family, consisting of jackdaws and rooks, or of only one of these species, often with the addition of one or more hooded crows. Examinations were made during morning hours in "open fields" and on the Vistula dike. We did not make observations in the fields with dense clumps and belts of trees, since despite frequent inspections no other species of the *Corvidae* family, apart from the crow, was encountered there. During our observations we noted weather conditions, the exact or approximate numbers of

birds of each species etc. Taking the work of Lorenz (1931) and Strauss (1939) as a basis, an attempt was made to distinguish between the sounds made by the species examined and then link them up with the situations which they accompanied. To facilitate a quantitative analysis of the question, we divided our material, in the same way as in the similar work by Lockie (1956a) into units of time ("samples"). One "sample" lasted for 3 minutes, and if the birds were silent during this time, then the sample was classed as "silent", and if they uttered sounds, the samples was classed as "sound"⁷. These observations covered a total period of 20 hours. No observations made when a strong wind was blowing (over force 4—5, Beaufort scale) or while rain was falling, were included in the quantitative analysis.

In order to analyse the connection between the sound uttered and the behaviour of the rook and jackdaw with which we were concerned, the material obtained was divided into groups as follows: birds feeding, birds starting up in flight, birds flying down to join the feeding flock, and finally those flying over the flock.

Feeding rooks just as often uttered sounds as maintained silence, they most often uttered sounds when starting up in flight, when sitting, and especially when joining the feeding flock, and also individuals flying over the flock often caw (tab. I). Dalmon (1932) mentions the silence of rooks while feeding. Contrary to the habits of the rook, jackdaws rarely feed in silence.

Gramet (in litt.) writes that when a tape recording was made of the sounds emitted by the *Corvidae* family it was possible under certain circumstances to cause birds hitherto invisible and coming from a distance (even of several km) to gather in the place where the tape was played back. Our experiments, to which I referred above, also confirm that birds at a distance of 1 km or more react to a warning cry, e.g. of a crow. It may often happen, however, that groups of birds of the *Corvidae* family at a greater distance react, not to the warning cry of a bird, but to the sight or sounds of birds closer to them.

⁷ Both the sounds made by the rook and maximum sensitivity of hearing of this species, and of the jackdaw and carrion crow, come within the limits of frequency audible to man (Gramet 1956b, Vallencien et al. 1955). It may therefore be concluded from these works that we hear the majority of the sounds uttered by these birds.

The role of acoustic contacts when the "alarm" is given in the case of the rook, jackdaw and crow, is easily perceptible by the observers. An exchange of sounds between birds at some distance from each other is seldom observed amongst feeding rooks, whereas this is often encountered in the case of jackdaws. Rooks often utter cries when they fly down to join the feeding flock, and this utterance has therefore for this bird a significance other than finding the feeding birds. For the other birds in the vicinity the voice of the rook, or exchange of sounds between it and the feeding flock may be a factor indicating the presence of this flock. Sounds uttered by birds in flight or starting up singly from the flock play a similar part. Sounds uttered by the flock as it starts up in flight and often, later, as it scatters, are of less significance to the rooks as an indicator of the site of plentiful food.

It has been stated in this work that rooks utter sounds less frequently during feeding than is the case with jackdaws. Rooks utter sounds as frequently as jackdaws when flying down to join the feeding flock, flying over it etc. No definite finding has been reached as to which form of contact predominates amongst the rooks while feeding — sight or hearing.

It has not been found possible in this work to prove active co-operation between birds of the species examined during their search for food, expressed in special forms of flight, cries etc.

2. SEASONAL VARIATIONS IN FORM OF FLOCKS OF ROOKS

The form of occurrence of rooks so as forms of the majority of social animals, changes over the course of the year, in relation to the sex cycle, migration and food factors. The rook also exhibits distinct variations in the form of flocking over the period of 24 hours. The variations analysed here in flock formations of rooks over the course of a year refer only to their form of occurrence in morning hours, i.e. during intensive feeding.

In the open fields in the spring period on only a few occasions were flocks of rooks exceeding 20 specimens in number (fig. 13) observed, and then almost solely in the vicinity of the colony. In the period preceding reaping (June, beginning of July) rooks occurred in the fields in very small numbers only, and usually as scattered individuals. Later groups of 3 do 20 specimens are increasingly frequently encountered. Flocks of over 20 rooks appeared exactly as reaping begins. After the harvest large flocks

Frequency of sounds uttered by rooks and jackdaws

/Different in acoustic activity of rooks and jackdaws feeding and joining the flock,
flying over the flock, starting up in flight/

Częstość wydawania głosów przez gawrony i kawki

/Różnica w aktywności akustycznej gawronów i kawek żerujących a przyłączających się do stada,
przelatujących nad nim, zrywających się/

