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Breeding phenology of Common Redstart *(Phoenicurus phoenicurus)* and its reproduction biology with artificial nests in Northeastern Ukraine

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Abstract The paper describes investigations on the reproduction biology (nesting, clutching, hatching, fledglings` departure) of the Common Redstart *(Phoenicurus phoenicurus)* in artificial nest boxes (AN) in Northeastern Ukraine. There were three sites of research: Hetman NNP, NPP "Gomilshansky Forests", and RLP "Feldman Ecopark". The research was performed during the nesting period from the first week of April to the first week of July in 2015–2020. Annually, 5–8 bird counts were conducted at each site. The first complete egg clutches at Hetman NNP were observed from 08.05 to 17.05 (2015–2020) and at NPP "Gomilshansky Forests" from 02.05 to28.05 (2017–2020). Dates of the first egg laying, at various conditions, had inter-annual variability because of unstable weather conditions in May. The average parameters of nests in AN at Hetman NNP were the following: diameter of nests (D) – 124.1±6.3 mm; diameter of trays (d) – 61.5±1.7 mm; nest height (H) – 63.5±9.4 mm; depth of trays (h) – 48.6±2.7 mm; nest mass (m) – 43.7±3.8 mm. The size of complete clutches in Northeastern Ukraine was calculated when eggs were incubated. According to the average indicators, during 2015–2020, the average size of the clutch was 6.9±0.3 (5–8) eggs at Hetman NNP, 6.2±0.4 (6–8) eggs at NPP "Gomilshansky Forests" and 8.5±0.5 (8–9) eggs at RLP "Feldman Ecopark". Incubation period of *Ph. phoenicurus* lasted on average for 15–20 days.

Keywords: Common Redstart, Hetman NNP, NPP "Gomilshansky Forests", RLP "Feldman Ecopark", artificial nestboxes (AN), reproduction biology

Összefoglalás A cikk a kerti rozsdafarkú *(Phoenicurus phoenicurus)* szaporodásbiológiájával (fészkelés, kikelés, fiókák kirepülése) kapcsolatos kutatásokat ismerteti, melyeket kihelyezett mesterséges fészkek alkalmazásával végeztek Északkelet-Ukrajnában. Három helyszínen történtek vizsgálatok, a Hetman Nemzeti Természeti Parkban, a „Gomilshansky Forests" Nemzeti Természeti Parkban és a „Feldman Ökopark" Regionális Tájvédelmi Parkban. A kutatást a fészkelési időszakban, április első hetétől július első hetéig végezték 2015–2020-ban. Évente 5–8 madárszámlálást végeztek minden helyszínen. A Hetman NTP területén május 8-tól május 17-ig (2015–2020 között), a „Gomilshansky Forests" NTP területén pedig május 2-től május 28-ig (2017–2020 között) figyelték meg az első teljes fészekaljakat. Az első tojásrakás időpontja évenként változott a májusi kiszámíthatatlan időjárás miatt. A Hetman NTP területén kihelyezett mesterséges fészekodúk esetén a fészkek átlag paraméterei a következők voltak: fészekátmérő (D) – 124,1±6,3 mm; fészekcsésze átmérője (d) – 61,5±1,7 mm; fészekmagasság (H) – 63,5±9,4 mm; fészekcsésze mélysége (h) – 48,6±2,7 mm; fészek tömege (m) – 43,7±3,8 mm. A teljes fészekaljméretet Északkelet-Ukrajnában a kotlás során számították ki. Az átlagos mutatók szerint 2015 és 2020 között az átlagos fészekaljméret a Hetman NTP területén 6,9±0,3 (5–8) tojás, a „Gomilshansky Forests" NTP területén 6,2±0,4 (6–8) tojás, a „Feldman Ökopark" RTP területén pedig 8,5±0,5 (8–9) tojás volt. A kerti rozsdafarkú inkubációs periódusa átlagosan 15–20 napig tartott.

Kulcsszavak: kerti rozsdafarkú, Hetman Nemzeti Természeti Park, „Gomilshansky Forests" Nemzeti Természeti Park, „Feldman Ecopark" Regionális Tájvédelmi Park, mesterséges fészkodúk, szaporodásbiológia

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Introduction

Progressive anthropogenic impact, climate change and the subsequent transformation of natural biogeocenoses significantly alter the number of species or whole complexes and affect the restructuring of bird populations, their phenology and reproductive biology (Kuranov 2009, Arikan & Turan 2020). Birds are most sensitive to anthropogenic changes during their reproductive period. That is when they must have the most stable topical connections and unlimited opportunities for nesting and feeding (Batary *et al.* 2014, Chaplygina 2015, Shupova & Chaplygina 2016).

Insectivorous hollow-nesting birds may be involved in the restoration of transformed areas by administering artificial nests, thus, the number of invertebrates can be regulated naturally (Erdoğan *et al.* 2005). In Northeastern Ukraine, many species of hollow-nesting birds inhabit artificial nests (Chaplygina 2018). Due to its small numbers and sporadic nesting, the Common Redstart *(Phoenicurus phoenicurus)* is insufficiently and fragmentarily studied in the region (Matvienko 2009, Savynska & Chaplygina 2016, Knysh 2017, Yuzyk & Chaplygina 2018), as well as in Ukraine in general (Shkaran 2008, Stankevich-Volosyanchuk 2008, Blinkova & Shupova 2018, Kovalska & Parkhomenko 2019, Dubovyk *et al.* 2020).

The Common Redstart is a representative of the European avifauna and one of the functionally important insectivorous birds inhabiting forests of various types (Stoyan *et al.* 2007). The species is distributed throughout Europe (Gatter 2007, Milchev 2010, Martinez 2012, Willemoes 2013), Turkey (Erdoğan *et al.* 2005) and Asia (Kuranov 2009) down to Northwest China (Poludy 2018). It is included in Annex II of the Bonn and Annex II of the Bern Conventions, and in the IUCN European Red List under the category "Least Concern" (LC).

In recent decades, there has been a tendency for expansion of its nesting area (Ilyinsky 2008, Yevtushenko & Lytvynenko 2009, Pidlatiuk 2013, Podobivskyi & Kotiv 2016, Redinov 2016, Korenieva *et al*. 2019). In Crimea, particularly, the birds have been found in mountainous forests, as well as on the southern coast of the peninsula (Appak *et al*. 2013). An increase in numbers of the species is also observed in Northeastern Ukraine, which served as one of the reasons for a close investigation (Chaplygina 2018).

