NAT. CROAT. | VOL. 10 | No 1 | 11–17 | ZAGREB | March 31, 2001

ISSN 1330-0520
UDK 598.822˙591.561(497.5/1-16)

original scientific paper / izvorni znanstveni rad

CORRELATIONS BETWEEN EGG CHARACTERISTICS AND LAYING ORDER IN THE STARLING (*Sturnus vulgaris*) IN NW CROATIA

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Dolenec, Z.: Correlations between egg characteristics and laying order in the starling (*Sturnus vulgaris*) in NW Croatia. Nat. Croat., Vol. 10, No. 1., 11–17, 2001, Zagreb.

This article analyses the effect of body weight and wing length of female starlings on clutch size as well as the effect of laying order on egg size. Egg length averaged 29.43 mm, egg breadth 21.32 mm, egg volume 6829 mm^3, egg weight 6.92 g and egg shape index 1.38. There was no significant relationship between female body weight and clutch size and egg size ($p > 0.05$). The same can be applied to the female wing length. A statistically significant positive correlation was found between mean egg volume and egg length ($r = 0.68$; $p < 0.001$; $n = 48$) as well as egg breadth ($r = 0.87$; $p < 0.001$; $n = 48$), egg length and egg shape index ($r = 0.81$; $p < 0.001$; $n = 48$), whereas a statistically significant negative correlation was observed between egg breadth and egg shape index ($r = –0.38$; $p < 0.01$; $n = 48$). Generally, the laying order did not affect egg volume. According to the value of $\%D = –1.8$ and the coefficient of egg weight variation ($CV = 9.39\%$) starlings follow the brood reduction strategy. The value of %D can be obtained by calculated the percentage of final egg volume in relationship to mean egg volume of the whole clutch (SLAGSVOLD *et al.*, 1984).

Key words: starling, egg size variations, laying order, NW Croatia

Dolenec, Z.: Korelacija između varijabli obilježja jaja i redoslijed polaganja jaja čvorka (*Sturnus vulgaris*) na području sjeverozapadne Hrvatske. Nat. Croat., Vol. 10, No. 1., 11–17, 2001, Zagreb.

U ovome radu analizirana je uzajamna ovisnost mase tijela ženki, duljina krila ženki, veličina pologa i dimenzije jaja populacije vrste čvorak *(Sturnus vulgaris).* Praćen je i utjecaj redoslijeda polaganja jaja u odnosu na volumen jaja. Prosječna duljina jaja iznosi 29.43 mm, širina 21.32 mm, volumen 6829 mm^3, masa jaja 6.92 g te indeks oblika jaja 1.38. Između mase tijela ženki i veličine pologa, te dimenzije jaja nije bilo statistički značajnih korelacija ($p > 0.05$). To se odnosi i na duljinu krila ženki. Statistički su značajne pozitivne korelacije između volumena i duljine jaja ($r = 0.68$; $p < 0.001$; $n = 48$), volumena i širine jaja ($r = 0.87$; $p < 0.001$; $n = 48$), duljine i indeksa oblika jaja ($r = 0.81$; $p < 0.001$; $n = 48$) kao i negativna korelacija između širine i indeksa oblika jaja ($r = –0.38$; $p < 0.01$; $n = 48$). Značajne korelacije između redoslijeda polaganja jaja i volumen jaja nije bilo niti jedne godine istraživanja. Prema iznosu %D vrijednosti (–1.8) i iznosa koeficijenta varijabilnosti mase jaja

(CV = 9.39 %) u čvoraka je tijekom razmnožavanja vjerojatno zastupljena strategija »smanjivanja legla« u slučaju nestašice hrane. Iznos %D vrijednosti dobijemo tako da izračunamo postotak volumena posljednjeg jajeta u odnosu na prosječni volumen pologa (SLAGSVOLD *et al.*, 1984).

Ključne riječi: čvorak, varijabilnost broja i dimenzija jaja, redoslijed polaganja jaja, sjeverozapadna Hrvatska

