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TEMPERATURE DEPENDENCE OF THE BREEDING PARAMETRES OF THE COLLARED FLYCATCHER (PASSERIFORMES, MUSCICAPIDAE) IN THE NATIONAL PARK HOMILSHANSKI LISY (NE UKRAINE)

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Temperature Dependence of the Breeding Parametres of the Collared Flycatcher (Passeriformes, Muscicapidae) in the National Park Homilshanski Lisy (NE Ukraine). Atemasov, A. A. & Atemasova, T. A. — The breeding phenology of Collared Flycatchers was studied over an 11-year period (2006–2011 and 2013–2017) in oak-maple-lime stands located in the Northern-East of Ukraine (in the National Park Homilshanski Lisy). In most years, egg laying began in the first and second ten-day periods of May. The earliest recorded first-egg date (368 broods) was 23 April, while the latest was 5 May. These dates varied from year to year. The relationship between the first-egg date and the date of daily average temperature transition through + 10 °C suggests that birds bred earlier due to warmer local temperatures. The clutch size was negatively correlated with the date of the average air temperature transition through + 5 °C. The earliest hatching date was 15 May, and the latest was 25 May. Fledging typically began in the first half of June. The breeding season's length ranged from 30 to 42 days, and the breeding cycle was positively correlated with the transition of the average daily temperature through +5 °C. To determine which factors explained the first egg date and clutch size, Generalized Linear Models (GLMs) were conducted. GLMs suggest a correlation between the first-egg date and the sum of effective temperatures (∑T150), arrival date temperature, migration route temperature, and average temperature of the third decade of April. Clutch size is determined by the sum of effective temperature accumulation (∑130) and migration route temperature. Reproductive success is negatively correlated with the average of 30 daily temperatures until the median date.
Key words: Collared Flycatcher, *Ficedula albicollis*, weather conditions, temperature, laying date, clutch size.

Introduction

The role of temperature and precipitation in affecting bird breeding is described (Slobodník et al., 2013). Climate change is believed to have caused shifts in the breeding times of many bird species over the past 30 years, with important implications for the dynamics of migratory species populations (Winkler, 1999; Hussell, 2003; Mazerolle et al., 2011; Ambrozini et al., 2006; Jankowiak et al., 2014).

The Collared Flycatcher, *Ficedula albicollis* (Temminck, 1815), was the one of several hole-breeding species, whose dates of the nesting season were a response to a rise in temperature in Eastern Europe (Eastern Czechia); in addition, it nested earlier and laid larger clutches after warm and humid weather conditions at wintering sites (Adamik & Kral, 2007; Przybylo et al., 2000). The many authors are use for illustrate the affection of local climatic conditions on nesting parameters very diversity indicators (Jankowiak et al., 2014; Artem'yev, 2008, 2015; Weidinger et al., 2007; Hussell, 2003; Mitrus, 2003), but key indicators have not been identified yet. In addition, the local climatic conditions on studied subpopulation of Collared Flycatcher at the borders of area (fig. 1) may to play a prime role in the limitation of bird breeding numbers. In addition, it was proved that some demographic indicators of flycatcher populations are affected by wintering conditions and climatic features on migration routes (North Atlantic Oscillation Index (NAO).

The studied subpopulation of Collared Flycatcher is located at the southern borders of the distribution of deciduous forests with which it is associated. The living conditions are characterization by drier climate, the early onset of the spring and summer.

In the maple-lime oak forest in the left-bank the Wood-and-Steppe border of Ukraine that we studied, the Collared Flycatcher is one of the four dominant species in the breeding bird assembles (Atemasov et al., 2011). During 11 monitored seasons, it was observed that the dates of the first egg lying of Collared Flycatcher vary within 14 days (Atemasova, 2014).

Our hypotheses suggest that in the studied area, the main data of breeding cycle of Collared Flycatcher affected by a whole complex of temperature characteristics and may differ from those in other parts of the range. This is the first time such studies are being carried out for this area.

The main purpose of present study was to determine the role of the key temperature characteristics of the local climate in shaping of breeding cycle of the Collared Flycatcher.

This was achieved by:

— studying how the local breeding phenology indicators (the first- egg date, clutch size, fledgling's productivity, the length of the breeding cycle) are affected by local temperatures.

