Ornithological research in the system of natural scientific education

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Abstract. Ornithological research on natural science education develops creative activity, independence, logical thinking, responsibility and initiative of students, the ability to correctly use biological methods, contribute to self-education and self-education, form an active life position. The study of the clutch size and morphometric features of great tit eggs showed their dependence on many factors that regulate the number of individuals and affect the formation of the population as a whole. The impact of exogenous factors on birds is perceived differently due to their heterogeneity, which was later expressed in the ratio of large and small clutches, a decrease in their number. The dependence of the formation of biological heterogeneity of great tit eggs in each clutch under the influence of environmental factors is established. The conducted research stimulates cognitive interest, activates mental activity, memory, attention, using a variety of form and content of ornithological methods that contribute to the formation of the foundations of worldview and moral experience of relationships with the environment.

1. Introduction
Solving environmental problems is a nationwide task that requires the formation of an environmental culture of the population and, first of all, students [1]. They will have to educate a generation that provides gentle ways of using natural resources and which can only exist in harmony with nature. Increasing the level of ecological education is successfully carried out in the implementation of applied ornithological research, especially those based on taking into account the influence of anthropogenic factors on the air avifauna. Therefore, in the system of developing the scientific foundations of nature protection and rational use of resources, a comprehensive study of the nesting life of birds is becoming more and more urgent. The aim of this work is to study the clutch size and morphometric characteristics of the eggs of the great tit (Parus major).

2. Material and research methods
The study was carried out on the territory of the agrobiostation of the Michurinsk State Agrarian University, located on the right bank of the Lesnoy Voronezh River near Michurinsk, Tambov Region in 2016-2019. In order to attract hollow nesting birds and obtain material on the great tit, artificial nests with removable covers were used, hung at a distance of 5 to 50 m from each other with a tap hole diameter of 3.5 cm. All artificial nests were mapped. The optimization of the food supply was carried...
out in the form of feeding the birds in the winter. The time of laying the first and subsequent eggs was noted [2, 3]. Statistical analysis was carried out using standard methods using the software packages Microsoft Excel, Statistica for Windows 5.02, FSTAT. The reliability of the data was determined by the Student’s t-test

3. Results and discussion

Mass nesting in the great tit in the studied region takes place in the period from 7.04 to 30.04, when the air temperature ranges from +1.6 to 13.5 °C, the earliest beginning of nesting in single pairs was recorded at 1.04, later at 1.05. This is no exception compared to other regions. One married couple builds a nest on average (\(n = 41\)) 16.2 days with fluctuations from 6 to 21 days.

The duration of the construction of the nest depends on several factors. The timing of the start of this process is of decisive importance. Couples who started building the nest in the first ten days of April completed it on average (\(n = 25\)) in 17.6 days, in the second ten days (\(n = 10\)) - in 15 days, and in the third ten days of April (\(n = 5\)) - 12 days. The size of the nest is of no small importance. Having chosen a nest niche, the great tit seeks to fill all its internal space with construction material. Our observations, as well as the work of a number of researchers, show that the size of the nest of this bird depends on the size of the nest it has chosen. In large nesting sites, the titmouse spend more time building a nest (on average 19.8 days) than in small ones (on average, 14.7 days, \(P = 0.992\)). It is interesting to note here that artificial nesting sites with a large internal area, in this case birdhouses, are populated mainly by early nesting individuals (90.9% of the number of birdhouses occupied by the titmouse).

Tits build nests in two stages. At the first stage, which lasts 2–7 days (on average 4.1 days), the birds make the base of the nest, which consists mainly of moss. The second stage is longer: 3–19 days (average 11.9 days). During this period, a tray is made of wool. As a rule, nesting, usually the second stage, in the great tit is overlapped by the egg-laying period, which is also typical for other representatives of the genus parus. Of the 40 surveyed nests, only in 2 (5%) construction was completed by the beginning of egg laying period, in 36 (90.0%) nests it was completed during the egg laying period and in 3 (5.0%) in the first 1-2 days. the actual incubation.