In artificial nests, the breeding ecology of the Common Redstart has been studied in Belarus (Abramova *et al.* 2012), Switzerland (Martinez 2012), the Czech Republic (Porkert *et al.* 2005), Finland (Veistola *et al.* 1996), Poland (Zawadzki *et al.* 2019), Asia (Koryakina 2018) and Northwestern Africa (Mullarney *et al.* 2000).

The objective of this research is to identify the peculiarities of phenology and reproduction biology of the Common Redstart in artificial nests to preserve its populations in Northeastern Ukraine. This included the investigation of the birds` arrival time frame, the peculiarities of reproductive indexes (timing of the reproductive period, construction and composition of nests, the size of the clutch, breeding success, death factors) in the recreational areas of the Nature Reserve Fund of Ukraine (Hetman NNP, NPP "Gomilshansky Forests", and RLP "Feldman Ecopark").

Material and Methods

The investigation area is located in Northeast Ukraine within the Dnieper lowland and Poltava plain *(Figure 1)*. According to physical and geographical zoning, the territory belongs to the Forest-Steppe Zone, Eastern Ukrainian Forest-Steppe Region, Kharkiv and Sumy Slope-Upland Regions.

The vegetation of the investigation area is represented by pine forests. Hetman NNP near Klementove village has *Pinus sylvestris* as the tree stand of the first tier; *Quercus robur, Tilia cordata, Prunus padus, Sambucus racemosa, Robinia pseudoacacia, Ulmus glabra* in the second tier; *Sorbus aucuparia, Corylus avellana, Acer tataricum* as the undergrowth, and *Polygonatum odoratum, Milium effusum, Convallaria majalis, Peucedanum oreoselinum, Stellaria holostea, Carex pilosa,* and *Poa angustifolia* as the lowest herbal-bushy tier. NPP "Gomilshansky Forests" near Zadonetske village has *P. sylvestris* as the dominant species of the tree stand in the first and second tiers. Its undergrowth consists of *Padus avium, C. avellana, A. tataricum, S. racemosa*, and its herbal tier contains *Festuca beskeri, Centaurea jacea, Knautia arvensis, Hypericum perforatum, Anthericum ramosum,* and *Euphorbia nicaeensis*.

"Feldman Ecopark" Regional Landscape Park is located in the zone of Maple-linden-oak forests. The tree stand of the first tier has *Q. robur* with an admixture of *T. cordata*, and *Acer platanoides* occurring singly, the second tier is usually unexpressed. *Acer campestre* occurs in the third tier. The undergrowth is of medium density with *C. avellana, A. tataricum, Euonymus europaeus, Cornus sanguinea* in its composition. The herbaceous tier is dominated by *C. pilosa, Anemone ranunculoides, P. multiflorum, Aegopodium podagraria, Asarum europaeum,* and *Scilla siberica*.

Artificial nests (AN) were of standard sizes made of plank material, with a notch diameter of 3 cm, and were placed at a height of 1–3 m from the ground. The front wall of the AN

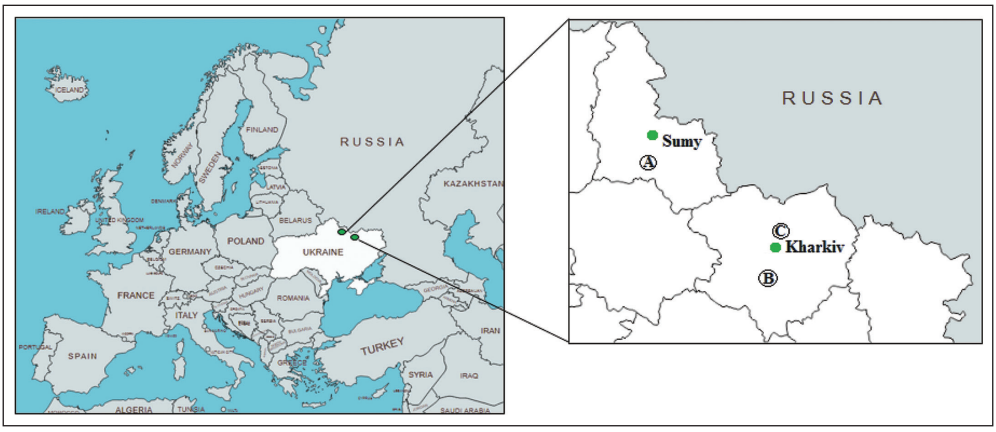

Figure 1. Map of Ukraine showing the location of the investigation areas. Regions: Hetman NNP (A), NPP "Gomilshansky Forests" (B) and Regional Landscape Park "Feldman Ecopark" (C) in Northeastern Ukraine

1. ábra Ukrajna térképe, a vizsgálati terület megjelölésével. Régiók: Hetman NNP (A), "Gomilshansky Forests" NTP (B) és "Feldman Ecopark" RTP (C) Ukrajna északkeleti részén

was removable, which facilitated their inspection. Over time, ANs may lose their front wall, which increases the diversity of species of different groups of animals and birds that use them optionally.

One hundred ANs were distributed on the territories of Hetman NPP (50° 22'57" N 34° 55'34" E), NPP "Gomilshansky Forests" (49° 38'12" N 36° 18'27" E), and RLP "Feldman Ecopark" (50° 06'09" N 36° 17'00" E) each.

The research was performed during the nesting period from the first week of April to the first week of July, during 2015–2020. Annually, 5–8 bird counts were conducted at each site. A total of 43 nests of the Common Redstart were described. Egg-laying was defined in 40 cases: in 2015 in Hetman NPP (3 nests), 2017 – (3), 2018 – (4), 2019 – (4), 2020 – (9); in 2017 in NPP "Gomilshansky Forests" (3), in 2018 – (4), 2019 – (5), 2020 – (5). In the RLP "Feldman Ecopark", nests were registered without any breeding activity. The terms of incubation of clutches are established at the laying of eggs Hetman's NNP (17 nests), NPP "Gomilshansky Forests" – (15); at the hatching of chicks (17 nests) in Hetman NPP; and in NPP "Gomilshansky Forests" (15); and by the age of the chicks (14). The sizes of 13 clutches were defined. Reproductive success and causes of death of eggs and chicks in Hetman NNP were determined for 24 nests containing 157 eggs; in NPP "Gomilshansky Forests" there were 18 nests and 103 eggs. The sizes of eggs and nests were measured according to generally accepted methods with calipers (Kostin 1977, Hoyt 1979, Schönwetter 1979, Myand 1988). Egg volume was determined by following the formula $V = 0.51LB^2$, sphere index (roundness) – B / L100%. In the above formulas, L is the length and B is the width of the egg. The arithmetic mean of eggs (M) is one of the main characteristics of the variation, which is the center of distribution around which all variants of the statistical population are grouped; Limits (Lim) – an indicator of variation, the values of the minimum (Xmin) and maximum (Xmax) options, between which are all the options of this set located. To compare the variability of the characteristics expressed by different units, we used the relative index of variation (CV) – a percentage of the standard deviation (Sx) to the arithmetic mean (M).

