ECOLOGY OF A MARGINAL CARRION CROW POPULATION
I. — DISTRIBUTION AND ABUNDANCE

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Although the Carrion Crow *Corvus c. corone* has been reported to be present in Camargue since the late 19th century (Clarke, 1898 ; Glegg, 1931 ; Hess, 1933 ; Oordt & van et Tjittes, 1933), population density has always been much lower than in other regions (Pinowski & Wasilewski, 1962 ; Kalchreuter, 1971 ; Loman, 1980 ; Möller, 1983). Since 1975 however numbers of the Carrion Crow, along with those of two other corvids, the Magpie *Pica pica* and the Jackdaw *Corvus monedula* have greatly increased in the Camargue (Blondel & Isenmann, 1981). This increase of such opportunistic predators has given rise to some concern about the potential impact upon other species of breeding birds. As a result a short term study of Carrion Crow ecology was undertaken in order to quantify current population distribution and density, breeding success, and interactions with other species. In this paper we report on the first part of this study, the distribution and habitat use of Carrion Crow in the Camargue.

STUDY AREA

The Camargue, 750 km^2 area of the delta of the river Rhône, southern France, is an open mosaic of cultivated land (37 %, cereals, sunflowers and mainly rice), salty pastures and freshwater marshes (30 %) brackish lagoons (17 %), salines (15 %), small villages and farm hamlets (1 % of the area). Woodland is sparse and tall trees are common only along the two main river arms and around scattered farm buildings. Trees in marshland, mainly *Tamarix gallica,* seldom exceed the height of 4 m.

METHODS

Three census methods were used (Figure 1) : (A) A roadside count was undertaken by car at fortnightly intervals throughout one annual cycle from February 1984 to January 1985 on a circuit of 45 km. Driving speed was on average 22.2 ± 2.9 km/h ($\bar{x}$ ± s) covering a census surface of 34.3 km^2. For this count, which was a type of line transect (Järvinen & Väisänen, 1977),

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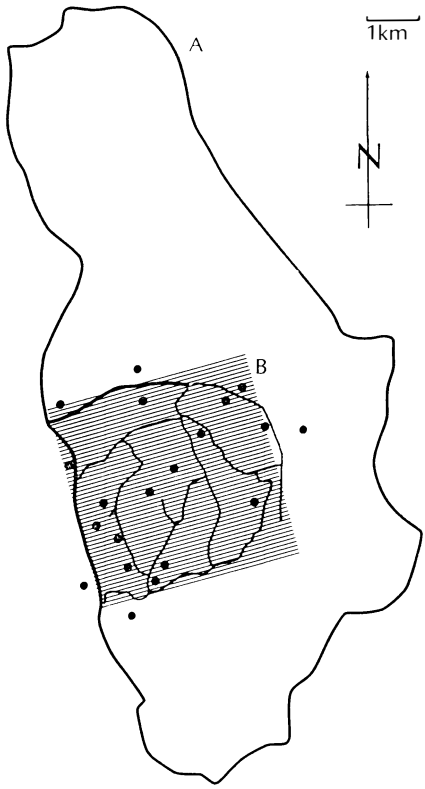

Figure 1. — Design of the three census methods.

Method A = roadside count circuit of 45 km, method B = 16 km² study plot (hatched) used for car censuses (thin lines), method C = complete survey revealed all resident breeding and non-breeding pairs (dots) on the study plot and in its surroundings.

we distinguished two census sectors, the main belt, the surface over which crows standing on the ground (e.g. feeding) could have been detected, and the supplementary belt, the surface over which flying crows could have been detected. The width of these two belts varied according to topography and vegetation between 15 and 500 m for the main belt, and between 15 and 3500 m for the supplementary belt. (The upper values are high, because the landscape of the Camargue is flat and open, and crows are large and conspicious birds). These values give areas of 9.7 km² for the main belt and an additional 24.6 km² for the supplementary belt, giving in turn coverage of 4.64 driven km per km² surface checked for the main belt, and 1.83 driven km per km² surface checked for the supplementary belt.