Tab. I

		Numbers of samples Ilość prób /n/	% of samples (3 min.) in which birds: Udział 3 min. prób w %, w których ptaki:		$\frac{ P_m - P_o }{n}^1$ G
			were silent milczały /P _m /	uttered sounds odzywały się /P _o /	
Rook - Gawron	Feeding /P ₁ / Żerujące	146	57,1	42,9	2,45
	Flying, starting up in flight, etc. /P ₂ / Przelatujące, zrywające się etc.	105	16,4	83,6	12,75
	$\frac{ P_1 - P_2 }{n}^1$ G		7,13	7,13	

Jackdaw - Kawka	Feeding /P ₁ / Żerujące	115	25,6	74,4	10,17
	Flying, starting up in flight, etc. /P ₂ / Przelatujące, zrywające się etc.	134	31,3	68,7	6,61
	$\frac{ P_1 - P_2 }{s}$ ¹		1,00	1,17	

¹ Reality of difference of two percents are defined by the following criterion: when the expression $\frac{|P_1 - P_2|}{s} \geq 3$ the difference is real, with reverse inequality difference varies within limits of accident. In this expression P₁ and P₂ are percentages, and s standard of their difference.

Istotę różnicy dwóch udziałów określamy za pomocą następującego kryterium: gdy wyrażenie $\frac{|P_1 - P_2|}{s} \geq 3$ różnica jest istotna, przy odwrotnej nierówności różnica waha się w granicach przypadku.

W wyrażeniu tym P₁ i P₂ są udziałami, a s jest standardem ich różnicy.

are more seldom encountered, the majority of the birds occurring in flocks of medium size. It is not until the migration period that the groups of rooks again increased in numbers and attain maximum size.

In densely wooded fields in the spring birds were most frequently encountered in ones or twos, or a few larger groups coming within the 3—20 individuals class (fig. 14). During the reaping period, in addition to the above classes of groups, flocks of over 20 individuals occurred. In the autumn sowing period a relatively large number of birds occurred singly, or in twos, and in medium-sized groups. There were practically no rooks to be seen during the migration period. The flock dynamics in 1955 were as above. In the preceding year in the second half of the summer and in the autumn when observations were made, the picture of the variations in groupings was similar to that of 1955, but during the migration period large migratory flocks were observed in this area.

On the banks of the Vistula in the spring period of 1955, in addition to the large number of medium sized groups there and birds occurring singly or in pairs, there were also large flocks of rooks probably composed of birds not yet reproducing, which were hatched the previous year (fig. 15). In the summer period a very large number of birds occurred in this area in small flocks, singly or in pairs. There are fewer large groups here during this period than in the open fields. Even during the autumn migration flights, contrary to the situation in the open fields, the majority of the rooks encountered occurred in medium-sized groups. Similar relations were observed the previous year, but there were then, however, far more large groups of birds.

From the data given above we can see that a relatively large number of birds occurred singly or in pairs during the period the birds were sitting on the eggs, or feeding the fledgelings (second half of April, May). As the female birds are then fed by the males, and later the young by their parents, the birds bringing food behave to a large extent independently of others. The increase in the flock formations of rooks during the autumn migration flight periods is also characteristic.

The most important phenomenon is the great difference between the flock formation of the rooks in sparsely and densely wooded fields. In the densely wooded area rooks practically never