The success of hatching chicks was determined by the formula: np / ne • 100%; where ne is the number of eggs, np is the number of hatched chicks. The success of the post-embryonic nesting period was determined by the formula: np2 / np1 • 100%, where np1 is the number of hatched chicks, np2 is the number of feathered chicks. Concerning statistical parameters, a standard deviation is given in most cases, excluding the size of a clutch, the size of eggs and parameters of nests, where the standard error is used. Birds were caught with mist nets and ringed with standard aluminum rings of the Ukrainian Bird Ringing Center. Public weather diaries from the website www.gismeteo.com and the weather archive from the website rp5.ua were used to calculate average air temperatures over the years of research. The beginning of the arrival of migrants was determined by the date of the first encounter.

Statistical analysis of the data was performed using the software STATISTICA 12. Differences in the average values of multidimensional traits in our research were considered significant if $P \leq 0.05$. Statistical processing of the results was performed using one-way analysis of variance (differences between the mean values were considered probable at $p<0.05$). Mean values and standard deviation ($x \pm SD$) were determined. Data were verified using the Kruskal-Wallis distribution normality criterion and the Fisher F-test before using

ANOVA in Past 4.03. Pearson correlation was used to determine the variability between the laying of the first egg of *Ph. phoenicurus* with the May temperature in Northeastern Ukraine, the Pearson correlation coefficient was calculated by the formula:

$$r = \frac{\sum(x-\overline{x})(y-\overline{y})}{\sqrt{\sum(x-\overline{x})^2 \sum(y-\overline{y})^2}}$$; where x and y are variables of the compared series.

Results and Discussion

Biotope

At the conditions of Northeast Ukraine, *Ph. phoenicurus* sporadically inhabits different types of forests. The main nesting places are well-lit areas in light or moderately closed tree stands with uneven fragmentary undergrowth. Birds avoid areas with tall and thick grass. They nest in Maple-linden-oak forests, near recreation centers and camps, where their numbers reach 3–4 pairs/km^2. In mature pine forests, their density sometimes amounts up to 10–12 pairs/km^2. In the last five years, it even tends to increase to 18 pairs/km^2.

Phenology of migration and nesting

At Hetman NNP, the arrival of *Ph. phoenicurus* was as follows: 16.04.2015; 23.04.2017; 21.04.2018; 16.04.2019; 10.05.2020. The average for the 5 years is 21.04±2.8 days. The dates of arrival at NPP "Gomilshansky Forests" were 22.04.2017; 30.04.2018; 18.04.2019; 01.05.2020; on average for the 4 years – 25.04±3.1 days. At the conditions of RLP "Feldman Ecopark", arrival dates were registered on 20.04.2019 and 03.04.2020. The average date for the 2 years was 26.04±6.5 days.

When selecting nesting sites, *Ph. phoenicurus* readily chooses ANs placed at on average 2.4 m (1.5–3.0). Construction of a nest in AN in the investigated areas began in late April 20–30 The first fully built nests in Hetman NNP were found during the first, second weeks of May (03.05–11.05), in NPP "Gomilshansky Forests" – the third week of May (17.05–25.05), while in RLP "Feldman Ecopark" – in 2019 – in the third week of April (30.04); in 2020 – in the second week of May (11.05). After the construction of the nest, the females immediately began to lay their eggs, which usually lasted 15–20 days on average. The first complete clutches were laid from 08.05 to 17.05 (2015–2020) at Hetman NNP and at NPP "Gomilshansky Forests" – 02.05–28.05 (2017–2020). Dates of the beginning of the first egg laying, at various conditions, have inter-annual variability because of unstable weather conditions in May.

In the investigated areas, *Ph. phoenicurus* was registered to usually lay a second clutch. We recorded the chicks of the second brood at Hetman NNP and NPP "Gomilshansky Forests" in 2020 (05.06–19.07). During 2015–2020, at Hetman NNP, the chicks began to hatch in the fourth week of May and the first week of June (26.05–03.06), and at NPP "Gomilshansky Forests" – from the third week of May to the middle of June (19.05–15.06). Mass hatching of chicks occurred in the fourth week (26.05–29.05) of May and the second (11.06–15.06)

Table 1. Phenology of reproduction of *Phoenicurus phoenicurus* at Hetman NNP during 2015–2020. Note: n is the number of nests, μ is the average value; m is the standard error of the mean

1. táblázat A kerti rozsdafarkú *(Phoenicurus phoenicurus)* szaporodásának fenológiája a Hetman NNP-ben 2015–2020 között. Megjegyzés: n a fészkek száma, μ az átlagos érték; m az átlag standard hibája

Year	n	Nesting beginning μ ± m	First egg laying μ ± m	Chicks hatching μ ± m	Fledglings departure μ ± m
2015	3	03.05±4.3	09.05±4.3	26.05±3.2	08.06±3.2
2017	3	09.05±4.3	15.05±4.4	31.05±4.3	23.05±14.7
2018	4	02.05±0.3	08.05±0.3	26.05±0.8	08.06±0.8
2019	4	07.05±4.1	13.05±4.1	28.05±1.0	10.06±1.0
2020	9	11.05±4.7	17.05±4.7	03.06±8.4	17.06±8.2
Together	23	06.05±3.5	12.05±3.6	29.05±3.5	07.06±5.6

Table 2. Phenology of reproduction of *Phoenicurus phoenicurus* at NPP "Gomilshansky Forests" during 2017–2020 Note: n is the number of nests, μ is the average value; m is the standard error of the mea.