(B) A similar fortnightly census by car was undertaken on a square sized study plot of 16 km² surface. On field paths an average distance of 37.6 ± 1.7 km was driven at an average speed of 19.4 ± 1.6 km/h giving average coverage of the census surface of 2.35 driven km per km² surface checked.

(C) On the same 16 km² study plot a complete survey was also undertaken in order to census each resident individual crow. An intensive prospection of the whole surface at the end of the nestling period, from 25 May to 4 June 1984, gave the numbers of crows present and provided a comparison with the results of the other two methods.

Habitats on the study plot and alongside the road circuit were divided into four categories : (i) cultivated land with abundant food and suitable nesting trees for crows, (ii) open cultivated land, where food is superabundant during some time of the year but breeding is prevented by the absence of suitable nesting trees (cultures at least distant 500 m from the next trees), (iii) marshland, where neither food nor nesting trees are regularly distributed, (iv) human settlements, where nesting trees and food are abundant (refuse dumps). The distribution of the crows on these habitat categories was compared using Chi²-test (Siegel, 1956) and preference indices according to Jacob (1974) :

$$P = X_1/X_2 - Y_1/Y_2 \; / \; X_1/X_2 + Y_1/Y_2$$

where X_1 is the number of individuals in one habitat and X_2 the total number, Y_1 is the size of that habitat and Y_2 the total area. The values range from — 1 to + 1. Habitats obtaining values from — 0,25 to + 0.25 are neither preferred nor avoided ; those obtaining values below are avoided ; those above preferred.

RESULTS

Breeding season censuses : comparison and validation of the methods

The complete survey (C) on the 16 km² study plot revealed the presence of 8 breeding pairs, 3 non-breedings pairs and 6 immature crows (2 pairs and 2 single crows). The territories of 2 additional pairs came only partly within the study plot. These have therefore each been accorded a value of 1 bird only. However the actual number of resident crows on the study plot did not remain stable during the five months of investigation. Only 6 pairs which bred successfully and raised young stayed in a distinct territory throughout the whole season. Two other pairs deserted their nest and territory within the study plot, while another pair started laying later, after first attempting and failing elsewhere. In addition non-breeding pairs and immature crows were very mobile (e.g. marked individuals were observed at locations 4 km apart during the course of the breeding season), and for at least 10 individuals of breeding and non-breeding crows the study plot covered only part of their home range. As a result of a combination of these factors the number of crows present simultaneously on the study plot could have fluctuated between 22 and 33 individuals. For the purposes of this analysis we have taken the values of 11 pairs, 6 immature crows plus 2 birds with their home range laying only partly on the plot, making 30 individuals given by the complete survey. Because of the form of these data statistical tests to compare the differences between this complete survey (C) and census methods (A) and (B) cannot be employed.

Nevertheless the data in table I show that on average a third of the individuals present, and nearly half of the pairs, were detected on the study plot during any one census by car (B). As part of the road circuit (7 km) lay within the plot, the accuracy of this count (A) was checked by comparing the results obtained with this method with those of the complete survey (C). This comparison revealed that on average one seventh of the individuals and one fifth of

TABLE I

Comparison of single census efficiency of both census methods (A) and (B) with the results of the complete survey (C).

	Method A		Method B		Method C	
	10 censuses February - June		10 censuses February - June		complete survey 25 May - 4 June	
	Individuals	Pairs	Individuals	Pairs	Individuals	Pairs
x ± S.D.	2.0 ± 2.4	1.5 ± 1.5			14	7
Range	0 — 8	0 — 5				
Coefficient of variation	117.85	100.62				
Mean %	14.3 %	21.4 %			100 %	100 %
Range %	0 — 57.1 %	0 — 71.4 %				
x ± S.D.			10.9 ± 2.5	7.2 ± 1.6	30	16
Range			7 — 13	5 — 10		
Coefficient of variation			55.96	33.33		
Mean %			36.3 %	45.0 %	100 %	100 %
Range %			23.3 — 43.3 %	31.3 — 62.5 %		