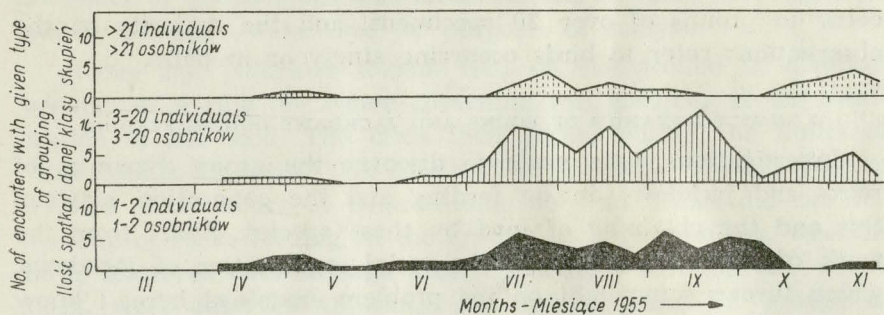


Fig. 13. Seasonal variations in form of flocks of rooks; sparsely wooded fields

Sezonowe zmiany wielkości skupień gawronów; pola rzadko zadrzewione

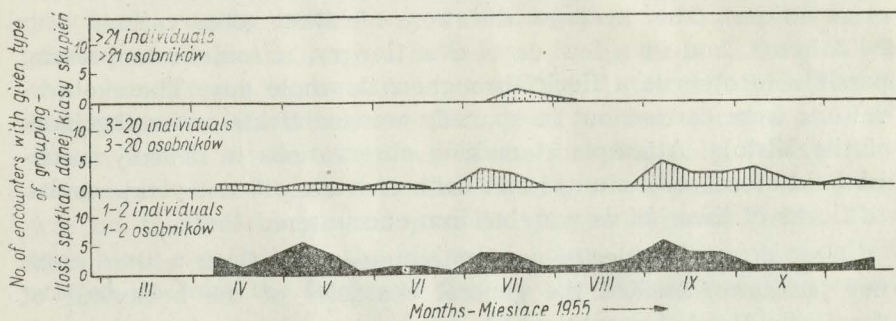


Fig. 14. Seasonal variations in form of flocks of rooks; densely wooded fields

Sezonowe zmiany wielkości skupień gawronów; pola gęsto zadrzewione

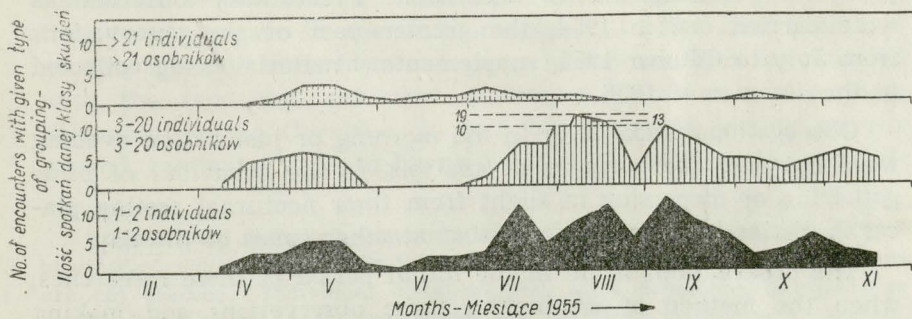


Fig. 15. Seasonal variations in form of flocks of rooks; bank of Vistula

Sezonowe zmiany wielkości skupień gawronów; brzeg Wisły

occur in groups of over 20 specimens, and the majority of the observations refer to birds occurring singly or in pairs.

3. GROUP DYNAMICS OF ROOKS AND JACKDAWS DURING FEEDING

Investigations were made to discover the group dynamics of rooks and jackdaws during feeding and the connection between this and the obtaining of food by these species. Apart from the work of Lorenz (1931) on the social organisation of jackdaws, which throws some light on the problem examined here, I know of no work on the group dynamics of these species while feeding.

The method used for the investigations was to observe for the longest possible time the behaviour of one group of birds of the *Corvidae* family. The observer watched the flock, and in case of need followed it up on his bicycle in order to continue his observations. The average duration of these observations was 2—3 hours, and in a few cases even longer, it sometimes proving possible to observe a flock throughout a whole day. These observations were carried out in sparsely wooded fields or on the bank of the Vistula. Attempts at making observations in densely wooded field areas, with clumps and belts of trees, did not yield results, as flocks of these birds were seldom encountered there.

Most often the species predominating in the flock, either rooks nor jackdaws, decided the general character of the behaviour of the flock. Hooded crows, which occurred singly, or in very small numbers, in the flock, only exceptionally influenced the behaviour of the whole group. The observations as a whole were therefore divided into two groups depending on whether rooks or jackdaws predominated in the flock. Preliminary observations were carried out in 1954, the greater part of the observations from July to October 1955, supplementary material being collected in the summer of 1956.

Observations made early in the morning or just before evening were not used for purposes of analysis, as the behaviour of birds gathering or dispersing in flight from their nocturnal resting places is distinctly different from that at other times of the day.

The observations made in the initial period of these researches, when the method of conducting these observations and making notes was still being worked out, and observations made under extreme weather conditions, were omitted altogether. A total of

97 hours of observations was obtained, and of these only approximately 50 hours were used for purposes of analysis.

Rooks and jackdaws seldom feed on the ground in compact groups. As a rule the factor governing this grouping is the localisation of the food. The birds then gather within the limits of "individual distances" (Conder 1949, Lockie 1956a)⁸. During a total of 26 hours of observations, only six times did we see a group of rooks feeding on the ground in large numbers, whereas birds scattered over a large area, but clearly forming one whole flock, were observed 18 times. Analogical figures for groups of jackdaws (or groups in which jackdaws were in the majority) are respectively 4 and 22. Rooks in these scattered flocks are distributed more or less evenly over the area in question. Jackdaws most often form distinct groups, which keep in contact by sound, and often fly from one group to another. I saw both rooks and jackdaws crossing in this way at distances of several hundred or more metres, in the form of a belt of flying birds. I have called this phenomenon "an avalanche cross-flight" (tab. II). Such flights happen most often where one flock joins another situated at a distance, and as a rule take place in one direction only. I have very often seen such flights near the Vistula, when part of the flock was on the river bank and part fed in the adjacent fields. This took place especially in the afternoon hours. Individual birds often started up from the flock and flew to the Vistula and vice versa.