2. táblázat A kerti rozsdafarkú szaporodásának fenológiája a NPP "Gomilshansky Forests" területén, 2017–2020 között. Megjegyzés: „n" a fészkek száma, „μ" az átlagérték, „m" az átlag standard hibája

Year	n	Nesting beginning μ ± m	First egg laying μ ± m	Chicks hatching μ ± m	Fledglings departure μ ± m
2017	3	18.05±3.4	24.05±3.4	11.06±3.2	24.06±3.2
2018	4	25.05±9.1	02.05±7.9	19.05±8.1	02.06±8.1
2019	6	17.05±7.1	28.05±8.3	15.06±8.5	28.06±17.5
2020	5	18.05±7.0	24.05±7.2	11.06±12.5	11.06±1.2
Together	23	19.05±6.7	19.05±6.7	06.06±8.1	16.06±7.5

week of June. The last year-on-year hatching of chicks was registered in 2019 in the second week of June (15.06). The mass departure of fledglings at Hetman NNP fell on the third and fourth weeks of June (02.06–28.06) *(Table 1, 2)*. After leaving the nests, the young birds, together with the adults, stayed near their artificial nests for two weeks.

The phenology of *Ph. phoenicurus* reproduction at RLP "Feldman Ecopark" during 2019–2020 was uneven. For the whole period of research, the following were registered (two nests): nesting (06.05±6.0), laying of the first egg (15.05±2.0). During the weekly inspections of ANs, it was found that the birds had left the two clutches that were observed.

Structure of nests

By the nature of the location of nests and their distance from each other, *Ph. phoenicurus* belongs to a group of single (territorial) birds that tolerates areas with high anthropogenic influence. The choice of nesting sites is determined by various parameters of the plant

group, including the species composition of the tree stand, its spatial structure and the degree of shading and humidity. These factors determine the food available for chicks, the temperature of the nest and its protection from adverse weather conditions. The birds mainly inhabited ANs, which were located in the *P. sylvestris* tree stand at Hetman NNP and NPP "Gomilshansky Forests". At RLP "Feldman Ecopark", the birds occupied ANs in the *Q. robur* tree stand. Less often, birds inhabited ANs placed on *A. platanoides* and *T. cordata*. The size of the nest depends on the size of the artificial nest and its type, but the most important requirement for the population of *Ph. phoenicurus* is a wide notch of ANs. The nest of *Ph. phoenicurus* is a dense cup, a regular hemispherical shape with thick sidewalls and a rounded recessed tray. The inside of the nest is lined up with thin dry grass of *Poaceae* (50%). The litter consists of last year's leaves (6%), tree bast (10%), needles (8%), moss (3%), *Equus* sp. (4%), fur (4%), maple lionfish (4%), feathers (6%) of various species of birds *(Parus major, Ficedula albicollis, Dendrocopos major)*. Sometimes the nests contained materials of anthropogenic origin (pieces of threads, ropes, bags) – 5%.

The average indexes of nests in ANs at Hetman NNP showed their maximum parameters to be as follows: diameter of nests (D) – 124.1±6.3 mm; diameter of trays (d) – 61.5±1.7 mm; nest height (H) – 63.5±9.4 mm; depth of trays (h) – 48.6±2.7 mm; nest mass (m) – 43.7±3.8 mm *(Table 3)*.

Over the years of research in Hetman NPP and NPP "Gomilshansky Forests", the length (L) of eggs was found not to differ significantly: from 18.6±0.1 to 19.1±0.4 (CV=0.9%), and from 18.6±0.2 to 18.9±0.16 (CV=0.9%). Diameter (D) of eggs varied from 13.5±0.05 to 14.4±0.4 (CV=2.4%) in Hetman NPP, and from 13.4±0.09 to 14.3±0.09 (CV=1.0%) in

Table 3. Nidological parameters of *Phoenicurus phoenicurus* nests in ANs in Northeastern Ukraine during 2015–2020. Note: μ is the arithmetic mean of the value, m is the error of the mean, Lim is the minimum and maximum value of the sign, σ is the standard deviation, and CV is the coefficient of variation

3. táblázat A kerti rozsdafarkú fészkek paraméterei Északkelet-Ukrajna mesterségesen telepített fészkelőhelyein, 2015–2020 között. Megjegyzés: μ az érték számtani közepe, m az átlag hibája, Lim az előjel minimális és maximális értéke, σ a szórás, CV a variációs együttható

Parameters	Hetman National Nature Park (n=6)			National Nature Park "Gomilshansky Forests" (n=6)			Landscape Park "Feldman Ecopark" (n=2)		
	$\frac{\mu \pm m}{Lim}$	σ	CV, %	$\frac{\mu \pm m}{Lim}$	σ	CV, %	$\frac{\mu \pm m}{Lim}$	σ	CV, %
Nest diameter (D)	$\frac{124.1 \pm 6.3}{101.2 - 141.3}, mm$	14.0	12.05	$\frac{116.1 \pm 2.2}{109.0 - 123.0}, mm$	4.8	4.2	$\frac{116.3 \pm 2.9}{115.6 - 119.2}, mm$	3.0	2.7
Tray diameter (d)	$\frac{61.5 \pm 1.7}{57.7 - 68.2}, mm$	3.8	6.3	$\frac{60.2 \pm 7.7}{56.5 - 88.05}, mm$	17.4	30.0	$\frac{1.0 \pm 0.9}{58.0 - 59.1}, mm$	1.0	1.5
Nest height (H)	$\frac{63.5 \pm 9.4}{46 - 105}, mm$	21.0	33.0	$\frac{59.2 \pm 6.6}{48 - 92}, mm$	14.3	25.0	$\frac{55.2 \pm 0.2}{55.1 - 55.3}, mm$	0.1	0.3
Tray depth (h)	$\frac{48.6 \pm 2.7}{41.5 - 60.0}, mm$	6.0	12.4	$\frac{42.1 \pm 1.7}{36.0 - 46.6}, mm$	3.8	9.1	$\frac{42.2 \pm 2.0}{42.1 - 44.1}, mm$	2.0	4.6
Nest mass (m)	$\frac{43.7 \pm 3.8}{37.7 - 56.4}, g$	8.5	18.7	$\frac{26.1 \pm 2.8}{13.0 - 32.2}, g$	6.3	24.2	$\frac{30.3 \pm 0.8}{29.5 - 31.1}, g$	0.8	2.6

