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MORPHOLOGY OF HATCHLING HOODED CROWS AND ITS RELATION TO EGG VOLUME[1]

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Abstract. The relationship between egg volume and the size of hatchling Hooded Crows *Corvus corone cornix*, was studied in 1982 and 1984, in the Trondheim area, Central Norway. A high positive correlation was found between egg volume and the magnitude of all the morphological characters studied (total body mass, net body mass, tarsus length, wing length, bill tip length, and claw length), and between egg volume and the yolk sac mass of the hatchling. There was a tendency for a relative increase in yolk sac mass with increasing egg volume. There was also a high positive correlation between the magnitudes of the different morphological characters of the hatchlings. When making a principal component analysis of the morphological, yolk sac, and egg volume data, four groups were separated. The middle toe and claw length had high scores on one component, the yolk sac on a second component, the tarsus length on a third component, and the other morphological characters and egg volume had moderate to high scores on all three components. At hatching, the bill tip was the most developed feature, compared to the same character for nestlings 24 days old, followed by the lengths of the tarsus, middle toe, claw, wing, and total body mass. The order of development of the different morphological characters during the embryonic stage was adapted to the hatchling's needs during the hatching process.

Key words: Corvidae; egg volume; embryonic growth; hatching; hatchling size; sex.

INTRODUCTION

The size of birds' eggs has always been a fascinating topic for study by ornithologists. The relationship between egg size and bird size was examined quite some time ago (Heinroth 1922). Furthermore, the variation in egg size in relation to such factors as season, year, weather conditions, size and condition of the female, clutch size and laying order, as well as the effect of egg size on egg hatchability, have already been examined for a large number of species (see Ojanen 1983 for a review, and Rofstad and Sandvik 1985 for some data concerning the Hooded Crow *Corvus corone cornix*). The intraclutch variation in egg size has been thoroughly discussed by Slagsvold et al. (1984).

The relationship between egg size and hatchling size has also been studied for many species and, in general, large eggs have been found to give rise to heavier hatchlings (Parsons 1970, Schifferli 1973, Nolan and Thompson 1978). Less attention has been paid to further analyses of these hatchlings; e.g., are heavy hatchlings also more advanced in their development of other morphological characters, or are they heavier simply because they possess a larger yolk reserve than hatchlings derived from smaller eggs?

In a previous study we found that a high positive correlation existed between egg volume and body weight in hatchling Hooded Crows (Rofstad and Sandvik 1985). In the present study we wished to examine whether or not this correlation also holds true for morphological characters other than body weight. We were especially interested in the relationship between egg volume and the size of the yolk mass of the hatchlings. This relationship may provide a valuable clue for a better understanding of the high mortality rate observed during the first few days after hatching, a mortality which very commonly occurs in many bird species (Lack 1954, O'Connor 1978, Clark and Wilson 1981), and which we also observed in the Hooded Crow population that we studied (unpubl. results).

MATERIALS AND METHODS

The field work was carried out during the breeding seasons of 1982 and 1984, in the Trondheim area, Central Norway (63°N, 10°E). A total of 230 Hooded Crow eggs and hatchlings (133 from 29 clutches in 1982 and 97 from 20 clutches in 1984) were collected late during the incubation period and hatched out in an incubator. Only complete clutches were collected. The incubator

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TABLE 1. The mean values of various morphological characters, together with the yolk sac weights of hatchling Hooded Crows; as absolute values and as percentages of the mean values for the same characters recorded for nestlings 24 days old (pooled data for both sexes).

Morphological character	Males	SD	Females	SD	% of respective mean values for 24-day-old nestlings
Total body weight (g)	13.6	1.96	13.5	1.62	3.5
Tarsus length (mm)	10.8	0.65	10.8	0.74	19.0
Wing length (mm)	13.1	0.64	12.8	0.56	7.6
Bill tip length (mm)	5.6	0.30	5.5	0.27	23.9
Middle toe length (mm)	7.7	0.51	7.7	0.47	19.0
Claw length (mm)	1.4	0.31	1.3	0.25	14.8
Yolk sac weight (g)	0.8	0.30	0.9	0.26	—
Net body weight (g)	12.3	1.38	12.4	1.28	—

was visited at least twice daily, and only the data for these hatchlings are included in the morphological analyses.

The eggs were measured with a sliding caliper, with an accuracy of ±0.1 mm. Egg volume was calculated from the formula: $V = 0.51 \times L \times B^2$ (Hoyt 1979), where V = egg volume, L = egg length, and B = egg breadth.

From all the eggs collected we obtained 103 hatchlings (26 from 12 different clutches in 1982 and 77 from 19 different clutches in 1984) for which the data for the eggs from which they hatched were accurately known. The following morphological characters of all these hatchlings were recorded: total body weight, net body weight (total body weight minus yolk sac weight), tarsus length, wing length, middle toe length, bill tip length, and claw length (on middle toe). In addition their yolk sacs were removed and weighed, to the nearest 0.1 g. For a fuller description of the morphological measurements see Rofstad (1986).