Most often the flock of rooks, after starting up in flight, scatters, to re-group in a new feeding place (tab. II). During the feeding period the flock rarely maintains a static form for long. Birds from the flock flew off in small groups or singly over an area sometimes several km. in diameter, to return again after a certain time to congregate in one or more places. I often saw flights of groups, or single birds from one group to another. This is connected with the tendency, exhibited by many birds, especially those belonging to the *Corvidae*, to join birds already sitting on the ground, motivated (acc. to Lorenz 1931) in addition to "sociabil-

⁸ "Individual distance" — an area particular to each bird, without distinct boundaries, which moves with the bird, and within which other individuals are not allowed. "Individual distance" may alter depending on the time of year, or the individual approaching, e.g. the bird's mate, young ones etc. (Conder 1949).

Behaviour of birds during feeding period

/number of observations of given type of behaviour during whole period of observations/

Zachowanie się ptaków w okresie żerowania

/ilość spostrzeżeń danego typu zachowania się w czasie całego okresu obserwacji/

Tab. II

Flock of one species or with distinct predomination of one species Stado jednogatunkowe lub z wyraźną przewagą jednego gatunku	No. of hours of observations Ilość godzin obserwacji	No. of times observed Ilość spostrzeżeń	"Avalanche" flight over distance of several hundred m Przelatują "lawinowo" na odległość kilkaset m P_1	Congregation and dispersion Skupiają się i rozpraszają P_2	Flock maintains compact form Stado zachowuje zwartość P_3	$P_2 - P_3$ ¹ 6
Rook Gawron	26	51	11,76 %	80,40 %	7,84 %	10,85
Jackdaw Kawka	23,30	73	13,70 %	45,20 %	41,10 %	0,51

¹ For explanation of symbols see Tab. I

Objaśnienie patrz Tab. I

ity", to an important degree by a "feeling of safety". The fact that the flock of rooks scatters after starting up in flight indicates that the "sociability" referred to above does not continue in the flock after rising from the ground. Other factors come into play here. Observations of birds congregating in, for instance, pastures, or freshly mown meadows etc. clearly indicates the role of the first birds sitting on the grounds as elements attracting the other rooks in the vicinity. The fact that this type of grouping and dispersion occurs during the period of intensive feeding by the rooks and that birds flying down to join them also begin feeding, indicates the role of this type of behaviour when searching for suitable feeding places. Scattered rooks, occurring in small groups, are capable of penetrating a larger area than when in a flock. It is sufficient for one bird or group to find a place where food is plentiful, to attract all the birds in the immediate vicinity there. It is a form of passive cooperation in searching for food⁹. To become aware of the site of a plentiful food supply by observing the behaviour of other birds is a common phenomenon in this group of animals (Rand 1954). In the case of many species of birds we know of some complicated form of active co-operation, e.g. the herring gull (Frings et al. 1955).

A group of rooks starting up in flight only maintains its compact form in certain definite circumstances, e.g. after a cry of fear has been uttered by one of the members. This phenomenon occurs both in flocks composed of rooks and of jackdaws. In 1956 Raszewski and I carried out two experiments concerning this problem. By inducing young rooks held in the hand to squawk, I evoked a warning cry from the hooded crows in flight overhead. The second person observed the behaviour of birds of

⁹ By "passive co-operation" I mean co-operation within the limits of which one bird finds, for example, food by observing the behaviour of other birds. In "passive co-operation" we do not perceive in the behaviour of the bird acting as "indicator" anything which extends beyond its own individual interests, i.e. it indicates the site of the food completely passively.

By "active or operative co-operation" I mean co-operation in which the "indicator" bird utters special cries or adopts a special method of behaviour, e.g. characteristic flight, the sole significance of which is a signal to the other birds in the vicinity (e.g. domestic cock which calls the hens by a characteristic sound when finding food; warning sounds made by several species of birds).

the *Corvidae* family in the fields. All the birds belonging to this family within a radius of two km rose suddenly from the fields and massed in one group, which flew over my head. Gramet (1956 a, b) has recently dealt with this problem in detail.