— selecting key climatic indicators that significantly influence the main parameters of the nesting period.

Study area

The study was carried out during the years 2006–2011 and 2013–2017 in the National Park Homilshanski Lisy (NE Ukraine, 49°37'31.1″ N, 36°19′ 28.7″ E).

Fig. 1. Map of boundaries of the Collared Flycatcher subpopulation study area (Keller et al., 2020).

The two studied plots (9 and 17.9 ha) are located in the south of the Wood-and-Steppe of Left-Bank Ukraine. It is covered by in the upland maple-linden oak forest (Acereto-Tilieto-Querceta graminosa) consisting of Common, Oak *Quercus robur* 40–150 age, Small-leaved Lime, *Tilia cordata*, Field Maple, *Acer campestre* (Gorelova & Alekhin, 2002), where human disturbance is restricted to a few tourist paths and the scientists' activity.

The annual course of temperatures has a pronounced continental type. The duration of spring is 50–60 days, with cooling and frost. Precipitation at the beginning of spring is insignificant, in April–May the amount of precipitation reaches 15–16 % of the annual norm. Summer (the transition of average daily temperatures through +15) begins in the 20th of May, lasts 120 days, 200 mm of precipitation falls during the summer (30 % of the annual volume). The studied oak forests are in the zone of insufficient moisture: the total number of dry days per year is 51, more often dry winds occur in May–August, from 2 to 15 days, with a predominance of southeast and east winds. On average, 538 mm of precipitation falls annually (Gorelova & Alekhin, 2002).

A part of the Collared Flycatcher population nesting in artificial nest-boxes was under observation (Atemasov et al., 2011). Artificial nest-boxes have been established on the territory of the biological station along the edge of the forest with a size of 9 hectares, as well as inside a homogeneous forest on a site measuring 17.9 hectares. The nest-boxes (100) were fixed to trees 1.5–2.5 m above the ground, spaced at 50 m intervals. All nest-boxes were identical during the whole study (10 × 14 × 20 cm). In these areas, birds use also natural tree cavities.

Material and Methods

All nest boxes were visited regularly during the breeding season to record the date of laying of the first egg, clutch size, date of hatching of eggs and number of fedglings. The date of laying the first egg (FED) was determined during a weekly check of artificial nest-boxes during the entire nesting period — either directly or by calculations based on the fact that one egg is laid per day.

The clutch size and the number of chicks in the brood were determined by examining the nests once a week or more often (if necessary) throughout the entire nesting period. The repeated clutches (clutches created 20 days after the median of the laying period (by Wesołowski, 1985)) were excluded from the analysis. Thus, data on 363 clutches of the Collared Flycatcher in artificial nest-boxes for 2006–2011 and 2013–2017 was used for analysis.

We tested indicators previously proposed by a number of authors to illustrate the influence of local climatic conditions on nesting parameters (Jankowiak et al., 2014; Artem'yev, 2008, 2015; Weidinger et al., 2007; Hussell, 2003; Mitrus, 2003) and identified those that have the greatest effect on the phenology of the nesting period of the Collared Flycatcher.

The influence of meteorological indicators on the start date and duration of the egg laying period, clutch size, on the success of reproduction of the Collared Flycatcher was analysed.

The arrival date (FAD) was recorded during a regular observations, carried out in 2006–2011 and 2013–2017 on linear transects from April 1 to June 10.

Based on the primary data, the egg-laying period and the average egg-laying period for each year (MLD) were calculated.

The number and age of chicks was determined during a weekly inspection of the nests. The reasons for the death of eggs and chicks were recorded. Young birds were marked with rings of series A and B Ukraine at 10 days of age, females were also ringed. The average clutch size, the percentage of successful nests (the nests from which the young birds flew), and the breeding success (the number of young birds flying out per nesting attempts) were calculated.

The following meteorological indicators were calculated on the basis of daily average temperatures:

— the average temperature of each decade — in April, May and June (by Mitrus, 2003);

— the average of the five average daily temperatures before the arrival date (T_{FAD}), before the start of laying time (T_{FED}), and for the median egg-laying period (T_{MLD});

— the sum of daily average temperatures between the arrival date and the beginning of the first clutch ($T_{sum\ FAD\text{-}FED}$) and the average value of this indicator ($T_{mean\ FAD-FLD}$);

— the average of 30 daily average temperatures until the median laying date (T_{breed});

— the average daily temperature for 30 days to the main median of the laying dates.