NPP "Gomilshansky Forests". There was no significant difference in volume of eggs (V) between the territories. In Hungary, the size of 68 eggs varied the length from 17.0 to 20.5 mm; the diameter from 12.9 to 14.6 mm, average is 18.9x13.98 mm (Solti 2010). The annual difference in Sphere index (Sph) of eggs ranged at Hetman NPP from 71.2±0.62 to 76.5±4.8 (CV=2.7%), and at NPP "Gomilshansky Forests" from 71.2±0.62 to 75.7±0.68 (CV=0.6%). The Sphere index (Sph) during 2015–2020 indicates that the morphometric parameters of *Ph. phoenicurus* eggs do not show significant differences. However, compared to Sph, calculations of the Elongation index (Iel) prove otherwise. At Hetman NPP, the indexes vary from 33.1±0.7 to 40.4±1.19 (CV=8.3%); in case of NPP "Gomilshansky Forests", from 32.3±1.18 to 33.8±1.3 (CV=2.2%). In our opinion, such variations can lead to the deterioration of the egg`s incubation properties in general. E. Peebles (2004) proved that the Elongation index (Iel) could significantly affect the position of the embryo during the development, which ultimately determines the effectiveness of its survival. Among the measurements we have taken, the most distinctive and important parameter is the weight of the egg. According to our data, at Hetman NPP, the average indexes vary from 1.7±0.02 to 1.9±0.02 (CV=5.0%), and at NPP "Gomilshansky Forests", from 1.9±0.04 to 1.9±0.05 (CV = 0.1%).

The return of *Ph. phoenicurus* to the nesting areas in Northeastern Ukraine, on average, falls to 24.04±1.5 days (2015–2020). Other reports of first arrival in Ukraine include: in the vicinity of Lake Pisochne Shatsky NNP in 2004 (06.04), 2005 (09.04), 2007 (14.04) (Shkaran 2008); at the ponds of Stanychno-Luhansk fish farm during 1986–2007 (15.04–21.04) (Yevtushenko & Lytvynenko 2009); in 21.04.1997 in the Alexandria district of Kirovograd region (Shevtsov 2008); in Southern part of Rivne region in 02.04.2012, 04.04.2014 (Ilchuk 2015); in the Nikolaev area on 23.04.1997, 25.04.2000, 22.04.2003 (Redinov 2016). In the

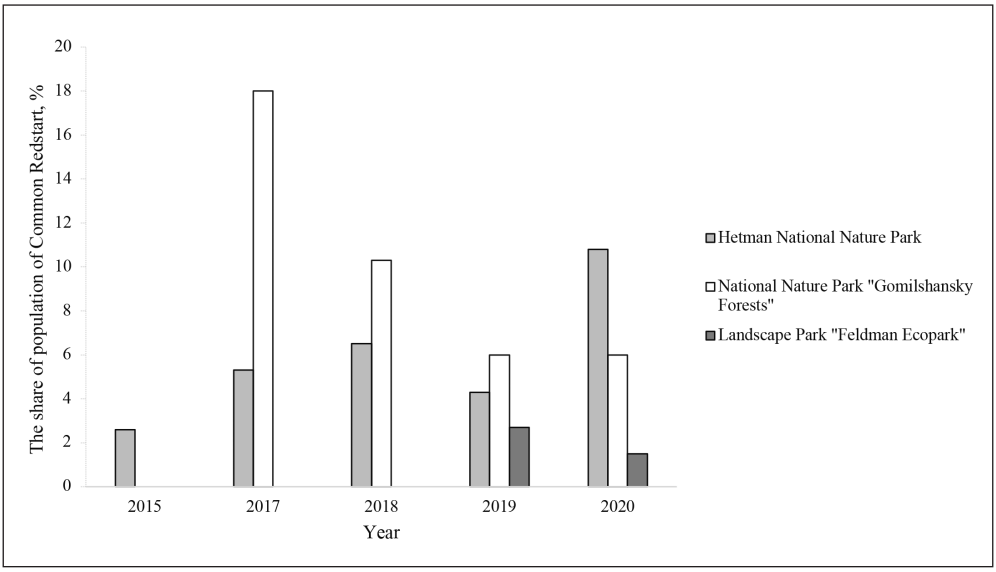

Figure 2. Population of *Phoenicurus phoenicurus* in ANs in Northeastern Ukraine during 2015–2020
2. ábra A kerti rozsdafarkú populációja Ukrajna északkeleti részén telepített mesterséges fészkelőhelyein, 2015–2020 között

Sumy region, for the last 50 years *Ph. phoenicurus* arrived from 14.04.1967 to 07.05.1983, with the average for 7 years: 27.04 (Knysh 2017).

The average populations in ANs at Hetman NPP (during 2015–2020) varied from 2.6% to 10.8%, at NPP "Gomilshansky Forests" (2017–2020) from 18.0% to 6.0%, and at the RLP "Feldman Ecopark" (2019–2020) from 2.7% to 1.5% *(Figure 2)*. In the Shatsk NNP in the biotope of *P. sylvestris* monoculture, the presence of Common Redstart population in 2005 was 6.2% (Shkaran 2009).

The obtained data of interannual population of *Ph. phoenicurus* in ANs at different conditions confirms its growth in the territory of Hetman NNP. The decrease of populations in ANs at NPP "Gomilshansky Forests" can be explained by the influence of predation by *Martes martes* and competition with *Bombus* spp. and *Vespa* spp. In RLP "Feldman Ecopark", the population of *Ph. phoenicurus* remains low due to the small Redstart numbers in the urban landscape.

