J. Field Ornithol., 62(1):132–138

SEXING ADULT AND YEARLING AMERICAN CROWS BY EXTERNAL MEASUREMENTS AND DISCRIMINANT ANALYSIS

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Abstract.—We recorded external measurements of adult and yearling American Crows (*Corvus brachyrhynchos*) in central Saskatchewan from late April to early July to develop a reliable sexing technique. The most repeatable measurement was of wing length, followed by head-bill, tail and tarsus lengths, bill length and bill depth. Regardless of age, males were larger than females and, regardless of sex, adults had longer wings and tails than yearlings. The sex of 87% of adult crows ($n = 104$) was determined using wing length alone. Most (86%) adult males ($n = 56$) had wing length >311 mm, whereas 88% of adult females ($n = 48$) had wing lengths <308 mm. A discriminant function analysis based on three measurements of size provided better sex discrimination (91.9%) than wing length alone; only males were consistently misclassified as females. Because of greater overlap in body size, discriminant function analysis with four measurements correctly classified only 79.5% of yearling crows ($n = 30$). Although sexual size dimorphism occurs within crow populations, geographical size variation may limit the extent to which these findings can be applied to crow populations outside Saskatchewan.

DETERMINACIÓN DEL SEXO DE ADULTOS Y AVES DE UN AÑO DE *CORVUS BRACHYRHYNCHOS* MEDIANTE MEDIDAS EXTERNAS Y ANÁLISIS DISCRIMINATIVO

Sinopsis.—De abril a julio, en la parte central de Saskatchewan, tomamos medidas externas de adultos y juveniles de un año de individuos del cuervo americano *Corvus brachyrhynchos* con el propósito de desarrollar una clave confiable para identificar el sexo en estas aves. Las medidas que más se repitieron resultaron ser el largo del ala, seguido del largo de cabeza-pico, rabo, tarso, pico y profundidad del pico. A cualquier edad los machos resultaron ser más grandes que las hembras, y sin tomar en consideración el sexo los adultos resultaron tener alas y rabos más largos que los juveniles de un año. El sexo del 87% de los adultos ($n = 104$) se determinó usando tan solo el tamaño del ala. La mayoría (86%) de los adultos ($n = 56$) resultaron con un largo de ala >311 mm, mientras que el 88% de las hembras adultas ($n = 48$) tuvieron un largo del ala <308 mm. Un análisis discriminativo de funciones, basado en tres medida de tamaño, proveyeron de una mejor discriminación de los sexos (91.9%) que el tamaño del ala por si solo; tan solo machos resultaron ser incorrectamente identificados como hembras. Debido al mayor solapamiento en tamaño corporal en los juveniles, el análisis discriminiativo funcional de cuatro parámetros nos permitió clasificar correctamente al 79.5% de los sexos ($n = 30$). Aunque entre poblaciones de cuervo ocurre dimorfismo sexual, variacion geográficas de tamaño podrían poner limites al uso de nuestro trabajo en poblaciones fuera del área de Saskatchewan.

The ability to identify the sex of birds is important to many studies, but in sexually monochromatic species, such as the American Crow (*Corvus brachyrhynchos*), sex determination is often difficult. Though American Crows are sexually dimorphic in size (Emlen 1936), Johnston (1961) found much size variation and overlap within a sex cohort but apparently did not analyze his data statistically. Discriminant function analysis of external measurements is a useful technique for distinguishing the sex of many monomorphic birds, including the Black-billed Magpie (*Pica pica*; Reese and Kadlec 1982, Kavanagh 1988), the Rook (*Corvus frugilegus*; Green 1982), and gulls (e.g., Hanners and Patton 1985). Our objectives were to determine whether it was possible to derive a reliable method of sexing American Crows by external measurements, to analyze statistically Johnston's (1961) measurements of crows (museum specimens) collected in Saskatchewan and Alberta, and to compare his results with measurements of crows that we collected in southcentral Saskatchewan.