It was clear from my data (fig. 16) that during the post-nesting period birds in sparsely wooded field areas flew in small groups or singly, and most often fed in large flocks. Birds sitting in trees occurred singly or in small groups. It will be seen from these data that the flocks of birds must have dispersed after starting up in flight, to gather again later. This material confirms the description

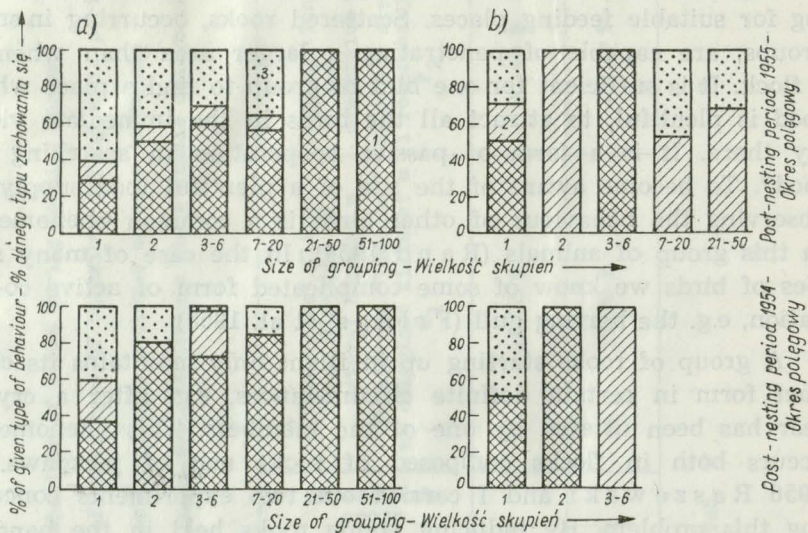


Fig. 16. Connection between behaviour of rooks and size of their groups; fields a) Fields with trees growing more sparsely than 200 m; b) Fields with trees growing more densely than 200 m; 1 — Birds feeding (on the ground); 2 — Birds sitting in trees; 3 — Birds flying

Związek między zachowaniem się gawronów a wielkością ich skupień; pola a) Pola o zadrzewieniach rozmieszczonych rzadziej niż co 200 m; b) Pola o zadrzewieniach rozmieszczonych gęściej niż co 200 m; 1 — Ptaki żerujące (znajdujące się na ziemi); 2 — Ptaki siedzące na drzewach; 3 — Ptaki przelatujące

previously given of the way in which the birds feed, consisting in surveying the area by flying over it in small groups or singly, and gathering in large flocks in places where food is abundant. During the post-nesting period, however, in the densely wooded area the birds fed singly or in very small groups, and sat in the trees or flew in large or small groups (fig. 16). These data indicate that in

densely wooded areas was no pulsation of the grouping of rooks (congregation and dispersion) as there is in sparsely wooded areas. In the hatching period in these fields also the rooks fed singly or in small groups, which is connected with the fact that the birds are either sitting on the eggs or feeding the nestlings.

On the bank of the Vistula, both during the nesting and the post-nesting periods, I found a distinct pulsation of grouping. The

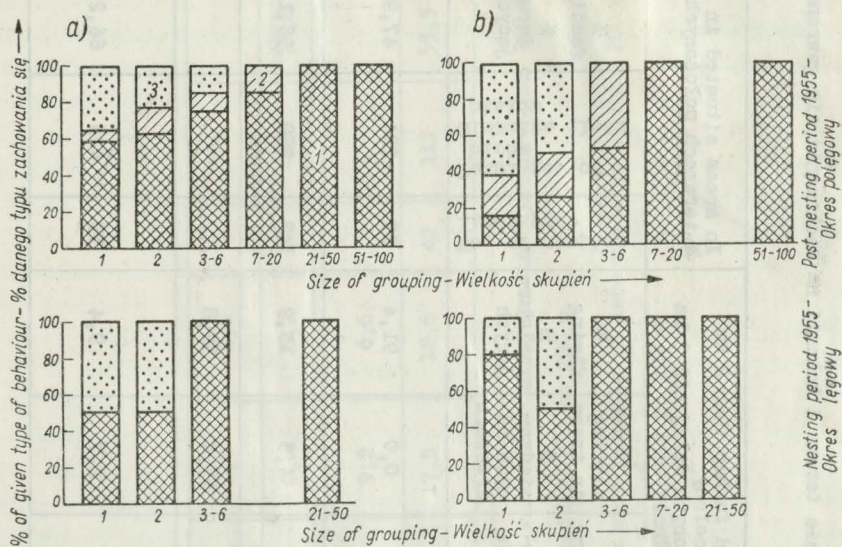


Fig. 17. Connection between behaviour of rooks and size of their groups; bank of Vistula

a) Bank of Vistula with trees growing more sparsely than every 200 m; b) Bank of Vistula with trees growing more densely than every 200 m;

For explanation of symbols see fig. 16

Związek między zachowaniem się gawronów a wielkością ich skupień; brzeg Wisły

a) Brzeg Wisły o zadrzewieniach rozmieszczonych rzadziej niż co 200 m; b) Brzeg Wisły o zadrzewieniach rozmieszczonych gęściej niż co 200 m;

Objaśnienie patrz fig. 16

rooks searched for food singly or in small groups, and collected in numbers in places where food was abundant (fig. 17).