Incubation period of *Ph. phoenicurus* lasts on average for 15–20 days. The first clutches at Hetman NNP can be seen between 08.05–17.05 and at NPP "Gomilshansky Forests" between 02.05–28.05. The earliest clutches in Central Europe are laid, on average, on 06.05

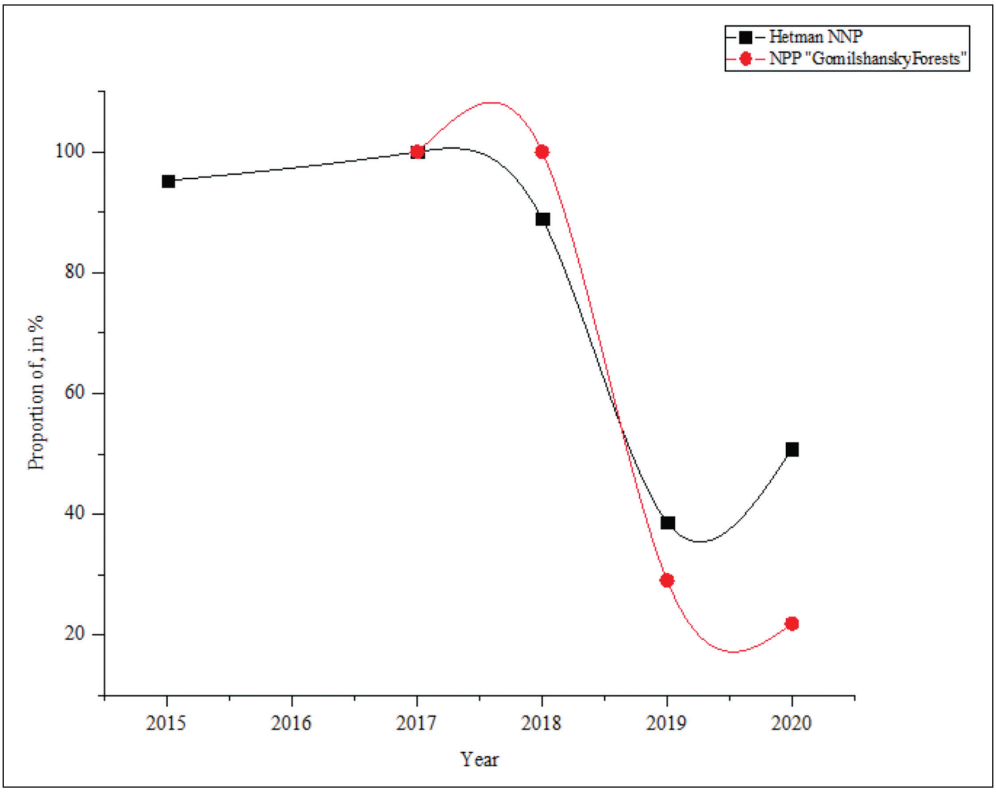

Figure 3. Dependence of the clutch size of *Phoenicurus phoenicurus* on temperature in Northeastern Ukraine during 2015–2020.

3. ábra A kerti rozsdafarkú fészekalj méretének alakulása Északkelet-Ukrajna hőmérsékletének függvényében, 2015–2020 között

Table 4. Indexes of average clutch size of *Phoenicurus phoenicurus* in Northeastern Ukraine during 2015–2020. Note. μ Arithmetic mean of the value, m error of the mean

4. táblázat A kerti rozsdafarkú átlagos fészekalj-méretei Ukrajna északkeleti részén, 2015–2020 között. Megjegyzés: μ Az érték számtani közepe, az átlag m hibája

Year	Hetman National Nature Park (n=23 clutches)	National Nature Park "Gomilshansky Forests" (n=18 clutches)	Landscape Park "Feldman Ecopark" (n=2 clutches)
	Size of egg clutch		
	μ±m	μ±m	μ±m
2015	7.0±0.1	–	–
2017	5.7±0.7	6.3±0.3	–
2018	6.7±0.3	5.3±0.3	–
2019	8.0±0.1	6.7±0.3	8.5±0.5
2020	7.3±0.7	6.7±0.9	

at 14.9 °C. In Finland, early egg-laying begins on 11.05–15.05, at an average temperature of 9.5 °C in the South, indicating that egg-laying is related to habitat interaction and spring weather, rather than just one of the investigated factors (Porkert *et al.* 2005). Data in the Utsjoki Valley (80–200 m above sea level) in Finland during 1982–1994 (Veistola *et al.* 1996) show the onset of clutching in ANs in mixed deciduous and coniferous forests on average on 04.06 (SD=6.89, n=136). Analysis of long-term data in Northeastern Ukraine shows a gradual increase in air temperature in May against the background of its strong year-on-year fluctuations of 19.5±1.14 (P≤0.05) *(Figure 3)*.

We found a significant correlation between the beginning of the first egg-laying of *Ph. phoenicurus* and the May temperature in Northeastern Ukraine (r=0.051, p≤0.01). With a slight increase in air temperature, egg-laying in 2019 increased at RLP "Feldman Ecopark" by 8.5±0.5, at Hetman NPP by 6.9±0.3 and at NPP "Gomilshansky Forests" by 6.7±0.3, which was similar to the average of 2020 (6.7±0.9).

In pine forests of the Northeast of Czech Republic and Central Europe, the average size of clutches in the "first" broods was 6.3 eggs (SD=0.88, n=100 nests), and in the "second" it was 5.4 eggs (SD=0.94, n=72 nests), and the difference was significant (Porkert 2005). The number of eggs in the clutch ranged from three to eight. The most common size of the first clutches was seven eggs that of the second was five. The size of the first clutches during 2011–2013 in Switzerland was 6.3±0.3 eggs, and that of the second was 5.0±0.3 eggs (Martinez & Zingg 2014). Studies in North Karelia recorded the laying of 6–7 eggs (μ=6.66, SD=0.95) (Avil *et al.* 2005). In the South-east of Western Siberia at the border between the southern taiga and subtaiga, in the central areas of Tomsk suburbs (1986–1990) and Seversk (1995–2007), Kuranov (2009) determined the average size of the first clutches to be 7.3±0.08 (CV=11.6±0.8), and that of the second ones to be 6.9±0.08 (CV=13.8±0.8). In the Hungarian oological collection are all together 52 cluch with 5.8 eggs/nest (6x4, 15x5, 14x6, 15x7 and 2x8 eggs) (Haraszthy 2019).