Mass oviposition in great tits in the area takes place from 16.04 to 2.05. The earliest was recorded on 10.04, the latest - 13.05. The duration of oviposition in one married couple is on average (\(n = 54\)) 11.7 days. In most cases, egg-laying proceeds rhythmically, after 24 hours. Arrhythmic clutches with a break of 48 hours or more were noted in only 30.4% of cases. The great tit in the first breeding cycle lays from 9 to 15 eggs (on average 11.5). Clutches of 10–12 eggs are more common than others. In the second cycle, birds lay 7–12 eggs (on average 8.7). Clutches of 8-9 eggs are most common. Differences in the size of the first and second clutches are reliable.

The average size of the eggs of the great tit, taking into account the first and second cycles, is 17.4 x 13.3 mm, and the mass of a freshly laid egg is 1.647 g. The variability of sizes is in the range of 14.9–20.0 x 11.5–14.1 mm. The mass ranges from 1.06 to 2.07 g. The largest number of eggs was from 1.61 to 1.80 g - 51.4%. The second most significant was the class with a weight from 1.41 to 1.60 g - 31.5%, the third - a class with a weight of 1.81–2.00 g. The class with an egg weight of 1.20–1.40 g was the largest number of options. In addition, one egg had a mass of 1.06, and another - 2.07 g. The female lay larger and heavier eggs in the second reproductive cycle. Their average size is 17.7–13.5 mm, weight – 1.758 g. In the first reproductive cycle, the average size of eggs is 17.4–13.2 mm, weight –1.626 g (\(P <0.999\)).

During the breeding season from April 28 to June 10, 2016, 6 clutches were revealed at an agrobiostation with an area of about 7 hectares, one of which was arrhythmic and 1 was repeated. The number of eggs in a clutch varies from 10 to 12, while the arrhythmic and repeated clutches have a smaller number of eggs, that is, 10. The mass of eggs, the largest in arrhythmic and repeated clutches, 1.93 ± 0.02 and 1.8 ± 0.01 g, respectively. The level of intra-layer variability of egg mass, determined through the coefficient of variation, is in the range of 3.21–6.82%, which shows the diversity females by the value of eggs variability within clutches. The interlayer variability is 4.8% (Table 1).
The characteristics of eggs in one clutch for 0.5 days of incubation after its completion are presented in Table 2.

It was found that after the completion of the laying, its mass decreased, while the relative "shrinkage" is $2.39 \pm 0.27\%$. However, the coefficient of variation of this indicator is significant (53.47%), which indicates significant differences in the change in weight during oviposition. The relative "shrinkage" increased on the 4th day of incubation and retained significant variability (64, 68%).

In 2017, oviposition was observed from April 27 to May 23, and the late clutch was repeated and laid in the nest, which contained day old chicks.

Table 1. Characteristics of oviposition of the great tit, 2017.

| Start oviposition | Number eggs in masonry | Type oviposition | Mass of non-incubated eggs, g |
|------------------|------------------------|-----------------|-------------------------------|
| Time             |                        |                 | Mmdl. ±m | lim | Cv, % |
| Start | End | Start | End | Rhythmic | 1.72±0.02 | 1.62-1.85 | 4.61 |
| 28.04 | 09.05 | 12 | Rhythmic | 1.78±0.02 | 1.64-1.98 | 6.82 |
| 13.05 | 24.05 | 12 | Rhythmic | 1.73±0.02 | 1.55-1.85 | 5.05 |
| 14.05 | 24.05 | 10 | Arrhythmic (9 eggs appeared after 48 hours) | 1.93±0.02 | 1.80-2.02 | 4.53 |
| 01.06 | 10.06 | 10 | Rhythmic (repeated in place of 1 clutch) | 1.8±0.01 | 1.7-1.9 | 3.21 |

The number of eggs in a clutch was on average 10 with vibrations from 8 to 12. There are 2 types of egg-laying: rhythmic ($n = 2$) and arrhythmic ($n = 3$). Arrhythmia was noted both from the middle of oviposition and at its end, while in a nest of 8 eggs, three delays in the appearance of the next egg were revealed. The total time of laying in rhythmic clutches fluctuates from 9 to 10, and in arrhythmic clutches 9–12 days. Clutches differ in egg mass from 2.09 ± 0.06 to 1.62 ± 0.04 ($t_a=6$).

