

LARUS Hrvatska akademija znanosti i umjetnosti	57 (2022)	7-12 str.	Zagreb 2022.
	Primljeno 7.7.2022. Prihvaćeno na sjednici Razreda za prirodne znanosti HAZU 17.11.2022.		

UDK 598.289(497.5)

Original scientific paper
Izvorni znanstveni članak
DOI: 10.21857/ydkx2co8n9

ADAPTIVE FINAL (LAST-LAID) EGGS IN THE EURASIAN BLUE TIT *Cyanistes caeruleus*

*Prilagodbe posljednje snesenih jaja kod plavetne sjenice
Cyanistes caeruleus*

ZDRAVKO DOLENEC

Mokrice 132, 49243 Oroslavje, Croatia

ABSTRACT

The study was carried out in 2021 using nestboxes. I examined the egg-laying pattern of the socially monogamous free-living Eurasian Blue Tit *Cyanistes caeruleus* that breeds only once a year in the north-western Croatia. Nestboxes were visited daily to record the laying date of the first and subsequent eggs. A total of 132 eggs from 12 clutches with 11 eggs in each nest (11-egg clutch is the dominant clutch size in the study area) was measured. The mean egg volume was 1.19 cm³ (\pm 0.12), and the mean egg volume of all final eggs was 1.22 cm³ (\pm 0.09). In this study, the %D-value was 2.46. According to this value, the Eurasian Blue Tit population in north-western Croatia adopt a "brood survival strategy", where females allocate greater resources in the final eggs.

Keywords: Eurasian Blue Tit, *Cyanistes caeruleus*, breeding strategy, %D-value, NW Croatia

INTRODUCTION

Egg size has proven to vary widely among populations of the same species and among species. The egg volume (or/and mass) in birds is among the most extensively investigated life-history parameters. Egg size is an important index of egg quality and is positively connected with hatching weight and chick survival

in numerous bird species (e.g. KRIST 2011). Egg size is correlated to many factors, such as female age (e.g. VERHOEVEN *et al.* 2020), maternal body mass (LISLEVAND *et al.* 2005), population density (PERRINS & McCLEERY 1994), laying sequence (SONG *et al.* 2016), habitat differences (e.g. BAÑBURA *et al.* 2010), year-to-year differences (e.g. ADAMOŪ *et al.* 2018), climate change (SKWARSKA *et al.* 2015), and elevation gradient (JOHNSON *et al.* 2006). SLAGSVOLD *et al.* (1984) and some other authors have searched for patterns of variation within clutches among bird species, in an attempt to uncover adaptive, ultimate adjustments in egg-size allocation patterns (hypothesized that female birds might adaptively vary egg size). The aim of this work was to exhibit the variation of eggs in the Eurasian Blue Tit population, with special regard to the relationship between the volume of final egg and the mean volume of all eggs in clutch (%D-value, according to SLAGSVOLD *et al.* 1984).

MATERIAL AND METHODS

a) The study species

The Eurasian Blue Tit is a small, socially monogamous and single-brooded passerine, common in mixed and deciduous forests throughout the Western Palearctic (CRAMP 1998). Single-brooded species lay only a single clutch in a short breeding season (replacement clutches can occur after brood failure). Females lay one egg per day until the clutch is complete (7-15 eggs in north-western Croatia, unpublished data). According to DOLENEC (2018), the population of the Eurasian Blue Tit in the study area was able to respond to spring warming changes during a 37-year period (the breeding date has advanced by 11 days). In north-western Croatia, the Eurasian Blue Tit is a bird of forest areas, parks, villages and small isolated forests. It also inhabits large gardens, especially where nestboxes are provided.

b) Study area, material and methods

The study was conducted in the 2021 breeding season in the Mokrice and Krušljevo Selo areas (45°58'–46°00'N, 15°51'–15°55'E, altitude approximately 140 m, mixed deciduous forests, dominate Pediculate Oak *Quercus robur* and Common Hornbeam *Carpinus betulus*), north-western Croatia. I studied the Eurasian Blue Tit breeding in nestboxes that had internal dimensions of approximately 120 mm × 120 mm × 220 mm, the diameter of the entrance hole being 26 and 32 mm, and the walls 25 mm thick. Numerous different ornithological works around the world (also in Croatia) have been based on the use of nestboxes by birds (e.g. HOOVER *et al.* 2020, DOLENEC 2021). In some hole-nesting bird species, nestbox orientation influences nestbox occupation and breeding success, however not in the Eurasian Blue Tit (GOODENOUGH *et al.* 2008). Therefore, nestbox orientation was not controlled. In several bird species, the use of nestboxes results in higher-quality breeding than with natural holes (e.g. NORRIS *et al.* 2018). In this study, all