During 2015–2020 at Hetman NNP, the chicks began to hatch in the third decade of May and the first decade of June (26.05–03.06); in different years at NPP "Gomilshansky

Table 5. Parameters of *Phoenicurus phoenicurus* eggs in Northeastern Ukraine during 2018–2020. Note: μ is the arithmetic mean of the value, m is the error of the mean, Lim is the minimum and maximum value of the sign, σ is the standard deviation, and CV is the coefficient of variation

5. táblázat A kerti rozsdafarkú tojások paraméterei Északkelet-Ukrajnában 2018–2020 között. Megjegyzés: μ az érték számtani közepe, m az átlag hibája, Lim az előjel minimális és maximális értéke, σ a szórás, CV pedig a variációs együttható

Parameter	Hetman National Nature Park														
	2015			2017			2018			2019			2020		
	$\frac{\mu \pm m}{Lim}$	σ	CV, %	$\frac{\mu \pm m}{Lim}$	σ	CV, %	$\frac{\mu \pm m}{Lim}$	σ	CV, %	$\frac{\mu \pm m}{Lim}$	σ	CV, %	$\frac{\mu \pm m}{Lim}$	σ	CV, %
Mass, g	–	–	–	$\frac{1.7 \pm 0.02}{1.6 - 1.7}$	0.04	2.4	$\frac{1.7 \pm 0.3}{1.6 - 1.9}$	0.1	0.1	$\frac{1.9 \pm 0.02}{1.8 - 2.0}$	0.1	3.2	$\frac{1.7 \pm 0.02}{1.7 - 1.8}$	0.1	3.2
Length (L), mm	$\frac{19.0 \pm 0.26}{18.15 - 20}$	0.6	3.3	$\frac{18.9 \pm 0.14}{18.5 - 19.2}$	0.3	1.5	$\frac{18.9 \pm 0.13}{18.45 - 19.4}$	0.3	1.6	$\frac{18.6 \pm 0.1}{18.3 - 19.0}$	0.2	1.3	$\frac{19.1 \pm 0.4}{17.1 - 19.8}$	0.8	4.3
Diameter (D), mm	$\frac{14.1 \pm 0.15}{13.65 - 14.8}$	0.4	2.7	$\frac{13.5 \pm 0.05}{13.3 - 13.6}$	0.1	0.8	$\frac{13.8 \pm 0.1}{13.5 - 14.3}$	0.3	1.9	$\frac{14.0 \pm 0.1}{13.7 - 14.3}$	0.2	1.6	$\frac{14.4 \pm 0.4}{14.0 - 16.2}$	0.7	4.9
Sphere index (Sph), %	$\frac{74.2 \pm 1.04}{70.4 - 78.8}$	2.6	3.4	$\frac{71.2 \pm 0.62}{70.2 - 73.5}$	1.2	1.7	$\frac{73.3 \pm 0.52}{70.8 - 75.6}$	1.5	2.1	$\frac{75.3 \pm 0.4}{73.6 - 76.7}$	1.0	1.4	$\frac{76.5 \pm 4.8}{70.7 - 99.1}$	9.0	11.4
Volume index (V), mm^3	$\frac{19.4 \pm 0.57}{17.7 - 21.8}$	1.4	7.2	$\frac{17.5 \pm 0.19}{16.8 - 17.8}$	0.4	2.1	$\frac{18.4 \pm 0.35}{17.3 - 19.9}$	0.8	4.2	$\frac{18.6 \pm 0.3}{17.6 - 19.9}$	0.8	4.1	$\frac{20.1 \pm 0.5}{19.4 - 22.5}$	1.0	5
Elongation index (Iel)	$\frac{34.8 \pm 1.87}{26.9 - 42.1}$	4.6	13.2	$\frac{40.4 \pm 1.19}{36.0 - 42.5}$	2.4	5.9	$\frac{36.6 \pm 0.94}{32.4 - 41.5}$	2.9	7.8	$\frac{33.1 \pm 0.7}{30.5 - 36.3}$	1.9	5.6	$\frac{33.6 \pm 4.8}{10.7 - 41.9}$	8.5	28.6

Parameter	National Nature Park "Gomilshansky Forests"									Landscape Park "Feldman Ecopark"		
	2018			2019			2020			2019		
	$\frac{\mu \pm m}{Lim}$	σ	CV, %	$\frac{\mu \pm m}{Lim}$	σ	CV, %	$\frac{\mu \pm m}{Lim}$	σ	CV, %	$\frac{\mu \pm m}{Lim}$	σ	CV, %
Mass, g	$\frac{1.9 \pm 0.04}{1.4 - 2.0}$	0.1	3.7	$\frac{1.9 \pm 0.05}{1.8 - 2.1}$	0.1	5.3	–	–	–	–	–	–
Length (L), mm	$\frac{18.9 \pm 0.12}{14.0 - 19.3}$	0.2	1.3	$\frac{18.6 \pm 0.2}{18.1 - 19.2}$	0.4	1.9	$\frac{18.9 \pm 0.1}{18.3 - 19.2}$	0.3	1.4	$\frac{18.9 \pm 0.16}{18.3 - 19.7}$	0.4	2.2
Diameter (D), mm	$\frac{14.3 \pm 0.09}{10.6 - 14.5}$	0.2	1.3	$\frac{14.0 \pm 0.1}{13.7 - 14.2}$	0.2	1.4	$\frac{14.1 \pm 0.1}{13.8 - 14.4}$	0.2	1.7	$\frac{13.4 \pm 0.09}{13.1 - 13.9}$	0.2	1.7
Sphere index (Sph), %	$\frac{75.7 \pm 0.68}{55.3 - 77.7}$	1.4	1.8	$\frac{75.2 \pm 0.4}{73.6 - 76.5}$	1.0	1.3	$\frac{74.8 \pm 0.7}{72.5 - 76.9}$	1.6	2.1	$\frac{71.0 \pm 0.62}{67.5 - 72.7}$	1.6	2.3
Volume index (V), mm^3	$\frac{19.8 \pm 0.29}{14.3 - 20.7}$	0.6	2.8	$\frac{18.7 \pm 0.4}{17.3 - 19.6}$	0.8	4.2	$\frac{19.2 \pm 0.3}{18.4 - 20.1}$	0.6	3.6	$\frac{17.3 \pm 0.3}{16.3 - 18.9}$	0.8	4.6
Elongation index (Iel)	$\frac{32.3 \pm 1.18}{21.6 - 35.7}$	2.4	7.5	$\frac{33.0 \pm 0.8}{30.7 - 36.0}$	1.8	5.4	$\frac{33.8 \pm 1.3}{30.1 - 38.0}$	2.8	8.2	$\frac{40.8 \pm 1.3}{37.6 - 48.1}$	3.3	8.1

Forests" it fell to the second decade of May and June (19.05–15.06). Mass-hatching of chicks in Northeastern Ukraine occurred in the third (26.05–29.05) decade of May and the second (11.06–15.06) decade of June. The last year-on-year hatching of chicks was registered in 2019 in the second decade of June (15.06) in Finland (Veistola *et al.* 1996) on 24.06 (SD=6.63, n=124).

