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Use of external biometrics to sex Carrion Crow *Corvus corone*, Rook *C. frugilegus* and Western Jackdaw *C. monedula* in Northern England

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Carrion Crow *Corvus corone*, Rook *C. frugilegus* and Western Jackdaw *C. monedula* culled as part of a predator control study in Northern England were sexed by inspecting internal reproductive organs and measured to determine whether external biometrics (wing, head-plus-bill and tarsus length) could be used to identify the sex of live birds. Tarsus length was found to vary between observers measuring the same bird so was not considered further. Due to considerable size overlap between the sexes it was not possible to sex all individuals correctly, particularly those less than a year old. The larger males and smaller females could be sexed with 85–93% accuracy, in adult birds using wing length of Carrion Crows of male >327 mm, female <309 mm; Rook male >320mm, female <307 mm; and Western Jackdaw male >246 mm, female <233 mm. Head-plus-bill length improved the number of birds sexed when used in combination with wing length for Carrion Crow and Rook.

Identifying the sex of individuals in a population greatly enhances the value of behavioural and demographic data. Sexing birds with monomorphic plumage and soft-tissue coloration is often problematic, however, especially if as in the Corvidae family the sexes overlap in size. During the breeding season, birds of a range of species can be sexed by observations of copulation and courtship (Baeyens 1981) or from the presence of a brood patch (Cowley 1999). DNA techniques are available (Ellegren & Sheldon 1997) but these require blood or feathers to be taken and access to appropriate laboratory facilities. Often the easiest and most cost-effective method of sexing birds in the hand is to measure external biometrics and determine the sex from either a single biometric (Coulson *et al* 1983) or a discriminant function (Green 1982). The usefulness of external biometrics depends on the accuracy and repeatability of the measurements in question (Hamer & Furness 1991) in addition to the degree of sexual size dimorphism within a species.

This study utilises the carcasses of birds culled for predator control in Northumberland, UK. We report on attempts to sex Carrion Crow *Corvus corone*, Rook *C. frugilegus* and Western Jackdaw *C. monedula* using three biometrics; wing, head-plus-bill and tarsus length.

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METHODS

Data collection

During 2001–08, the majority of birds were culled between March and July (95% of 1,563 across all species and ages) and were sexed from examination of internal organs. External measurements were taken from all individuals not in active primary moult and with no damage or abrasion to the relevant body parts (see Redfern & Clark 2001 for full details of measuring techniques): i) head-plus-bill length to the nearest 0.1 mm using Vernier callipers; ii) tarsus length (minimum tarsus) to the nearest 0.1 mm using Vernier callipers; iii) wing (maximum chord) length to nearest 1 mm using a stopped rule.

Birds were aged as <1 year old (EURING code 3 and 5) or older (adults), using upper mandible and plumage coloration (Svensson 1992). In the months after fledging, sexual organs were difficult to distinguish, so yearlings measured before December were excluded. As found previously for corvids (Henderson 1991) wing length was shorter in yearlings than in adults (Table 1: Carrion Crow males $t_{183} = -7.70$, $P < 0.001$; females $t_{457} = -8.62$, $P < 0.001$). Therefore criteria for sexing adults and yearlings were explored separately when >30 birds in each age category were available (668 adult and 305 yearling Carrion Crows, 424 adult Rooks and 166 adult Western Jackdaws).

Table 1. Mean, SD, coefficient of variation (CV), sexual size dimorphism (SSD), cut point (midway between the mean values for females and for males) from half the sample and the accuracy of using the cut point on the other half of the sample for wing length and head-plus-bill length for Carrion Crow, Rook and Western Jackdaw.

			Wing length (mm)						Head-plus-bill length (mm)					
		N	Mean	SD	CV%	SSD%	Cut point	Accuracy	Mean	SD	CV%	SSD%	Cut point	Accuracy
Carrion Crow														
Adults	Male	343	327	10.9	3.2	4.0	≥321	76%	99.0	3.3	3.4	4.8	≥96.7	77%
	Female	325	314	9.5			<321		93.7	3.4			<96.7	
Yearlings	Male	199	319	9.1	2.8	3.6	≥312	76%	97.7	3.3	3.5	5.7	≥95.6	74%
	Female	106	307	8.5			<312		93.3	3.2			<95.6	
Rook														
Adults	Male	213	323	8.9	2.8	5.6	≥314	85%	100.2	3.0	3.3	5.1	≥97.7	76%
	Female	211	306	8.4			<314		95.3	3.4			<97.7	
Western Jackdaw														
Adults	Male	114	243	5.6	2.5	4.3	≥237	84%	70.7	2.8	4.2	4.2	≥70.2	69%
	Female	52	233	6.4			<237		67.8	2.8			<70.2	

Data analyses

In a preliminary test for variation within and between observers, 20 Carrion Crows were measured twice each by three observers. For each biometric and each observer, variation was quantified using an ANCOVA with observer and occasion (first or second) as fixed factors and bird identity as a covariate.