Reference values of 100 % are those revealed by the complete survey (C). They concern the whole 16 km^2 study plot for comparison with the census by car on this plot (B), but only the sector alongside the part of the road circuit lying in the study plot for comparison with the roadside count (A). This sector covers surface within and outside the study plot.

the pairs were detected during any one roadside count. Due to the high variability in the results of single censuses, as shown by the high coefficients of variation (CV = 100 s / $\bar{x}$), statistical comparison between method (A, roadside count) and method (B, plot census) did not show a significant difference of the proportion of individuals or pairs detected (Wilcoxon, $P > 0.05$). However CV are notably higher in method (A) than in method (B) and higher for individuals than for pairs in both methods.

As methods (A) and (B) consist of repeated censuses, their accuracy can be increased by cumulating the successive results of single censuses. This was done for pairs only. In doing so single crows were assigned to a particular pair, if sighted in its discrete territory. Other sightings of single crows were ignored. Examination of figure 2 reveals that seven censuses by car (B) on the plot were

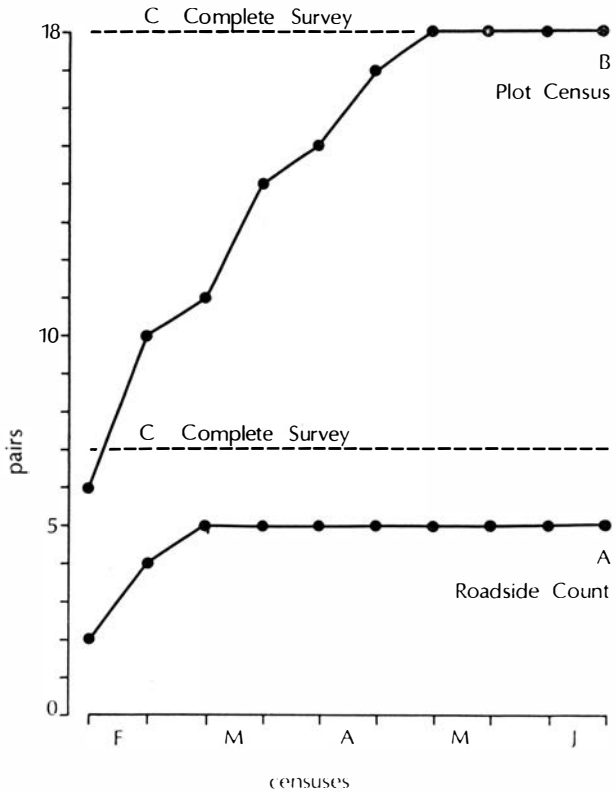

Figure 2. — Cumulative curves of crow pairs recorded during 10 censuses.

A = roadside count, B = plot census. The broken lines indicate the maximum number of pairs present (not necessarily simultaneously) on the surface censused.

sufficient to detect all resident pairs and suggests that, if this method is repeated sufficiently frequently, it will allow accurate census of the number of crow pairs. In comparison the roadside count (A) revealed only some of the resident crow pairs after 10 censuses. Indeed, for the part of the road circuit laying on the

study plot, where comparison was effected, 5 pairs occured within the main belt and 2 additional pairs in the supplementary belt. Cumulation of census results allowed detection of all 5 pairs in the main belt, but not of those in the supplementary belt.