METHODS

We used dial calipers and a ruler to measure American Crows shot either on breeding territories, or at a roost, within 40 km of Saskatoon, Saskatchewan. Crows were collected from mid-April to mid-July 1985–1989. Damaged appendages were not measured. Crows with tail molt, or those which had shed primaries 8 or 9, were not measured. We followed Johnston's (1961) methods to measure wing, tail, tarsus and bill lengths. Wing length (flattened wing) was taken from the blunt end of the wrist joint to the tip of the longest primary. Tail length was taken from the insertion of the middle retrices to the tip of the longest retrix. Tarsus length was taken from the joint of the tibiotarsus and tarsometatarsus to the distal edge of the most distal unbroken scute overlying the middle toe. Bill length was taken from the anterior point of the nostril to the tip of the bill. In addition, we measured bill depth taken at the anterior point of the nostrils, and head–bill length taken from the occipital ridge of the skull to the tip of the bill (calipers held perpendicular to the top of the head). Initially, we also recorded bill width taken across the base of the bill under the proximal point of the nostrils, middle toe length taken from the proximal point of the last divided scute to the base of the claw, and tarsus width (front to back) taken at the midpoint of the tarsus.

To learn which mensural characters were most repeatable, two observers (RGC and PCJ) measured a sub-sample of 20 after-second-year (hereafter adult) crows twice. Paired *t*-tests were used to compare the two measurements made by the same observer (i.e., intra-observer repeatability) and, for consistency, the second measurements made by each observer (i.e., inter-observer repeatability). Based on these results (details below), RGC subsequently made all measurements.

The sex of each crow was determined by dissection after measurements were recorded. Age (yearling or adult) was determined using plumage characteristics (Emlen 1936). We used *t*-tests to compare sizes of male and female, and yearling and adult crows, and to compare our results

with those of Johnston (1961). Mensural characters that were most repeatable and most important in separating males and females (as judged by the magnitudes of the *t*-test statistics) were retained for discriminant function analysis. Analyses were performed to identify the combination of variables that would provide maximum sex separation. We used Cohen's Kappa to calculate chance-corrected classification success (see Titus et al. 1984). A sample of adult crows collected in 1989 was used to test the utility of the sex classification procedure developed with measurements of crows collected from 1985 to 1988.

Statistical tests follow Zar (1984). Analyses were executed on the Statistical Analysis System (SAS 1985) and Statistical Package for the Social Sciences (SPSSX 1983).

RESULTS

Measurement repeatability.—Intra-observer repeatability was examined by comparing the first and second sets of measurements made by each observer. Overall, in 18 paired comparisons (nine mensural characters measured by two observers) only one achieved significance (middle toe length, $P < 0.05$); this outcome is expected by chance alone (i.e., $1/18 = 0.056$). Nevertheless, toe length was relatively difficult to measure and it was excluded from further analysis.

Inter-observer repeatability was examined by comparing each observer's second set of measurements. In 10 paired comparisons, only the difference in bill length was significant. However, this was subsequently attributed to differences in the amount of pressure applied to the nostril during measurement and thereafter this was corrected by applying only slight pressure. Overall, multivariate analysis of variance confirmed that intra- and inter-observer effects on size measurements were small (R^2s < 0.02), except bill width, which was influenced to a small extent ($R^2 = 0.07$, $P < 0.07$) by these factors. Bill width was excluded from further analysis.

Differences in size among sex and age cohorts.—Across age cohorts, males were larger than females, and this pattern was most pronounced in adult crows (Table 1). In both sexes, adults had longer wings and tails than yearlings (*t*-tests, $P < 0.05$). In eight correlations (two sexes, two ages and two measurements) between wing or tail length and day of measurement (Julian date), none was significant ($P > 0.10$) and five were positive coefficients. In short, if feather wear influenced our results, the effect was small. Bill, tarsus and head–bill measurements did not differ between age cohorts except that yearling females had longer bills than adults.

An analysis of Johnston's (1961) measurements also showed that adult males were larger than females (Table 2). Furthermore, sexual size dimorphism in adult crows found in the present study was similar to that calculated from Johnston's (1961) data. However, our measurements (Table 1) generally were larger than those reported by Johnston (Table 2), except for bill length, where the pattern was reversed. In adult males,

TABLE 1. Sex-related sizes (mm) of yearling and adult American Crows in Saskatchewan. Shown is the mean ± SE (sample sizes in parentheses).