To summarise each measurement, in each species, the co-efficient of variation [(SD/mean)*100] and sexual size dimorphism [((male mean/female mean)-1)*100] was calculated (Weidinger & van Franeker 1998). Within each species and age category, *t*-tests were undertaken on all data to look for any sexual difference in each measurement. The data for each species were then ordered by date of capture across all years and split in half to give an even sample of male and female in each age category. The early sample was used to generate sexing criteria and the late sample was used to assess the accuracy in all methods.

The following analytical methods were used to explore sexing criteria. Cut points (midway between the mean value for females and the mean value for males) were calculated (following Weidinger & van Franeker 1998) for each species and age category. For all biometrics, males were on average larger (Table 1) so we assumed all birds equal to or above the cut point were male and calculated the proportion that were correctly sexed using cut point alone.

Within the early sample we determine what value for each biometric would result in 95% of individuals being correctly sexed (*ie* sexing the larger males and smaller females). This was then tested by determining what proportion of the sample remained unsexed and how accurate these criteria were within the sexed individuals.

Biometrics were combined in a stepwise discriminant analysis for each species (Sokal & Rohlf 1981) and the proportion of birds that were correctly sexed was determined.

All statistical analyses were undertaken using SYSTAT version 12 (SYSTAT Software Inc, Richmond, USA).

RESULTS

Repeatability of measuring biometrics

Within-observer variation was not significant in any biometric (ANCOVA: head-plus-bill length $F_{1, 113} = 0.40$, $P = 0.5$; wing length $F_{1, 113} = 0.01$, $P = 0.9$; tarsus length $F_{1, 113} = 0.00$, $P = 1.0$). Between-observer variation was significant in tarsus length ($F_{2, 113} = 6.50$, $P = 0.002$) but not in head-plus-bill ($F_{2, 113} = 1.89$, $P = 0.2$) nor wing length ($F_{2, 113} = 2.02$, $P = 0.1$). As tarsus length was not repeatable between observers it has not been considered further as a sexing parameter.

Sexing using single biometrics

In all species there was a significant difference between males and females in each biometric (*t*-tests, all $P < 0.001$). For each sex, within each species, the mean values for wing length and head-plus-bill length are shown in Table 1, with the most reliable biometrics for sexual differentiation typically showing low coefficient of variation and high sexual size dimorphism. The cut-points method showed that measuring wing or head-plus-bill length gave similar accuracies in sexing Carrion Crows (74–77%, Table 1), but that wing length gave the highest accuracy in Rooks (male ≥314 mm, 85%) and Western Jackdaws (male ≥237 mm, 84%).

The criteria that sex only larger males and smaller females (Table 2) improved the sexing accuracy: 85% of Carrion Crows adults (using male >327 mm and female <309 mm in wing length); 89% of Carrion Crows yearlings (using male >98.9 mm and female <93.2 mm in head-plus-bill length); 93% of Rooks (using male >320mm and female <307 mm in wing length); 91% of Western Jackdaw (using male >246 mm and female <233 mm in wing length).

Sexing using a combination of biometrics

Using the criteria to sex larger males and smaller females for wing length and head-plus-bill length, the proportion of the sample that could be sexed increased, but only in Carrion Crow did the accuracy increase (Table 2) and in the case of Western Jackdaws it decreased.

The discriminant-function method of sexing achieved higher accuracy than cut points for Carrion Crow (83% using wing and head-plus-bill length, Table 3) but not for Rooks (78% using wing and head-plus-bill length, Table 3) nor Western Jackdaws (71% using wing and head-plus-bill length, Table 3).

DISCUSSION

Wing length and body mass are the most commonly used external biometrics recorded by ornithologists. Body mass shows high variability within individuals, however, both diurnally and seasonally, and could not be used within this study as some birds had been frozen prior to measuring. The effect of freezing on biometric measurements is not well documented, but is likely to be smaller over the short timescales that carcasses were frozen, compared to the long-term effect of drying recorded in museum skins (Knox 1980). Therefore the measurements reported here are expected to be comparable with live specimens. We found that wing, head-plus-bill and tarsus length could be measured with minimal variation by a single observer but that tarsus length showed significant between-observer variation, so was excluded from the sexing criteria.