Variation in number, group size and habitat use of crows during the annual cycle

Censuses using methods (A) and (B) were carried out through one complete annual cycle in order to detect variations in number, group size and habitat use of Carrion Crows in the Camargue. On the basis of the results obtained (Figure 3) we have identified 3 seasons : (i) breeding season, when

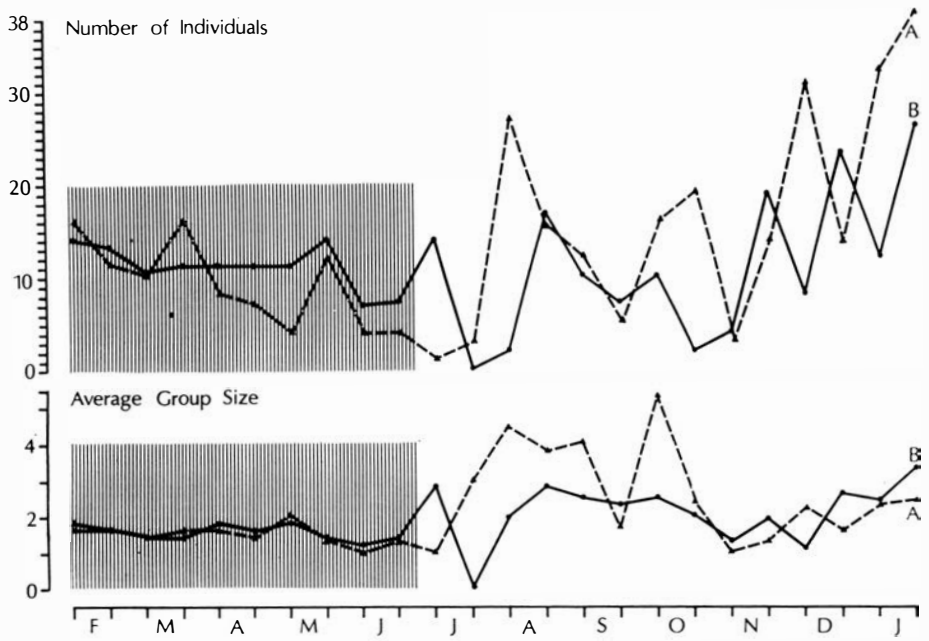

Figure 3. — Number and groupe size of crows censused throughout the annual cycle. A = roadside count, B = plot census. The hatched part of the annual cycle denotes the breeding season. Average group size was calculated according I/G, where I = number of individuals for one census and G = number of groups for the same census.

breeding pairs remain within their territories (February to June) ; (ii) post-breeding, when adults moult, juveniles disperse and large flocks form in suitable habitats (July to mid-October) ; (iii) winter, when large communal roosts are established (mid-October to January).

Number of crows and group size are markedly stable during the breeding season, while there is much variation during the moult/dispersal and winter periods. Average values for the 3 periods (Table II) indicate that the number of crows along the road circuit (A) was highest in winter and lowest during the breeding season, while fewest crows were seen on the study plot (B) during the moult/dispersal period. Statistical comparison of counts using method (A) revealed a significantly higher number of crows in winter than during the bree-

TABLE II

Number and group size of crows in different seasons as revealed by census methods (A) and (B).

		Breeding season	Moult and Dispersal	Winter
Number of censuses		10	7	7
Dates		February - June	July - 15 October	16 October - January
Number	method A (road)	9.2 ± 4.6	11.3 ± 9.1	21.6 ± 12.5
of crows	method B (plot)	10.9 ± 2.5	8.5 ± 6.1	13.4 ± 9.4
Group	method A (road)	1.5 ± 0.3	3.3 ± 1.5	1.9 ± 0.6
size	method B (plot)	1.5 ± 0.2	2.1 ± 1.0	2.1 ± 0.8

Shown are means ± standard deviations for 3 seasons.

ding season and larger group size during moult/dispersal than during the breeding season. Comparison of values obtained using method (B) revealed no significant differences (Table III).

TABLE III

Paired comparison of differences in number and group size of crows between the seasons.

	Method A (road count)				Method B (plot census)		
	Breeding season	Moult-Dispersal	Winter		Breeding season	Moult-Dispersal	Winter
Breeding season		0.56 n.s.	2.51 *	Breeding season		0.96 n.s.	0.69 n.s.
Moult-Dispersal	3.12 *		1.76 n.s.	Moult-Dispersal	1.62 n.s.		1.15 n.s.
Winter	1.63 n.s.	2.33 n.s.		Winter	1.93 n.s.	0.09 n.s.	