Character	Yearling			Adult		
	Male		Female	Male		Female
Wing length	304.9 ± 1.8 (18)	**	294.7 ± 2.4 (12)	319.6 ± 0.9 (56)	***	301.3 ± 0.9 (48)
Tail length	170.8 ± 1.1 (17)		165.9 ± 2.5 (11)	181.0 ± 1.0 (55)	***	171.2 ± 0.8 (46)
Tarsus length	59.4 ± 0.3 (18)	***	56.7 ± 0.5 (12)	58.9 ± 0.3 (56)	***	56.2 ± 0.3 (46)
Bill length	33.7 ± 0.2 (18)	**	32.4 ± 0.3 (12)	33.8 ± 0.2 (55)	***	31.2 ± 0.2 (45)
Bill depth	16.5 ± 0.1 (18)	**	15.6 ± 0.2 (12)	16.6 ± 0.1 (55)	***	15.6 ± 0.1 (46)
Head–bill length	91.1 ± 0.4 (18)	***	87.4 ± 0.3 (12)	91.1 ± 0.3 (55)	***	86.2 ± 0.3 (45)

**, *** $P < 0.01$ and 0.001, respectively, by t-tests.

significant differences (t-tests) between the two sets of measurements occurred with wing ($P < 0.01$), tail ($P < 0.001$), tarsus ($P < 0.01$) and bill ($P < 0.05$) lengths. In adult females, differences occurred with tail ($P < 0.001$) and tarsus ($P < 0.01$) lengths.

Wing length was closely associated with the sex of adult crows during the breeding season, with minimal overlap (13% of adults) occurring from 308 to 311 mm (Fig. 1). Adults with wings longer than 311 mm were male, whereas those with wings shorter than 308 mm were female. From 1985 to 1988, we recorded whether brood patches occurred in adult males that we dissected; three (17%) of 18 males collected in May and June (i.e., breeding season) had brood patches.

Discriminant function analysis.—Using wing, tarsus and head–bill measurements recorded from adults collected before 1989, we derived a discriminant function which correctly classified 92% of the crows (40 males and 34 females). The misclassified crows (three males) could not be sexed correctly using more measurements. This discriminant function was used to predict correctly the sex of 92% ($n = 26$) of the adults examined in 1989. We then derived a new discriminant function which incorporated 1989 measurements. The same variables remained important and, furthermore, the misclassified crows (four males) could not be sexed correctly using more measurements. The sex of adult crows was determined by substituting original measurements to solve the equation:

$$\begin{aligned} D = &-56.83352 + 0.1060057\ (\text{wing length}) \\ &- 0.0946648(\text{tarsus length}) \\ &+ 0.3294016(\text{head–bill length}), \end{aligned}$$

where D is the discriminant score, and males have positive scores and females have scores ≤ 0. Mean discriminant scores were 1.472 for males

TABLE 2. Sizes (mm) of adult male and female American Crows reported by Johnston (1961). Shown are the mean ± SE (sample sizes in parentheses) and sexual size dimorphism coefficients.[a]

Measurement	Johnston's study[b]			Size dimorphism	
	Adult males		Adult females	Johnston	This study
Wing length	313.9 ± 1.7 (22)	***	300.6 ± 1.1 (25)	1.04	1.06
Tail length	173.5 ± 1.4 (22)	***	165.6 ± 1.3 (25)	1.05	1.06
Tarsus length	57.5 ± 0.3 (23)	***	54.8 ± 0.3 (26)	1.05	1.05
Bill length	34.6 ± 0.4 (22)	***	31.9 ± 0.4 (26)	1.08	1.08

[a] Size dimorphism coefficient is $\bar{x}$ male size/$\bar{x}$ female size.
[b] Specimens collected in Saskatchewan, Alberta, Yukon and Northwest Territories between April and September.
*** $P < 0.001$, by t-tests.

($n = 55$) and −1.840 for females ($n = 44$). Six after-hatching year crows (three males, three females) collected from late July to late September also were sexed correctly using the discriminant function. Because of greater size overlap in yearlings (Table 1), four measurements were needed to achieve only 79.5% classification success. Consequently, we have not presented a discriminant function for yearlings.

DISCUSSION

In the American Crow population we studied, during the breeding season the sex of many adults can be determined by wing length. However, Johnston's (1961) work suggests that geographical size variation may limit the extent to which our findings can be applied to other crow populations. For instance, our measurements and those of Johnston (1961) produced similar sexual size dimorphism estimates, and both data sets showed highly significant size differences between males and females, but the two sets differed in six of eight comparisons (two sexes and four measurements; Table 2). We do not believe that our methods differed substantially from Johnston's because we carefully followed his measurement descriptions.