observations were recorded by author. All nestboxes had a sliding top in order to monitor the nest. Nestboxes were visited daily to record the laying date of the first and subsequent eggs. All eggs in the clutch were numbered with indelible ink. The maximum length (L) and the maximum breadth (B) of egg were measured with calliper to the nearest 0.01 mm. Egg volume (V) was calculated according to HOYT's (1979): $V = 0.51 (\text{constant}) \times L \times B^2$; for example, this method was used by GÓRSKI *et al.* 2015, DOLENEC 2020, etc. Relative size of the final egg was calculated as percent deviation from mean volume of all eggs in the clutch: %D-value = $(VF - VM)100 / VM$, in which VF = volume of the final egg and VM = mean egg volume of the clutch (SLAGSVOLD *et al.* 1984). Statistical analyses were conducted using SPSS software Version 17.0.

RESULTS AND DISCUSSION

I examined the egg-laying pattern of the Eurasian Blue Tit in north-western Croatia. A total of 132 eggs was included in the analysis from 12 clutches with 11 eggs in nest (11-egg clutch is the dominant clutch size in the study area). The mean volume of all eggs was $1.19 \text{ cm}^3 (\pm 0.12)$, and the mean egg volume of final eggs was $1.22 \text{ cm}^3 (\pm 0.09)$. In this study, the %D-value was 2.46. SLAGSVOLD *et al.* (1984) identified two strategies (based on the hypothesis that female birds might adaptively vary egg size): birds laying relatively larger final eggs adopt the "brood survival strategy" (the last nesting is capable of rivalry with its older siblings), whereas birds laying relatively small final eggs adjust to the "brood reduction strategy" (the last nestling will be sacrificed in the event of food shortage). According to GRAVES *et al.* (1984), the final egg may serve as "insurance" against loss of an earlier-laid egg or an older sibling species, in which the entire brood rarely fledges or survives to breed. Following the arguments of SLAGSVOLD *et al.* (1984), the Eurasian Blue Tit population in north-western Croatia would therefore adopt a "brood survival strategy", where females allocate greater resources in the final eggs of the clutch which have a high reproductive value. "Brood survival strategy" in passerine was documented for numerous bird species. For example, in the Black Redstart *Phoenicurus ochruros* (DOLENEC 2006, SONG *et al.* 2016), the Grey-backed Shrike *Lanius tephronotus* (FAN *et al.* 2021), the Blackcap *Sylvia atricapilla* (DOLENEC 2004), the Goldcrest *Regulus regulus* (HAFTORN 1986), the Barn Swallow *Hirundo rustica* (DOLENEC 2002), etc. Contrary thereto, the female Saxaul Sparrow *Passer ammodendri* (BAO *et al.* 2020) adopts a "brood reduction strategy" for both the first (negative %D-value) and the second clutches (also negative %D-value). According to DOLENEC *et al.* (2011), the multi-brooded Tree Sparrow *Passer montanus* uses both these strategies within one season. According to the %D-value, the Tree Sparrow females choose the "brood reduction strategy" for the first and third clutches (negative %D-value), whereas for the second clutch they follow the

“brood survival strategy” (positive %D-value). Furthermore, the impacts of climate change on worldwide are beginning to be seen across the Earth. Many studies have demonstrated that particular species of birds are arriving and breeding earlier than in the past. For example, the Eurasian Golden Oriole (*Oriolus oriolus*) arrival dates in Croatia (DOLENEĆ 2022) have become six days earlier during the study period (1991–2016). The relationship between spring temperatures and year, and spring temperatures and timing of arrival was significant. This result suggests that the Eurasian Golden Oriole respond to spring temperatures by earlier arrival at breeding grounds. Furthermore (DOLENEĆ 2019), the laying date of the Common Starling *Sturnus vulgaris* advanced up approximately eight days in the study period from 1980 to 2016. The clutch initiation date was significantly negatively correlated with the spring temperature over the study period. This result suggests that the laying date of the Common Starling is influenced by warm springs. Therefore, the impact of climate change ought to be even more strongly involved in the investigation of biological performance in birds.