Previous studies have explored sexing members of the Corvidae family using a range of biometrics such as mass, wing length, head-plus-bill length, skull length, tarsus length, bill length and bill depth (Green 1982, Reese & Kadlec 1982, Kavanagh 1988, Clark *et al* 1991, Kenward *et al* 2004, Alarcos *et al* 2007, Lee *et al* 2007) with high levels of accuracy (90–100%). The wing and minimum tarsus length of Western Jackdaws have been previously used to sex 65% of 141 birds with 96.7% accuracy (Henderson 1991) and wing and bill length of Rooks have been used to calculate a discriminant function with 98.7% accuracy (Green 1982). The present study had larger sample sizes than many others but the accuracy achieved was in general lower. This may be due to the involvement of multiple observers, but this will mean that the sexing criteria presented here should be robust enough for use by other observers.

Using cut points of individual biometrics or more complex discriminant function equations to combine

Table 2. Using half the sample to create sexing parameters allowing 5% error, then determining the % accuracy and % left unsexed from the second half of the sample.

	Male	Female	% accuracy	% unsexed
Carrion Crow – adults				
Wing length (mm)	>327	<309	85%	55%
Head-plus-bill length (mm)	>98.7	<93.9	85%	34%
Either wing or head-plus-bill lengths #	(as above)		90%	25%
Carrion Crow – yearlings				
Wing length (mm)	>321	<300	77%	71%
Head-plus-bill length (mm)	>98.9	<93.2	89%	44%
Either wing or head-plus-bill lengths #	(as above)		88%	38%
Rook – adults				
Wing length (mm)	>320	<307	93%	36%
Head-plus-bill length (mm)	>100.6	<96.5	88%	41%
Either wing or head-plus-bill lengths #	(as above)		93%	20%
Western Jackdaw – adults				
Wing length (mm)	>246	<233	91%	60%
Head-plus-bill length (mm)	>73.7	<66.8	82%	59%
Either wing or head-plus-bill lengths #	(as above)		79%	49%

if sex recorded from wing and head-plus-bill was not the same, birds were left unsexed

Table 3. The discriminant function (D) calculated from wing length (W) and head-plus-bill length (HB) using half the sample and the accuracy of the formulae on the second half of the sample where D<0 = female and D>0 = male.

	Wilks' lambda	F	df	*P*	% sexed correctly
Carrion Crow – adults					
D = 0.100W - 32.007	0.703	141	1, 333	<0.001	76%
D = 0.342HB - 33.040	0.545	278	1, 333	<0.001	77%
D = 0.047W + 0.271HB - 41.113	0.486	175	2, 332	<0.001	83%
Carrion Crow – yearlings					
D = 0.115W - 35.776	0.788	41	1, 151	<0.001	76%
D = 0.337HB - 31.984	0.712	61	1, 151	<0.001	76%
D = 0.062W + 0.248HB - 42.929	0.641	42	2, 150	<0.001	81%
Rook – adults					
D = 0.110W - 34.438	0.681	43	1, 92	<0.001	74%
D = 0.321HB - 31.384	0.866	14	1, 92	<0.001	66%
D = 0.080W + 0.201HB - 44.956	0.655	24	2, 91	<0.001	78%
Western Jackdaw – adults					
D = 0.160W - 38.435	0.724	31	1, 81	<0.001	82%
D = 0.361HB - 25.498	0.899	9	1, 81	0.003	61%
D = 0.140W + 0.111HB - 41.662	0.703	17	2, 80	<0.001	71%

biometrics was accurate on less than 86% of occasions (76–85% for wing length, 69–77% for head-plus-bill length and 71–83% combining biometrics). By trying to sex only larger males and smaller females, wing length accurately sexed adult birds on between 85% and 93% of occasions (parameters in Table 2). For Carrion Crow yearlings these wing length criteria were accurate on 77% of occasions, so should be used with great caution. Using head-plus-bill length in addition to wing length was useful in adult Carrion Crows and Rooks where it increased the accuracy and/or the proportion of the sample that could be sexed. From the data collected we found that the sexes of these three species overlapped in wing and head-plus-bill length, but in birds more than a year old larger males and smaller females can be identified to an accuracy acceptable for pooling ringing data to study demography.

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