At least two other likely explanations exist for the disparities between our study and Johnston's (1961). First, in Johnston's study, Saskatchewan crows composed about 30% of the sample with the remainder from Alberta (one from the Yukon and one from the Northwest Territories); his sample may therefore have included birds from populations with different morphologies. Second, Johnston's sample included crows collected in late summer (August and September), so some may have been 1.5 yr old, whereas we restricted our sample to the period from April to mid-July to reduce the effects of feather wear and molt (Good 1952; R. G. Clark and P. C. James, unpubl. data) on sex differences. Johnston excluded crows with badly worn feathers, but he did not indicate whether he excluded specimens with wing or tail molt.

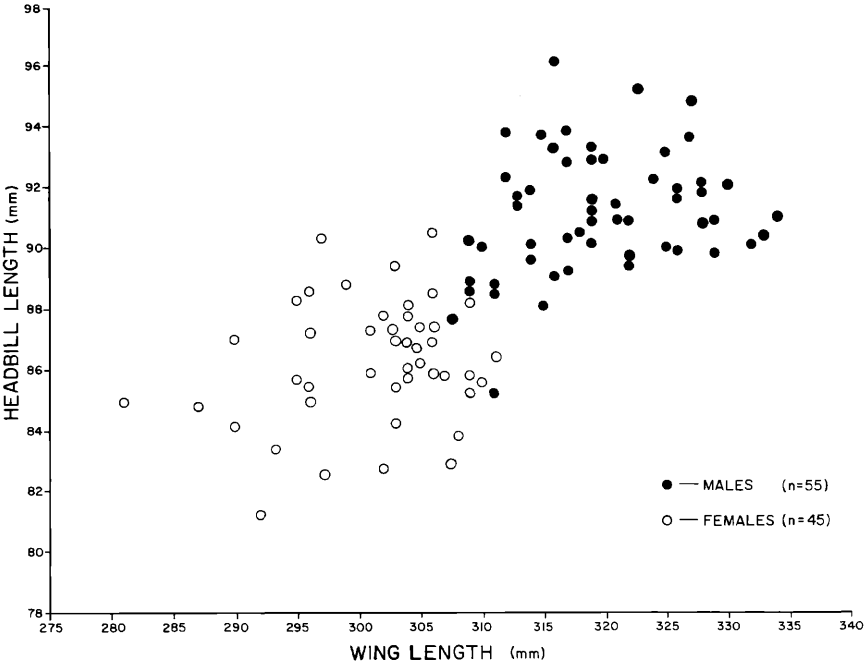

FIGURE 1. Wing and head-bill lengths of adult American Crows in Saskatchewan.

Our inability to identify correctly the sex of all crows indicates the need for alternative sexing methods. Specifically, in the range of wing length overlap of adults (308–311 mm), laparoscopy is necessary (Richner 1989) because additional measurements in combination with discriminant function analysis did not improve our ability to identify the sex of some (male) crows. Furthermore, the likelihood of correctly sexing crows with the discriminant function is proportional to the absolute value of D (e.g., Desrochers 1990, Maron and Myers 1984). Therefore, for field application, the sex of adult crows with values of D near 0 should be verified with alternative methods (see Hanners and Patton 1985:161). In yearlings, laparoscopy would be needed because of greater overall size overlap (Table 1).

Also, we were interested to learn that some males had brood patches, but we do not know whether they incubated eggs or brooded nestlings. Bent (1946:233–234) cited anecdotal accounts of males and females sharing incubation, but Good (1952:77) and Goodwin (1976:89) felt that males did not incubate. Further study of individually marked American Crows is needed to confirm whether females alone incubate eggs, as shown in two small groups of crows in Florida (Kilham 1984) and in Northwestern Crows (*C. caurinus,* Butler et al. 1984). Further studies also are needed regarding age-related morphological changes and molt patterns.

ACKNOWLEDGMENTS

It is a pleasure to thank G. Bain, J. Black, D. Dzadik, M. Gloutney, J. Ignatiuk and D. Meger for their assistance in collecting crows, and R. Dawson, J. Ignatiuk, D. Meger and A. Tuchscherer for help with dissections. T. Diamond and L. Hanners made many helpful comments on drafts of this paper.

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Received 13 Nov. 1989; accepted 30 Sep. 1990.