The mass departure of fledglings in Hetman NNP occurred in the second and third decades of June (June 2–June 28). We did not investigate the second broods by the same couples in detail due to the destruction of the nests during the egg-laying stage. Porkert *et al.* (2005) generally believe that further hatching of broods in one season, together with smaller clutches, can pose a threat in case of short daylight periods and high nest predation. Interpretations of the large number of second broods in Central Europe remain unclear and cannot be easily explained by different weather conditions or different estimation methods. Accordingly, data on the survival of second broods are needed for a more detailed analysis of the reproductive strategy of *Ph. phoenicurus*.

Based on these studies, we determined the success and reproductive productivity of *Ph. phoenicurus*. During 2015–2020, this species had high reproduction success rates *(Figure 4*, *Table 6)*.

We found that the overall success rate of reproduction at Hetman NNP varied from 95.2% (2015) to 50.8% (2020) with an average for the entire period of 74.2%. At NPP "Gomilshansky

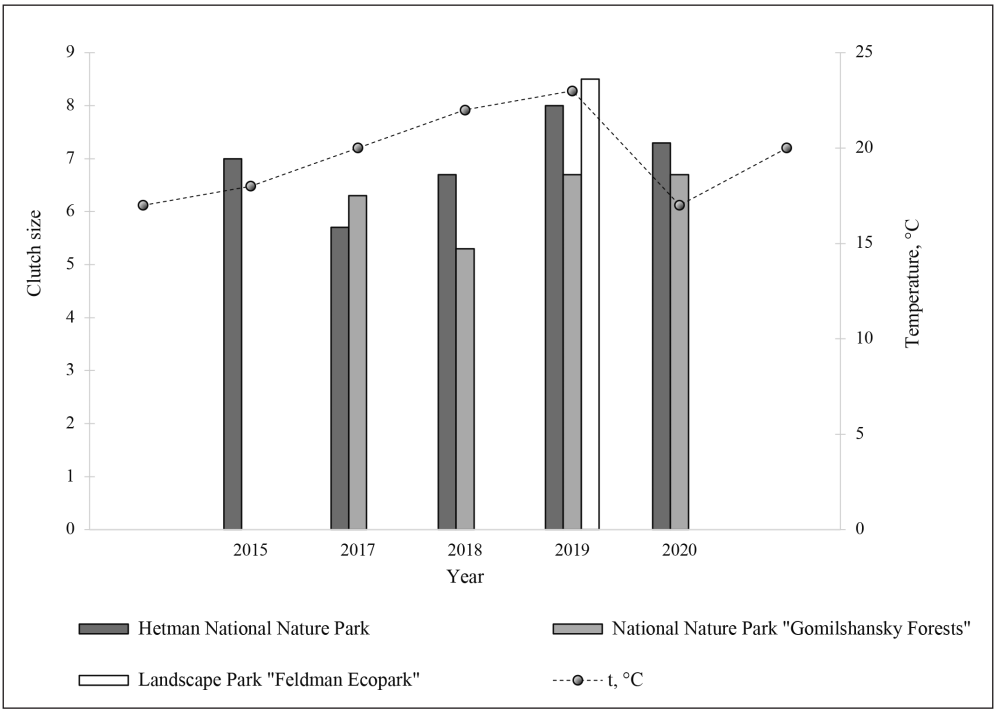

Figure 4. Success of reproduction of *Phoenicurus phoenicurus* in Northeastern Ukraine during 2015–2020.

4. ábra A kerti rozsdafarkú költési sikere Északkelet–Ukrajnában, 2015–2020 között

Table 6. Reproductive productivity of *Phoenicurus phoenicurus* at Hetman NNP during 2015–2020.

6. táblázat A kerti rozsdafarkú költési sikeressége a Hetman NTP területén, 2015–2020 között

							Newly born	Fledglings
Year	n nests	n eggs	Quantity of dead eggs	n hatched chicks	n fledglings	Quantity of dead chicks	On average per one couple	On average per one couple
2015	4	21	1	20	20	0	5.0	5.0
2017	3	17	0	17	17	0	5.7	5.7
2018	4	27	3	27	27	0	6.8	6.8
2019	4	31	19	31	31	0	7.8	7.8
2020	9	61	30	61	61	0	6.8	6.8

Forests", the lowest success rate was registered at 21.9% (2020), the highest one was in the first year of the survey was 100% (2017), and the average for the entire period was 62.7%.

To establish the interannual reproductive productivity, we studied (n=24) nests. The maximum number of eggs was registered in 2020 (n=61), whereas the lowest numbere in 2017 (n=17). The main reasons for the low egg numbers in Hetman NNP are unfertilized eggs, embryonic mortality and destruction of clutches by predators (*Dryomys nitedula* and *Dendrocopos major*).

Table 7. Reproductive productivity of *Phoenicurus phoenicurus* at NPP "Gomilshansky Forests" during 2017–2020.

7. táblázat A kerti rozsdafarkú költési sikeressége a "Gomilshansky Forests" NTP területén, 2017–2020 között

							Newly born	Fledglings
Year	n nests	n eggs	Quantity of dead eggs	n hatched chicks	n fledglings	Quantity of dead chicks	On average per one couple	On average per one couple
2017	3	19	0	19	19	0	6.3	6.3
2018	4	21	0	21	21	0	5.3	5.3
2019	6	31	8	23	9	14	3.8	1.5
2020	5	32	16	16	7	9	3.2	1.4

At NNP "Gomilshansky forests", the largest share of the total success of reproduction was determined during 2017–2018 (100%) and the lowest in 2020 (21.9%) *(Table 7)*.

Nests (n=18) were studied in the pine forest of NNP "Gomilshansky Forests". The number of dead eggs in 2019 were n=8, in 2020 n=16. The cause of death of chicks at NPP "Gomilshansky Forests" was mostly predation by *Martes martes* (n=23 chicks). The average number of chicks per couple during 2017–2020 was 3.6±1.2 (CV=60.8%). The main positive factor in the success of *Ph. phoenicurus* reproduction in Hetman NNP in comparison with NNP "Gomilshansky Forests" were the weakening of predation pressure and the reduction of the share of abandoned broods.

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