In general it was found that over 80% of the rooks encountered over the entire area of sparsely and fairly densely wooded fields at a distance from the colonies were feeding, whereas in the very densely wooded fields in 1955 there were very few birds feeding — only 9.8%. This difference is statistically significant.

Influence of the degree to which area is wooded and of nesting colonies on the behaviour of the rooks

Wpływ stopnia zadrzewienia terenu i kolonii na zachowanie się gawronów

Tab. III

Area - Teren	Period Okres	Degree of den- sity of trees Stopień zagęsz- czenia zadrze- wien	In areas situated further than 2 km from colony W terenach położonych dalej niż 2 km od kolonii					In areas situated in vicinity of colony W terenach położonych w pobliżu kolonii				
			No. of samples Ilość prób	Total no. of birds Globalna ilość ptaków	% feeding % żeru- jących	% sitting in trees % siedzą- cych na drzewach	% flying % przelatu- jących	No. of samples Ilość prób	Total no. of birds Globalna ilość ptaków	% feeding % żeru- jących	% sitting in trees % siedzą- cych na drzewach	% flying % przela- tują- cych
Fields - Pola	Nesting 1955 Lęgowy 1955	Z ₁ ¹	162	81	8,6	0,0	91,4	39	294	47,9	0,0	52,1
	Post- nesting 1955 Polegowy 1955	Z ₁	224	851	81,6	4,5	13,9	48	260	56,1	0,0	43,8
		Z ₂ ²	112	122	9,8	57,4	32,8					
	Post- nesting 1954 Polegowy 1954	Z ₁	225	365	87,9	2,7	9,4	39	423	66,2	10,8	23,2

Vistula bank Erzeg Wiszy	Nesting 1955	Z ₁	99	114	97,4	0,0	2,6					
	Lęgowy 1955	Z ₂	69	94	96,6	0,0	3,2	24	60	76,6	1,7	21,7
	Post- nesting 1955	Z ₁	156	360	84,2	9,2	6,6					
	Polegowy 1955	Z ₂	99	114	71,9	17,5	10,6	42	117	55,5	0,0	44,4

- ¹ Fields in which trees or clumps of trees were situated at greater distance than 200 m apart
Pola o zadrzewieniach rozmieszczonych rzadziej niż co 200 m
- ² Fields in which trees or clumps of trees were situated at lesser distances than 200 m apart
Pola o zadrzewieniach rozmieszczonych gęściej niż co 200 m

In 1954 despite the large number of "samples" made in the very densely wooded area, so few rooks were seen that it was impossible to calculate the percentages of their various types of behaviour in this area. On the other hand on the bank of the Vistula this same difference is statistically untrue, although the percentage of birds feeding in the sparsely and fairly densely wooded areas is larger (84%) than in the very densely wooded area (72%) (tab. III).

In this work it was found that in the densely wooded fields the number of rooks during the feeding period is several times less than in the sparsely wooded fields. Apart from the stand of trees and other factors in this environment, such as soil and the moisture content of the soil, the crops cultivated here etc. should influence the increase in the numbers of rooks in this area. According to many authors, e.g. Catuneanu (1953), Csörgy (1926), Vertse (1943) rooks avoid dry and sandy areas, and pastures attract these birds almost the entire year, just as meadows do during the periods when their vegetation mantle is still low. Beet-roots, barley, oats and wheat are crops attractive to the rook.

It is also found that rooks exhibit passive co-operation when feeding. They search for food singly, or in small groups, and gather in places where food is abundant, using the behaviour of other birds as indicators of its localisation. Pulsation of gatherings of this kind were found to take place only in sparsely wooded fields. Pulsation of gathering is absent in densely wooded areas, and the percentage of birds feeding there is very small. Flocks consisting of over five individuals were only observed in this area four times from a total of 286 "samples". They were observed during the haymowing period only in the area adjoining a large stretch of treeless meadows. The flock feeding here came within the limits of the wooded area.

Gatherings of rooks in wooded areas was confirmed in the fenced pastures near Czosnów in which cattle spent the greater part of the day. This type of pasture is a great attraction to the rooks, which find here a constant and abundant food supply (large quantity of manure).