Body weight of the hatchlings was recorded both years ($n = 103$, from 31 different clutches), whereas the magnitudes of the other morphological characters and the yolk sac weights were only recorded in 1984 ($n = 77$, from 19 different clutches). The middle toe and claw lengths of three hatchlings failed to be recorded due to an oversight, so these two morphological characters are only known for 74 hatchlings (from 19 different clutches). In 19 cases the yolk sac broke during its removal. The yolk sac weight data therefore cover only 58 of the hatchlings (from 18 different clutches). All hatchlings were sexed by gonadal inspection.

When examining how egg volume and hatchling size varied between clutches, means within clutches were used, while in the other analyses each hatchling was used as an independent observation. In the comparisons of the hatchling data with the equivalent ones for nestlings 24 days old, the latter are taken from Rofstad (1986). A standard computer program was used for the statistical analyses (Nie et al. 1975, Nie 1983).

RESULTS

SIZE OF HATCHLINGS

No significant difference was found in the magnitudes of any of the morphological characters in relation to the hatchling sex (Table 1). The data for all the hatchlings were therefore pooled in the subsequent analyses.

At hatching, the bill tip was the most developed character, being 23.9% of the mean bill tip value for nestlings 24 days old. The respective proportions for toe, tarsus, and claw lengths were 19%, 19%, and 14.8%. Least developed was the overall (total) body weight, being only 3.5% of that of nestlings 24 days old (Table 1). The mean yolk sac weight was 0.84 g, equivalent to 5.9% of the mean total body weight of the hatchlings.

In general, positive correlation existed between all the different morphological characters studied (Table 2), excepting tarsus length, which was only significantly correlated to net body weight, wing length, and bill tip length. No significant correlation was found either between yolk sac weight and middle toe length or claw length.

By controlling for egg volume during a partial correlation analysis, the following correlations were now significant or nearly significant: the yolk sac weight was positively and significantly correlated only with the total body weight ($P = 0.057$), and the tarsus length was positively and

TABLE 2. Correlation coefficients obtained for the relationship between the different morphological characters of hatchling Hooded Crows (numbers of observations shown on left hand side). Statistical significance: $*P < 0.05$, $**P < 0.01$, $***P < 0.001$.

	Total body weight	Net body weight	Yolk sac weight	Tarsus length	Wing length	Bill tip length	Middle toe length	Claw length
Total body weight	–	0.987***	0.616***	0.176	0.693***	0.665***	0.451***	0.593***
Net body weight	58	–	0.478***	0.443***	0.753***	0.636***	0.436***	0.280*
Yolk sac weight	58	58	–	0.180	0.290*	0.391**	0.071	0.200
Tarsus length	77	58	58	–	0.365***	0.286*	0.121	−0.091
Wing length	77	58	58	77	–	0.552***	0.315**	0.387***
Bill tip length	77	58	58	77	77	–	0.423***	0.544***
Middle toe length	74	58	58	74	74	74	–	0.504***
Claw length	74	58	58	74	74	74	74	–

TABLE 3. Partial correlation analysis, controlling for egg volume, for the relationship between the magnitudes of the various morphological characters of hatchling Hooded Crows. Statistical significance: $*P < 0.05$, $**P < 0.01$, $***P < 0.001$.

	Total body weight	Net body weight	Yolk sac weight	Tarsus length	Wing length	Bill tip length	Middle toe length	Claw length
Total body weight	–	0.955***	0.254	÷0.095	0.418***	0.314**	0.117	0.270*
Net body weight	58	–	0.049	0.421***	0.560***	0.254	0.095	÷0.415***
Yolk sac weight	58	58	–	0.030	÷0.119	0.023	÷0.293*	÷0.203
Tarsus length	77	58	58	–	0.268*	0.161	÷0.002	÷0.298**
Wing length	77	58	58	77	–	0.272*	0.045	0.070
Bill tip length	77	58	58	77	77	–	0.188	0.297*
Middle toe length	74	58	58	74	74	74	–	0.332**
Claw length	74	58	58	74	74	74	74	–

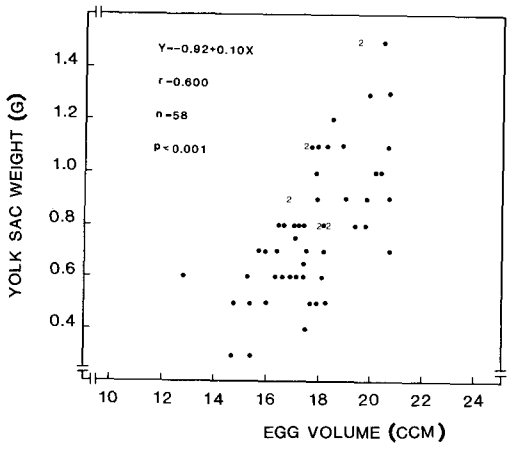

FIGURE 1. Scattergram for the yolk sac weights of hatchling Hooded Crows in relation to the volumes of the eggs from which they hatched. Each egg/hatchling treated as an independent observation.

significantly correlated with the net body weight and the wing length. The claw length and the middle toe length were positively and significantly intercorrelated, and the claw length was also positively and significantly correlated with the bill tip length and the total body weight. The total body weight, the net body weight, the wing length, and the bill tip length were all positively and significantly intercorrelated (Table 3; $P = 0.057$ for the correlation between net body weight and the bill tip length). Besides, there were negative significant correlations between the middle toe length and the yolk sac weight, the claw length and the net body weight, and the claw length and the tarsus length.