INTRODUCTION

Egg size dimensions are generally held to be important indices of egg quality and correlate with chick survival in many bird species, e.g. PARSONS (1970, 1975), NISBET (1973, 1978), MURTON *et al*. (1974), VERBEEK (1988) and HEGYI (1996). Birds possess several mechanisms by which they can adjust the magnitude and pattern of their breeding effort to environmental conditions and their own breeding condition (SLAGSVOLD *et al*., 1984). Research focuses on the variation of egg size as one of the mechanisms for adjusting the number of offspring (e.g. HOWE, 1976; RYDEN, 1978; GRANT, 1982; ZACH, 1982; POTTI, 1993; WILLIAMS, 1994). Nestlings hatched from large eggs grow faster (e.g. SCHIFFERLI, 1973), achieve higher fledgling mass (e.g. GREIG-SMITH *et al*., 1988), or have higher survival rates (e.g. O'CONNOR, 1979). According to SLAGSVOLD *et al*. (1984) the last egg in the clutch is of special importance. Birds which lay relatively big final eggs are adopting the brood-survival strategy (the last nestling is capable of rivalry with his older siblings), whereas birds which lay relatively small final eggs are adjusting to the brood-reduction strategy (the last nestling will be sacrificed in the event of food-shortage). If the incubation period increases with egg mass within a clutch and eggs hatch in the order laid, then the overall hatching asynchrony will be influenced by the relative size of the first and last laid eggs. A relatively large last-laid egg or small first-laid egg will increase the hatching asynchrony, while a small last-laid egg or large first-laid egg will reduce it (MAGRATH, 1992).

STUDY AREA, MATERIAL AND METHODS

The research took place in the village of Mokrice (46°00' N, 15°55' E) in NW Croatia. My studies comprise the period from 1998 to 1999. The study area is a mixed farming area with small meadows and arable land. The houses are surrounded by gardens and orchards. The arable land contains small woods (up to 10 ha) dominated by common oaks *(Quercus robur*) and hornbeams *(Carpinus betulus).* Many authors consider this kind of habitat the most adequate for the breeding of starlings (e.g. CRAMP & PERRINS, 1994). Nesting boxes used were made of wood and placed on trees in the orchards and forests within the arable land. From March 25 onwards, the nesting boxes were visited daily in order to record the laying of the first eggs. With no exception the females concerned laid one egg each morning until the clutch was completed. Starlings are known for intraspecific parasitism (e.g. YOM-TOV *et al*., 1974). Parasitically laid eggs were excluded from the analysis. In 1998 and 1999 each egg was numbered with a felt-tipped, waterproof marking pen

on the day it was laid to establish its laying order and measured to the nearest 0.01 mm with dial callipers. Using a precise »Tehnica« scale I determined the mass of 55 eggs (0.01 g).

Egg volume was calculated from the formula $V = 0.51\ LB^{2}$, where L is maximum egg length and B is maximum egg breadth (HOYT, 1979). The value of %D was calculated following the instructions by SLAGSVOLD *et al*. (1984) and used by other authors (e.g. BANBURA & ZIELINSKI, 1995). The value of %D can be obtained by calculating the percentage of final egg volume in relationship to the mean egg volume of the whole clutch. Egg shape index (ES) was calculated using the formula ES = L/B, where L is the length and B the breadth of the egg (SCHÖNWETTER, 1967–1979). Female wing length was measured by the maximum chord method to the nearest 0.5 mm. Only the first clutch was analysed. The starlings from Mokrice belong to the subspecies *S. v. vulgaris* (VAURIE, 1959).

RESULTS AND DISCUSSION

Egg size in relation to female characteristics and clutch size, mean values and correlations between egg-size variables

Egg length averaged 29.43 mm, egg breadth 21.32 mm, egg volume 6829 mm^3, egg weight 6.92 g and egg shape index 1.38 (Tab.1). This study is based on clutches rather than on single eggs. Between-clutch coefficients of variation are 4.03% for egg length, 2.46% for egg breadth, 8.17% for egg volume, 9.39% for egg weight and 4.35% for egg shape index. Tab. 2 shows the correlation between female body weight and female wing length, as well between some variables of egg dimensions. Egg volume and egg weight data are correlated in starlings ($r = 0.94$; $p < 0.001$; $n = 55$). Female body weight showed a statistically significant correlation with wing length, while other variables showed no correlation ($p > 0.05$). A positive correlation between female body weight and egg volume was registered in several species (e.g.

Tab. 1. Dimensions of eggs and the body weight and wing length of starling females in Mokrice village during 1998–99. Only first clutches included.

variable	mean	SD	range	N
wing length (female), mm	128.4	1.69	125.0–132.0	48
body weight (female), g	81.1	3.34	73.5–89.0	48
egg length, mm	29.43	1.18	25.95–31.58	93[a]
egg breadth, mm	21.32	0.52	20.02–22.36	93[a]
egg volume, mm^3	6829	548.55	5631–7867	93[a]
egg weight, g	6.92	0.65	5.81–8.06	55[b]
egg shape index	1.38	0.06	1.28–1.52	93[a]

a = number of clutches, b = number of eggs

Tab. 2. Pearson's correlation coefficients (2-tailed) between female body size and egg dimensions of starlings in Mokrice village during 1998–99 (n=48). Only first clutches included. Statistical significance: **p<0.01, ***p<0.001.