Data presented in Figure 3 and Table 2 were analysed with a t-test of equality of the means of 2 samples whose variances are assumed to be unequal (Sokal & Rohlf, 1981), shown are values of t' and their significance (n.s. = $P > 0.05$; * = $P < 0.05$). Above the diagonal are values for the number of crows, below the diagonal values for group size.

The relative distribution of crows on different habitats is shown in figure 4. The null hypothesis, that crows use the habitats according to their availability (relative surface), was tested using Chi^2 and Jacob's indices of preference. Chi^2-tests of the distribution of the crows on different habitat — without the category human settlements which makes only 0.5 % of the area and was not used by crows — gave the significance values shown in figure 4. The calculation of Jacob's indices of preference gave similar but somewhat more detailed results (Table IV) i.e. no habitat selection during the breeding season on both census surfaces (A and B), but a clear selection of open cultivated land with simultaneous avoidance of cultivated land and marshland during the moult/dispersal period along the roadside circuit (A), and avoidance of cultivated land (but no preference of marshland) during the moult/dispersal and winter periods on the study plot (B).

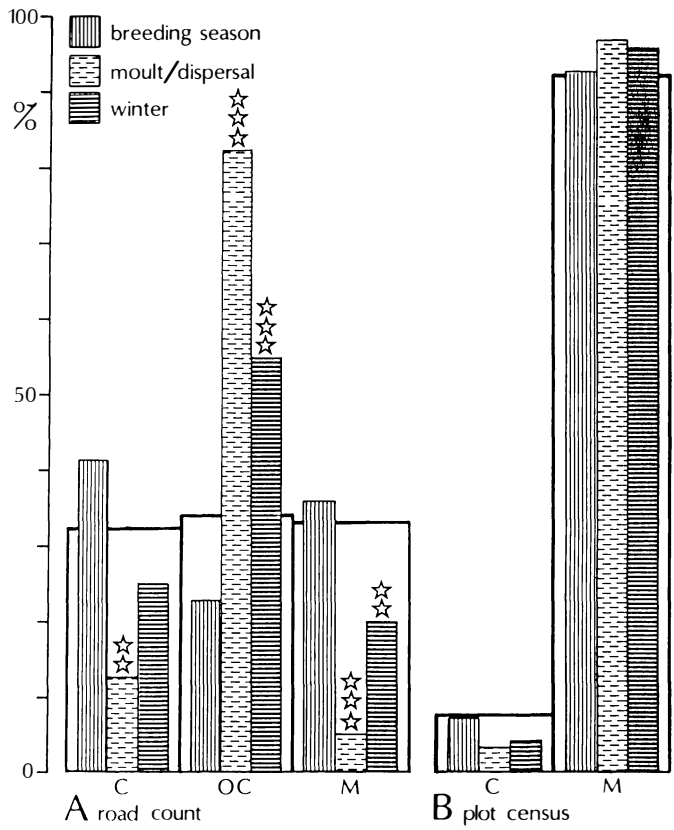

Figure 4. — Habitat use of crows in different seasons as revealed by census methods A and B.

Broad white bars show the relative surface of habitats : C = cultivated land, OC = open cultivated land, and M = marshland. The study plot (B) does not contain open cultivated land. Human settlement was omitted as it consists in case A and B of only 0.5 % and was completely avoided by crows. Significant preference or avoidance of a habitat was tested with Chi^2-test for the original data (km surface, number of crows) and is shown with asterisks (** = $P < 0.01$, *** = $P < 0.001$).

TABLE IV

Habitat selection of crows in different seasons along the road circuit and on the study plot.

	A (road count)			B (plot census)		
	Breeding season	Moult-Dispersal	Winter	Breeding season	Moult-Dispersal	Winter
Cultivated land	— 0.20	— 0.44 (av)	— 0.13	— 0.01	— 0.38 (av)	— 0.27 (av)
Open cultivated land	0.12	0.41 (pr)	0.24	—	—	—
Marshland	0.04	— 0.73 (av)	— 0.25	0.01	0.02	0.02
Number of crows observed	92	79	151	110	60	94

Shown are Jacob's indices, av = avoided habitat, index $<$ — 0.25, pr = preferred habitat, index $>$ + 0.25.