Densely wooded field areas make it difficult for the rooks to gather in places where food is abundant. Only where food is constantly plentiful in one and the same place, i.e. where the problem of finding food does not arise, do rooks gather independently of

the degree to which the area is wooded. This is confirmed by the facts that in the afternoon hours or at a different time of day when the rooks are not feeding, we do not observe the pulsation of gatherings characteristic of this bird, nor avoidance of wooded areas. They then as a rule occur in large flocks (Dobrowolski 1959, my own observations).

On the riverside areas of the Vistula there are no variations in the numbers of rooks or in their behaviour in sparsely or densely wooded areas. Pulsation of gatherings took place throughout the area regardless of the amount of trees there. Rooks feeding in the vicinity of the river bank are visible from a great distance when observed from the mainstream. The birds were most often so distributed while feeding that part of them were on the pastures, or even in the fields, and part on the very bank of the river. In effect at least part of the flock was always visible. In addition, owing to the distinct localisation of the most attractive feeding grounds, i.e. pastures in a narrow belt alongside the Vistula, contact between individuals feeding in this area was far easier than in extensive fields. Data from this area confirms the role of "passive co-operation" during the search for food by the birds of the species under discussion.

The biological significance under natural conditions of hierarchy, leadership, nesting colonies, flocks as a protection against attack by predators and territorialism still evokes lively discussion, and is not always clearly understandable (Allee 1951, 1952, Darling 1952a, b, Fisher 1954, Hinde 1956, Kalela 1954 a, b and many others). The influence of the above structures within the population on the numbers of the bird and mammals populations under natural conditions is little known, and few research workers have hitherto examined this question. Apart from the work by Kluyver (1957) describing the mechanism of the influence of sexual domination on survival, I know of other works (Chitty 1952, Davis 1949, Errington 1943, 1946, 1951, 1954, Errington and Hamerston 1936, Kluyver and Tinbergen 1953, Southern and Morley 1950) but these are mainly attempts at explaining the variations in the population numbers in the natural environment its organization.

The biological significance of cooperation between birds in searching for food is in general incontestable. However, although descriptions have been given of various forms of co-operation be-

tween birds when searching for food (Frings et al. 1955, Hickling 1957, Rand 1954 and others) I know of no works examining the influence of a definite form of co-operation on the numbers of the bird population in a given environment.

On the basis of the material presented in this work we may at least put forward the hypothesis that the difficulties the rooks encounter as regards carrying out "passive cooperation" when searching for food in densely wooded areas may produce a decrease in the numbers of birds of this species during the hours of intensive feeding in densely wooded areas. We are therefore concerned with the influence of group phenomena on the numbers of population in a given environment.

1. The rookery influence the distribution of the rooks during the hours of intensive feeding both in the spring nesting period and in the autumn period.

2. The numbers of rooks in various field environments during the hours of intensive feeding, depends on the accessibility of food, and this in turn depends in the first place on the vegetation mantle, density of distribution of clumps of trees or belts of trees, and the degree of development of crops etc. (e.g. corn).

3. The numbers of rooks (during the period of intensive feeding) are greater in sparsely wooded fields than in those densely wooded and altogether the percentage of feeding rooks (of the total number of birds studied) is greater in sparsely than in densely wooded fields).

4. Rooks utter sounds while feeding far less frequently than jackdaws, but call as frequently as jackdaws when settling down amongst the feeding flock, flying over it etc.

5. During the post-nesting period the rooks feed flocks, which searching for food disperse over a wide area, to gather again on the site of an abundant food supply. This type of behaviour exhibited by rooks in fields was only found to exist in area in which small numbers of trees grew, and which were characterised by good visibility. On the banks of the Vistula the grouping pulsation described also took place in densely wooded areas.

6. In fields with closely located clumps and belts of trees the rooks when feeding hardly ever occurred in groups consisting of more than five individuals, whereas in treeless field areas large flocks frequently occurred.

7. The hypothesis is put forward that dense stands of trees which make "passive co-operation" difficult during the search for food may influence the decrease in the number of birds of this species in such area during the hours of intensive feeding.

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CZYNNIKI WPŁYWAJĄCE NA LICZEBNOŚĆ GAWRONÓW
(*CORVUS FRUGILEGUS FRUGILEGUS* L.)
W RÓŻNYCH ŚRODOWISKACH POLNYCH

Streszczenie

Materiały do niniejszej pracy zbierano pod Warszawą, na obszarze położonym między Wisłą a skrajem Puszczy Kampinoskiej, poczynając od miejscowości Prochownia do wsi Czosnów (fig. 1). Badany teren zajęty jest przez pola i pastwiska. Pastwiska zajmują jedynie wilgotne tereny, leżące między wsiami Czosnów i Czastków a wałami wiślanymi oraz obszary między wsiami Dziekanów Polski i Kiełpin a Kępą Kiełpińską. Zadrzewienia śródpolne, kępy i pasy drzew są rozmieszczone gęsto na tarasie I, brak ich zaś na tarasie II (fig. 1, 2, 3).