In conclusion, the Eurasian Blue Tit population in north-western Croatia has adopted a “brood survival strategy”, where females allocate greater resources in the final eggs. This is consistent with the view put forward by HOWE (1976), stating that larger egg size (volume or mass) represents parental effort to increase the survival chances of the late hatched young. Future research should concentrate on following the fledgling and recruitment success of chicks in relation to their position in the laying sequence.

References

- ADAMOŪ, A. E., TABIB, R., KOUIDRI, M., OUAQID, M. L., GŁADALSKI, M., BAŃBURA, J. (2018): Egg Size and Shape Variation in Rufous Bush Chats *Cercotrichas galactotes* Breeding in Date Palm Plantations: Hatching Success Increases with Egg Elongation. *Avian Biology Research* 11: 100-107.
- BAŃBURA, M., SULIKOWSKA-DROZD, A., KALIŃSKI, A., SKWARSKA, J., WAWRZYŃIAK, J., KRUK, A., ZIELIŃSKI, P., BAŃBURA, J. (2010): Egg size variation in Blue Tits *Cyanistes caeruleus* and Great Tits *Parus major* in relation to habitat differences in snail abundance. *Acta Ornithologica* 45: 121-129.
- BAO, X., ZHAO, W., LIU, F., LI, J., MA, D. (2020): Egg investment strategies adopted by a desertic passerine, the Saxaul Sparrow (*Passer ammodendri*). *Avian Research* 11:15 <https://doi.org/10.1186/s40657-020-00201-0>
- CRAMP, S. (1998): Complete Birds of Western Palaearctic's on CD-ROM. Oxford University Press, Oxford.
- DOLENEĆ, Z. (2002): Breeding characteristics of the barn swallow (*Hirundo rustica*) in NW Croatia. *Natura Croatica* 11: 439-445.
- DOLENEĆ, Z. (2004): Relationship between laying order and egg dimensions in the Black-cap *Sylvia atricapilla*. *Acta Ornithologica* 39: 176-179.

- DOLENEC, Z. (2006): Egg dimensions variation in relation to the laying order in Black Redstart (*Phoenicurus ochruros* Gmelin, 1774) in NW Croatia. *Belgian Journal Zoology* 136: 257-258.
- DOLENEC, Z. (2018): Results of long-term monitoring of timing of laying in deciduous forest Blue Tit (*Cyanistes caeruleus* L.) in northwestern Croatia. *Šumarski list* 142: 381-386. (In Croatian with English summary)
- DOLENEC, Z. (2019): Temporal shift in timing of breeding of European starling (*Sturnus vulgaris* Linnaeus) population. *Current Science*, 116: 29–30.
- DOLENEC, Z. (2020): Contribution of oology of the Eurasian wryneck *Jynx torquilla*. *Natura Croatica* 2: 123-128.
- DOLENEC, Z. (2021): Nestbox floor area size and breeding performance: a study on the Common Starling *Sturnus vulgaris*. *Larus* 56: 67-71.
- DOLENEC, Z. (2022): Dates of arrival of the Eurasian golden oriole *Oriolus oriolus* (Linnaeus, 1758) in relation of local air temperature in NW Croatia. *Šumarski list* 146: 149-152.
- DOLENEC, P., KOCIJAN, I., DOLENEC, Z. (2011): Intra-seasonal changes in reproductive strategy of a multi-brooded passerine: the tree sparrow *Passer montanus*. *Ethology Ecology and Evolution* 23: 368-374.
- FAN, L., GAO, L., ZHU, Z., ZHANG, X., ZHANG, W., ZHANG, H., LI, J., DU, B. (2021): The Grey-backed Shrike parents adopt brood survival strategy in both the egg and nestling phases. *Avian Research* 12:11. <https://doi.org/10.1186/s40657-021-00244-x>
- GOODENOUGH, A. E., MAITLAND, D.P., HART, A. G., ELLIOT, S. L. (2008): Nestbox orientation: a species-specific influence on occupation and breeding success in woodland passerine. *Bird Study* 55: 222-232.
- GÓRSKI, A., NOWAKOWSKI, J. J., BAŃBURA, J. (2015): Variation in egg-size traits of the European Roller (*Coracias garrulus*) in eastern Poland. *Ornis Fennica* 92: 213-220.
- GRAVES, J., WHITEN, A., HENZI, P. (1984): Why does the herring gull lay three eggs? *Animal Behaviour* 32: 798-804.
- HALUPKA, L., CZYŻ, B., DOMINQUEZ, C. M. M. (2020): The effect of climate change on laying dates, clutch size and productivity of Eurasian Coots *Fulica atra*. *International Journal of Biometeorology* 64: 1857-1863.
- HOOVER, J. P., DAVROS, N. M., SCHELSKY, W. M., BRAWN, J. D. (2020): Local conspecific density does not influence reproductive output in a secondary cavity-nesting songbird. *Auk* 137: 1-15.
- HOWE, H. E. (1976): Egg size, hatching asynchrony, sex, and brood reduction in the Common Grackle. *Ecology* 57: 1195-1207.
- HOYT, O. F. (1979): Practical methods of estimating volume and fresh weight of bird eggs. *Auk* 96: 73-77.
- JOHNSON, L.S.C., OSTLIND, E., BRUBAKER, J. L., BALENGER, S. L., BONNIE G. P. JOHNSON, B. G. P., GOLDEN, H. (2006): Changes in egg size and clutch size with elevation in a Wyoming population of Mountain Bluebirds. *Condor* 108: 591-600.
- KRIST, M. (2011): Egg size and offspring quality: a meta-analysis in birds. *Biological Reviews* 86: 692-716.