variable	female wing	clutch size	egg volume	egg length	egg breadth	egg shape index
female weight	0.43***	–0.03	0.03	–0.13	0.15	–0.21
female wing	_	0.18	–0.05	–0.04	–0.04	–0.02
clutch size	_	_	–0.20	–0.07	–0.07	–0.20
egg volume	_	_	_	0.68***	0.87***	0.11
egg length	_	_	_	_	0.25	0.81***
egg breadth	_	_	_	_	_	–0.38**

VÄISÄNEN *et al*., 1972; JÄRVINEN & PRYL, 1989). Clutch size showed no statistically significant correlation with other variables either. According to OJANEN *et al*. (1978) the starling is one of those birds whose egg size increases with clutch size. However, the results of this study are closer to those of GREIG-SMITH *et al*. (1988), according to whom an increase in clutch size causes the decrease of egg size. Egg length showed a positive correlation with mean egg volume and egg shape index. Egg breadth showed a significant positive correlation with mean egg volume and a significant negative correlation with egg shape index. A low negative correlation between clutch size and egg shape index may suggest the trend of mere rounded eggs in bigger clutches, whereas eggs in smaller clutches tend to be more oval. That would enable better covering during incubation and smaller loss of calcium.

Egg size variations in relation to the laying order

52 clutches were measured to analyse how laying order affects egg size (Fig.1). Only clutches of 5 or 6 eggs were analysed, which was the most common clutch size in the study area (DOLENEC, 1997). 14 clutches of 5 eggs and 13 of 6 eggs were analysed in 1998 and 13 clutches of 5 eggs and 12 of 6 eggs were analysed in 1999. In a comparison of the two years, 1998 and 1999, egg volumes in clutches of 5 eggs were significantly different ($F=2.02$; $p=0.004$; $df=25$), and the same could be applied to clutches of 6 eggs ($F=1.51$; $p=0.087$; $df=23$). The study shows a trend that in clutches of 5 eggs the biggest were in the middle of the laying order. This did not apply to clutches of 6 eggs. The biggest eggs of these clutches were laid on the 1st and 5th day. The laying order had no effect on egg volume in either year (1998: clutches of 5 eggs, $r=–0.01$; $p>0.05$; $n=70$, and clutches of 6 eggs, $r=–0.12$; $p>0.05$; $n=78$; 1999: clutches of 5 eggs, $r=–0.04$; $p>0.05$; $n=65$, and clutches of 6 eggs, $r=–0.12$; $p>0.05$; $n=72$). GREIG-SMITH *et al*. (1988) obtained similar results while OJANEN *et al*. (1981) registered a relationship between laying order and egg volume in clutches of 6 eggs, but not in clutches of 5 eggs. Analysing the laying order and

egg size per nest a significant correlation could be found in 16 out of 52 nests investigated. There are six statistically significant positive correlations (four $p<0.05$ and two $p<0.01$) and 10 negative correlations (five $p<0.05$, three $p<0.01$ and two $p<0.001$). These data are not sufficient for the making of a general conclusion that starlings adopt either the brood-survival strategy or the brood reduction strategy. In 1998 values of %D=–0.82 for clutches of 5 eggs and %D=–2.63 for clutches of 6 eggs were calculated. In 1999, values of %D=–1.41 for clutches of 5 eggs and %D=–2.38 for clutches of 6 eggs were found. For both study years values %D=–1.81 for a total of 52 clutches could be calculated. Since the final eggs are relatively small, there is a suggestion that starlings adopt the brood reduction strategy. This means that in the event of a food shortage, the last nestling is sacrificed. The coefficient of egg weight variation for the Mokrice area is CV=9.39%. O'CONNOR (1978) interprets variation in egg size as enhancing sibling competition, which should be high in brood reduction and small in clutch adjustment: Typical representatives of the brood reduction strategy, like the house sparrow *Passer domesticus*, have a coeffi-