DISCUSSION

Comparison of census methods

Only very few studies compare the efficiency of different census methods for one particular species (e.g. Redmond, Bicak & Jenni, 1981 ; Fjeldsä, 1983). This may be because in most studies a census method, which best fits the goal of the study, is chosen a priori.

In the present study on Carrion Crows comparison of the results of a line transect method (A) and a mapping method (B) with the real number of crows present on a census surface (C) revealed two major conclusions : (i) Without detailed knowledge it was not possible to discern individual crows from pairs, and breeding pairs from non-breeding pairs. (ii) Line transect (A) only gives accurate results for the main census belt, the crows observed on the supplementary belt representing only a proportion of all crows living there. Given these restrictions it revealed inappropiate to extrapolate census results to an exact estimation of population size and density outside the census area, as was hoped to be done for the whole Camargue. A more accurate estimation of the total Camargue crow population would only be possible by carrying out similar investigations as with method (C) on several plots of different habitat structure, which are representative of the habitat composition of the whole Camargue. In conclusion we recommend, that when working with species for which methodological studies are not available, great care should be taken in selecting an appropiate census method, and if possible a comparison of different methods be made.

Seasonal variation in numbers and habitat use

The habitat composition of the census areas (A) and (B) was quite different (Figure 4). Study plot (B) consists almost totally of marshland and reflects the situation of a typical marsh nesting population of crows, while the surface along the road circuit (A) consists of a mosaic of habitats representative of the whole Camargue. On the study plot, the crow population is quite distinct and remains relatively stable throughout the year (Table III). The roadside count reflects the situation on a larger scale : a significant increase in the population during winter when crows move in from outside the census area and flocking of crows on open cultivated land which offers abundant food during the moult/dispersal and winter period. These are the same trends as those shown by studies on more dense crow populations (Pinowski & Wasilewski, 1962 ; Kalchreuter, 1971 ; Möller, 1983 ; P. Gaucher *pers. com.*). The reason for the increase in numbers in winter might be the establishment of a communal roost holding up to 900 birds in December, which lays only 1.5 km from the road circuit in a riverine forest alongside the Rhône. This might have attracted a considerable proportion (estimated at one occasion at 11 %) of crows which feed during the day on cultivated land outside the Camargue delta region. Interestingly the Camargue Carrion Crow population does not contain large non-breeder flocks during the reproductive season as recorded elsewhere (Wittenberg, 1968 ; Charles, 1972 ; Tompa, 1975 ; Böhmer, 1976), but only single and paired non-breeding crows. Flocking of the crows in the Camargue is therefore, in contrast to more dense populations, a feature occuring only outside the reproductive season.

SUMMARY

A low density population of the Carrion Crow *Corvus c. corone* was censused in the Camargue delta region, southern France. Three methods were used : (A) a line transect along 45 km roadside, (B) mapping of the crows on a 16 km² study plot by car, and (C) a complete survey revealing all resident crows during the breeding season on the same plot. Accuracy of the two estimates (A) and (B) was checked with those of method (C). This revealed that 7 censues gave accurate results for both method (B) and for the main belt census sector for method (A). Fortnightly counts using methods (A) and (B) served to monitor number, group size and habitat use of the crows during one whole annual cycle. Size and composition of the population of the study plot, which lays entirely in marshland did not show significant differences between seasons, while a significant increase in number of crows in winter and larger group size and a preference of open cultivated land during the moult/dispersal period, was found along the roadside circuit. Extrapolation of crow distribution and density for the whole Camargue region (750 km²) revealed to be difficult because neither methods (A) and (B) gave results about the population structure and percentage of non-breeders. It is concluded that only repeated surveys (C) in different habitat could provide accurate results.

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