Arrhythmia determines a large heterogeneity in the mass of eggs within one clutch. So, if the coefficient of variation in rhythmic clutches was small and equal to 1.46 and 3.26%, then in arrhythmic ones it was significant and ranged from 13 to 17%. Length and width of eggs are the least variable compared to weight.

Observations of the growth of chicks of the great tit evidence of their heterochronicity, which, to a certain extent, is caused by the difference in time of hatching. The hatching of chicks in six nests was monitored every hour, and their weighing was monitored every three days. The materials on the growth of chicks were combined into one group depending on their time rank. The time rank of the eggs was not taken into account. There was a regular increase in the initial weight of chicks from the first (1.237 g) to the fifth (1.28 g), followed by a decrease in the sixth (1.19 g), the seventh (1.06 g), the last four chicks had a high weight again. In the first 8 days, the first - sixth chicks grow most intensively. By this time, their mass exceeds 12.1 g. The mass of subsequent chicks ranges from 9.26 (eleventh chick) to 11.57 g (seventh chick). Only in the tenth was it 12.01 g. In the last days of stay in the nest (15 days old), the weight of the first seven chicks, with the exception of the third, is higher and ranges from 18.85 g (first chick) to 19.35 g (sixth chick). The mass of the last four is lower - from 18.55 g (eleventh chick) to 18.79 g (tenth chick). The third chick has a minimum weight of 18.42 g.
Table 2. Characteristics of eggs of one rhythmic clutch of great tit, 0.5 days of incubation after its completion, 12 eggs.

| Indicators | M mdl. ±m | lim | Cv, % |
|------------|-----------|-----|-------|
| The mass of eggs, g | | | |
| of non-incubated eggs | 1.78±0.02 | 1.640–1.980 | 6.82 |
| 0.5 days of incubation after the laying is complete | 1.74 ± 0.02 | 1.590–1.944 | 7.01 |
| Egg length, cm | 1.75±0.01 | 1.700–1.840 | 2.59 |
| The width of the egg, cm | 1.39±0.01 | 1.31–1.46 | 2.92 |
| The index of elongation eggs, % | 79.32±0.46 | 74.85–82.46 | 2.86 |

"Shrinkage" of eggs

| absolute, g | 0.05 ± 0.01 | 0.007–0.089 | 40.74 |
| relative, % | 2.39 ± 0.27 | 0.34–5.0 | 53.47 |

Analysis of the relative growth over equal time intervals also makes it possible to trace the heterochronism of the growth of the great tit chicks [4]. From the first to the fourth days of nesting life, the weight of the first seven chicks increased by 460–498%, and the last four - only by 362–424%; on the fifth to twelfth days, on the contrary, the average gain in the seventh to eleventh chicks was lower than in the first to sixth (from 307 to 358% and from 274 to 292%, respectively). From the thirteenth to the eighteenth days, the growth of all chicks in the brood had similar values (110–117%).

The results of the analysis allow us to divide the brood of the great tit into 2 groups: main and additional. The main one includes the first to sixth chicks, the additional one - the seventh to eleventh. In both groups, an increase in the initial mass of chicks from the first to the last is observed. Only in the sixth does the mass decrease. This pattern allows all chicks of a given group to develop relatively evenly.

There is also a relationship between the nature of the increase in the mass of chicks and their death [5,6]. Trampling of weak chicks occurs mainly in the first days of their life. During this period, weight gain is higher in the first group, which increases the percentage of survival of the chicks in this group. In the studied broods, only the second group died of chicks. From the fifth to the twelfth day, the higher weight gain of the chicks of the second group allows the remaining chicks to catch up in growth of the individuals of the first group. In the last days of nesting life, the development of all chicks is approximately the same.