- LISLEVAND, T., BYRKJEDAL, I., BORGE, T., SAETRE, G.-P. (2005): Egg size in relation to sex of embryo, brood sex ratios and laying sequence in northern lapwings (*Vanellus vanellus*). *Journal of Zoology* 267: 81-87.
- NORRIS, A. R., AITKEN, K. E. H., MARTIN, K., POKORNY, S. (2018): Nest boxes increase reproductive output for Tree Swallows in a forest grassland matrix in central British Columbia. *PLoS ONE* 13(10): e0204226.
- PERRINS, C. M., MCCLERY, R. H. (1994): Competition and egg-weight in the Great Tit *Parus major*. *Ibis*: 136: 454-456.
- SKWARSKA, J., KALIŃSKI, A., WAWRZYŃIAK, J., BAŃBURA, M., GLĄDALSKI, M., MARKOWSKI, M., ZIELIŃSKI, P., BAŃBURA, A., BAŃBURA, J. (2015): Variation in egg sizes of Pied Flycatchers *Ficedula hypoleuca* in central Poland: a long-term decreasing trend. *Acta Ornithologica* 50: 85-94.
- SLAGSVOLD, T., SANDVIK, J., ROFSTAD, G., LORENTSEN, O., HUSBY, M. (1984): On the adaptive value of intra-clutch egg-size variation in birds. *Auk* 10: 685-697.
- SONG, S., CHEN, J., JIANG, B., LIU, N. (2016): Variation in egg and clutch size of the Black Redstart (*Phoenicurus ochruros*) at the northeastern edge of the Qinghai-Tibetan Plateau. *Avian Research* 7:20. DOI: 10.1186/s40657-016-0055-0
- VERHOEVEN, M. A., LOONSTRA, A. H. J., MCBRIDE, A. D., TINBERGEN, J. M., KENTIE, R., HOOIJMEIJER, J. C. E. W., BOTH, C., SENNER, N. R., PIERSMA, T. (2020): Variation in Egg Size of Black-Tailed Godwits. *Ardea* 107: 291-302.

SAŽETAK

Na šumskom području Mokrica i Krušljevog Sela (45°58'– 46°00'N, 15°51'–15°55'E; sjeverozapadna Hrvatska) na drveće su postavljane škrinjice za gniježđenje sjenica kako bi se prikupili podaci za analizu strategije gniježđenja plavetne sjenice *Cyanistes caeruleus*. Jaja su svakodnevno označavana vodootpornom tintom kao bi se znalo koje je posljednje sneseno jaje u gnijezdu. Prvih dana inkubacije sva su jaja izmjerena kako bi se izračunao njihov volumen. %D-vrijednosti (postotak volumena posljednje snesenih jaja u odnosu na volumen svih jaja u gnijezdu) izračunat iznosio je 2,46. Ptice pozitivne %D-vrijednosti primjenjuju „strategiju preživljavanja potomstva“ što znači da ženke plavetnih sjenica usmjeravaju najviše resursa u posljednja jaja kako bi potomci iz tih jaja bili konkurenti ostalim mladuncima u gnijezdu.