EGG VOLUME IN RELATION TO HATCHLING SIZE

A significant positive correlation was found between egg volume and the magnitudes of the various morphological characters of the hatchlings, except the tarsus length (Table 4), and between egg volume and the yolk sac weight of the hatchlings. The regression coefficient of the logarithm of yolk sac weight on the logarithm of egg volume was 1.60 (0.43 SE, $r = 0.68$) indicating a relative increase in yolk sac weight with increasing egg volume. The slope was not significantly different from a value of 1 (95% confidence interval of X ranging 2.51–0.70). When making this analysis using each egg/hatchling as an independent observation, the regression coefficient of the logarithm of yolk sac weight on the logarithm egg volume was 2.07 (0.37 SE, $r = 0.59$). The slope was now significantly different from a value of 1 ($P < 0.01$, 99% confidence interval of X ranging 3.06–1.07; Fig. 1).

TABLE 4. Correlation analysis (simple correlation coefficients, and partial correlation coefficients when controlling for yolk sac weight) for the relationship between egg volume and the magnitudes of the various morphological characters of hatchling Hooded Crows.

Morphological character	Simple correlation coefficient	n	Partial correlation coefficient (controlling for yolk sac weight)	n
Total body weight	0.933***	31	0.881***	18
Wing length	0.795***	19	0.716***	18
Tarsus length	0.373	19	0.162	18
Bill tip length	0.782***	19	0.707**	18
Middle toe length	0.598**	19	0.731***	18
Claw length	0.646**	19	0.762***	18

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

The correlation existing between egg volume and the net body weight of the hatchlings was also highly significant ($r = 0.938$, $n = 18$, $P < 0.001$). Only the yolk sac weight showed a relative increase with increasing egg volume. Also, when controlling for yolk sac weight, there was a significant positive correlation between the egg volume and the size of all the morphological characters, except tarsus length (Table 4). In other words, hatchlings hatched from large eggs possessed relatively larger yolk sacs than those hatched from smaller eggs, and the morphological characters were larger.

DISCUSSION

In the Hooded Crow, as for a variety of other species, hatchlings from larger sized eggs are heavier and possess larger sized morphological characters, than those from smaller eggs (Parsons 1970, Schifferli 1973, Nolan and Thompson 1978, Birkhead and Nettleship 1982).

Larger sized eggs of birds often contain a larger yolk mass than small eggs (Parsons 1970, Ricklefs 1977a, Ricklefs et al. 1978, Ankney 1980), but smaller eggs often contain a relatively larger yolk mass (Ricklefs 1977b, Nisbet 1978, Ricklefs et al. 1978; see also Birkhead 1984 and Bancroft 1985). This relationship has hitherto not been examined for the Hooded Crow, although this study showed that larger eggs produce hatchlings

with relatively more yolk reserve (cf. also Alisauskas 1986).

In the Hooded Crow, the mean yolk sac weight was only 5.9% of the mean total body weight of the hatchlings. The high degree of correlation found between egg volume and hatchling body weight was not due to the yolk sac weight, because there was also a high degree of correlation between egg volume and body weight when controlling for yolk sac weight.

In species with a marked intraclutch egg size variation (e.g., the Hooded Crow, with decreasing egg volume with laying order, Rofstad and Sandvik 1985), and where large sized eggs give rise to larger sized hatchlings, this may have a severe effect on intrabrood competition (cf. Bengtsson and Rydén 1981). Larger sized hatchlings are not only heavier but also have larger sized morphological characters. They often possess greater energy reserves (a heavier yolk mass; Parsons 1970, Ankney 1980, this study, but see also O'Connor 1979). This may enable these larger hatchlings to resist periods of starvation for a longer time than smaller hatchlings, with their smaller yolk masses. Indeed, the hatchlings from large sized eggs are known to have better survival rates than hatchlings from small sized eggs (Parsons 1970, 1975; Nisbet 1978; Lundberg and Väisänen 1979; Ankney 1980).

The growth and development during the embryonic stage, of the different morphological characters studied, seemed to follow a pattern that was adapted to the needs of the embryos during the hatching process. During the climax stage (Oppenheim 1972), the young extend their tarsal joints into the pointed end of the egg and thrust their head and beak vigorously backwards against the eggshell (Oppenheim 1972). The bill and feet are therefore the most important of all morphological characters at this stage, and indeed they were precisely those found to be the most advanced in development. The bill tip, in particular, was highly advanced, being as much as 24% of the size of the bill tip of 24-day-old nestlings, while later on during the nestling stage the bill tip grew at a more even rate (Rofstad 1986).

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