Of particular interest is the analysis of the breeding success of the great tit [7,8]. In total, 871 eggs were laid in 88 nests of the first and second cycles, of which 79.6% hatched, and 73.6% of chicks left the nest. In the first reproductive cycle, breeding success is 73.5% and is achieved due to the high survival rate of chicks (94.4%); in the second case, it is equal to 74.0% due to almost the same survival rate of embryos and chicks (85.1 and 87.0%, respectively). In general, the great tit has a higher chick survival rate (92.5%) than that of embryos (79.6%).

The main reasons for the abandonment of embryos and chicks are embryonic mortality, which means the percentage of talkers and suffocators without taking into account the death of eggs from predators, abiotic factors and as a result of the owners leaving the nests. We also included eggs that have shrunk due to an overly thin shell in this category.

In the first reproductive cycle, embryonic mortality is noticeably higher (9.2%) than in the second (7.2%). In general, in the great tit it is characterized by instability: in 1983 - 15.1%; in 2016 - 6.6%; in 2017 - 9.4%; in 2018 - 7.5%. The 60 talkers you found were distributed as follows: 1 egg in 27 nests (75.0%), 2 eggs in 6 (16.6%), 4.6 and II in 1 nest (2.8%). The ratio of these two categories of defective eggs was 1: 1, but it should be noted that a high percentage of suffocation was obtained due to their
large number in individual nests. Nests with talkers are much more common (25 nests, or 69.4%) than with suffocated nests (11 nests, or 30.6%). In the first reproductive cycle, the number of talkers and suffocators is higher than in the second (25.0%). In addition, 1-4 eggs with very thin shells were found in 7 nests of the first cycle: they were eliminated due to drying out.

In general, embryonic mortality in the great tit is 42.7% of the total egg loss. The remaining 57.3% die as a result of the abandonment of clutches due to the frequent disturbance of birds by humans (69.6% of the number of abandoned birds), competition from the pied flycatcher (18.6% of eggs). In one case (11.8% of eggs), a nest with hatched eggs was abandoned as a result of an attack by black forest ants.

The main reason for the death of nesting chicks of the great tit is the trampling of the weaker ones by the strong, who hatched last. Moreover, the greater the extension of the hatching of the brood, the more chicks are trampled in it. We found 45 trampled chicks: 1 chick each in 7 nests (35.0%), 2 each in 8 nests (40.0%), 3-4-5 each in 1 nest (5.0% each), 6 - in 2 nests (10.0%). In addition, in one nest, a case of death of a part of the brood due to illness was noted (presumptive diagnosis - psittacosis): the birds were weak, breathing heavily, and mucus secreted from the nostrils. 7 out of 8 chicks died 2-4 days before departure.

The mortality rate of chicks in the first cycle was 5.6%, in the second - 13.0% - The overall mortality rate reached 7.5%. In conclusion, it should be noted that in the region under study, one pair of great tits per season raises an average of 10.0 chicks before leaving the nest, which is 73.6% of the total number of laid eggs. Two broods per season have on average 50.0% of pairs of tits, with fluctuations in different years from 32.1 (2016) to 83.3% (2018).

Thus, the adaptive mechanisms of reproduction of the great tit are aimed at the formation of strong offspring.

4. Conclusions
The dependence of the clutch size and morphological parameters of eggs in the great tit on the time of clutch appearance was established. Early clutches are larger in size, and eggs in them with smaller morphometric parameters compared to later clutches. In the identified relationship, we see an adaptive mechanism of the population aimed at its successful reproduction. The size of the clutch of birds corresponds to the largest number of chicks that parents, under average conditions, can provide with food. Late nesting individuals breed in the worst conditions. Consequently, their clutch is smaller, but individual eggs are larger than in early clutches. Larger and stronger chicks hatch from them, due to which the worst conditions are leveled. To this should be added the indications of a number of researchers that the variability of the size of the clutch and the external characteristics of the eggs of the great tit is hereditary.

Ornithological research in the system of natural science education not only expands the scientific horizons of students, but also allows them to develop research competencies and form the ecological culture of future teachers.

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