Obserwacje prowadzono z roweru, jadąc z szybkością 7—10 km na godzinę, obejmując wzrokiem pas obserwacyjny szerokości 400 m (po 200 m z każdej strony trasy). Uzyskany materiał dzielono na próby (1 próba — obserwacje przeprowadzone na trasie długości 600 m). W latach 1954 i 1955 zebrano 2667 prób i przejechano w ramach badań ilościowych 1600 km, zaobserwowano 9980 okazów gawronów. Prócz tego od 1954 do 1957 r. przeprowadzono badania

nad zachowaniem się stad gawronów w czasie żerowania, w koloniach lęgowych i w miejscach noclegu.

Stwierdzono, że w okresie polegowym, poza zasięgiem wpływu kolonii, tj. co najmniej w odległości 2 km, liczebność gawronów na polach gęsto zadrzewionych (kępy, pasy drzew rozmieszczone gęściej niż co 500 m) jest kilkakrotnie mniejsza niż na polach rzadko zadrzewionych (kępy, pasy drzew rozmieszczone rzadziej niż co 500 m) (fig. 4).

Kolonia lęgowa zarówno w okresie lęgowym jak i polegowym (jesień) wpływa wyraźnie na rozmieszczenie gawronów w godzinach ich intensywnego żerowania (fig. 5, 6, 8, 9). Nie stwierdzono natomiast wpływu miejsca noclegu gawronów na ich rozmieszczenie w tym czasie.

Zbadano dynamikę liczebności gawronów na polach bez zadrzewień, na polach o gęsto rozmieszczonych zadrzewieniach oraz na terenach przybrzeżnych Wisły. Najistotniejszym czynnikiem, warunkującym zmiany ilościowe gawronów w godzinach rannych na polach, przynajmniej w okresie badanym, jest stan roślinności zielonej. Bujna roślinność, np. zboże wysokości 15 cm, utrudnia gawronom żerowanie.

Stwierdzono, że gawrony w czasie żerowania odzywają się o wiele rzadziej niż kawki. Równie często jak kawki odzywają się gawrony przy dosiadanu do żerującego stada, przelatywaniu nad nim itp. (tab. I). Nie rozstrzygnięto, jaka forma kontaktu przeważa u gawronów — wzrok czy słuch.

Gawrony wykazują wyraźne zmiany stadowości w cyklu rocznym. Analizowane tutaj zmiany dotyczą tylko formy występowania ich w godzinach rannych, tj. w okresie intensywnego żerowania. W czasie lęgowym stada liczące powyżej 20 sztuk prawie nie występowały na polach, częściej spotykano je nad brzegiem Wisły (fig. 13, 14, 15). Charakterystyczny jest wzrost stadowości gawronów w okresie jesiennych przelotów. Najbardziej znamienne jest tutaj różnica w stadowości gawronów na terenie polnym, rzadziej i gęsto zadrzewionym.

Stwierdzono, że gawrony w okresie żerowania wykazują pulację skupień (tab. II); pojedynczo lub w małych grupach mogą spenetrować większy teren, niż skupione w stadzie. Wystarczy, że jeden ptak lub grupa znajdzie pokarm, aby ścigały tam wszystkie

ptaki w okolicy. Jest to forma „biernej kooperacji” przy wyszukiwaniu pokarmu (fig. 16,17).

W terenie polnym, gęsto zadrzewionym, brak pulsacji skupień (fig. 15), a udział procentowy ptaków żerujących jest bardzo mały (tab. III). Obszar polny, gęsto zadrzewiony, utrudnia gawronom skupianie się w miejscach nagromadzenia pokarmu. Tylko wtedy, gdy pokarm stale występuje obficie, tj. gdy odpada problem jego wyszukania, gawrony skupiają się niezależnie od stopnia zadrzewienia terenu. Potwierdza to także fakt, że gdy gawrony nie żerują, nie obserwujemy charakterystycznej dla nich pulsacji skupień i unikania zadrzewień. Z reguły występują one wtedy w większych stadach.

Na podstawie materiału przedstawionego w niniejszej pracy, możemy postawić hipotezę, że teren gęsto zadrzewiony, utrudniająca gawronom „bierną kooperację” przy wyszukiwaniu pokarmu, może wpływać na spadek ich liczebności na tych obszarach w godzinach intensywnego żerowania. Mamy tu do czynienia z wpływem zjawiska grupowego na liczebność populacji w danym środowisku.