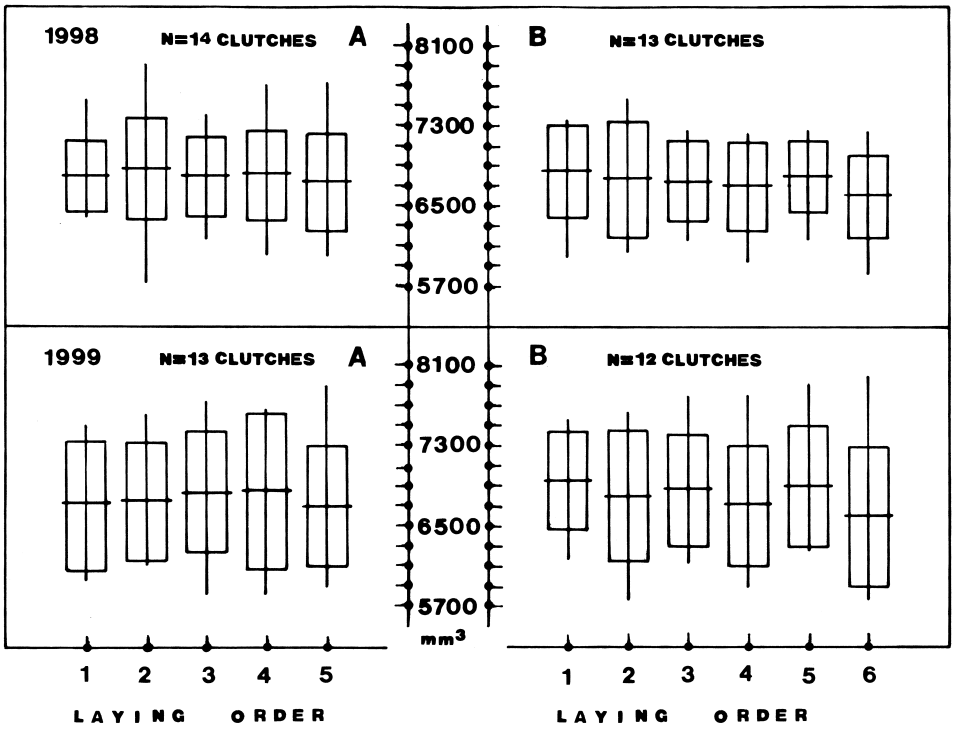

Fig. 1. Egg volume vs. laying sequence in 5 egg (A), and 6 egg clutches (B) of the starling in Mokrice village during 1998–99. Vertical lines indicate the range, horizontal lines the mean, and boxes one standard deviation on either side of the mean. Only first clutches included.

cient of variation for egg weight of 10.2%. According to this criterion the starling adopts the brood reduction strategy. According to both the value of %D and the coefficient of egg weight variation, starlings employ the brood reduction strategy.

Received February 10, 2000

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SAŽETAK

Korelacija između varijabli obilježja jaja i redoslijed polaganja jaja čvorka (*Sturnus vulgaris*) na području sjeverozapadne Hrvatske

Z. Dolenec

Posljednjih nekoliko desetaka godina mnoga su ornitološka istraživanja usmjerena prema nidobiološkim problemima. Ptice su tijekom razmnožavanja pod različitim utjecajem prilika u okolišu i vlastitih genetičkih obilježja. U ovome radu raspravlja se o korelaciji između dimenzija jaja, veličine pologa, tjelesne mase ženki, duljine krila ženki, te ovisnosti veličine jaja o redoslijedu polaganja jaja. Zatim, razmatra se koju strategiju primjenjuje čvorak u razdoblju razmnožavanja. Znatan broj ornitologa suglasan je da ptice primjenjuju dvije strategije: strategiju »preživljavanja legla« ili strategiju »smanjivanja legla« gdje bi u slučaju nedostatka hrane došlo do »žrtvovanja« jednog ili više potomaka (primjerice HOWE, 1976; O'CONNOR, 1979; SLAGSVOLD *et al.*, 1984). U ovome radu provjeravane su tri hipoteze. Prva hipoteza: ptice koje rabe strategiju »preživljavanja legla« karakterizira porast veličine jaja redoslijedom njihovog polaganja, a smanjenje veličine jaja redoslijedom polaganja karakterizira strategiju »smanjivanja legla«; druga hipoteza: nizak iznos koeficijenta varijabilnosti veličine jaja karakterističan je za strategiju »preživljavanja legla«, a visok iznos za strategiju »smanjivanja legla«; treća hipoteza: posljednje je jaje veće u odnosu na srednju vrijednost gnijezda kod strategije »preživljavanja

legla«, a manje ili sličnih vrijednosti prosjeka gnijezda kod strategije »smanjivanja legla«. Prema rezultatima ovih istraživanja u čvorka je vjerojatno prisutna strategija »redukcije legla« budući da je registriran visok iznos koeficijenta varijabilnosti mase jaja i posljednje jaje je manje u odnosu na srednju vrijednost pologa. Rezultati prve hipoteze nisu podržali niti jednu od spomenutih strategija, budući da nije bilo niti statistički značajnog rasta niti smanjivanja volumena jaja redoslijedom polaganja.