It's the dates of the transition of daily average temperatures through + 5 °C (T5) and through + 10 °C (T10) were also used for the analysis (by Schul'tz, 1981). The effective temperature sum indicator (the sum of air temperatures from a date with a temperature of + 5 °C to the required date) was used for calculations (by Schul'tz, 1981).

The following were calculated:

— the sum of the effective average daily temperatures at the start of the laying;

— accumulation dates of the sum of effective temperatures 130° (ΣT 130), 150° (ΣT 150), 170° (ΣT 170) — the date, when the sum of temperatures above + 5 °C reaches the corresponding values (by Schul'tz, 1981).

The following temperature readings were also used:

— temperatures at wintering places (Tanzania, Zambia, Zimbabwe, Malawi), average for February (Twin);

— temperature on migration routes (Egypt, Libya), average for March (Tmig);

— North Atlantic Oscillation Index (NAO), variant EA / WR (eastern Atlantic / western Russia, NOAA Climate Prediction Center, http://www.cpc.ncep.noaa.gov), the average value for December–March.

Data on average daily temperatures were obtained from the archive of meteorological data for Kharkov and Zmiev (Kharkiv Region, 7 km from the study area) for 2006–2017.

The correlation coefficients between phenological dates, reproduction productivity parameters and temperature indicators were calculated. The statistical significance of the correlation coefficients was checked on the basis of a randomization test (Shitikov & Rosenberg, 2013). Calculations performed using the program "Resampling" (Howell, 2007).

Generalised Linear Models (GLMs) with a Poisson error distribution was conducted for determine which factors explained the first egg date (FED) and the clutch size (eggs). T5, T10, ΣT130, ΣT150, ΣT170, the average daily temperature over the decades (in March, April, May and June), T_{FAD}, T_{FED}, T_{MLD}, T_{breed}, $T_{mean\ FAD–FED}$, $T_{sum\ FAD-FED}$, T_{win}, T_{mig}, NAO and EA/WR were considered as explanatory variables.

To build the models, we used the Gimulti package (Calcagno, 2013) for R version 3.5.1 (R Core Team, 2018). The resulting models were compared using the small sample sizes' corrected Akaike Information Criterion (AICc, Burnham, Anderson, 1998). The model with the lowest AICc was rated as the best model. For analysis, we also used all models whose AICc values did not exceed the AICc values of the best model by more than two units (ΔAICc < 2). The coefficients associated with each variable and their relative importance's were estimated using a multimodel average.

Results

The first arrival date

The first Collared Flycatchers usually arrived to the Gomol'sha Forest during the 9–19 April; (mean = April 15) in different years (fig. 2). In this period an average daily air temperature fluctuates from +7.5 °C to +14.5 °C, but may be a temporarily decline to 0 °C (April, 17 on 2017). Arrivals are usually accurately marked for males that are more visible. Therefore, all the dates indicated are the dates of the first registration of males in the study area. Significant correlation between arrival dates and temperature on investigation plots are don't detected.

Table 1. The correlation coefficients between the arrival dates, dates of egg laying, clutch size, nesting success and temperature indicators

Temperature indicators	FAD	FED	MLD	Eggs	Nestling by female	Brood
T5	0.29	−0.24	**0.62**	**−0.63**	−0.42	−0.58
T10	0.20	**0.62**	0.39	−0.49	−0.06	−0.24
ΣT130	0.19	0.27	**0.65**	−0.52	0.13	−0.09
ΣT150	0.12	0.20	**0.67**	−0.45	0.27	0.08
ΣT170	0.16	0.22	**0.67**	−0.46	0.26	0.06
April, I decade (average air temperature)	−0.14	0.17	−0.31	0.27	−0.08	0.12
April, II decade (average air temperature)	−0.38	**−0.62**	−0.31	0.29	0.11	0.21
April, III decade (average air temperature)	0.13	−0.03	−0.16	0.08	−0.32	−0.37
May, I decade (average air temperature)	0.26	−0.03	0.24	−0.17	−0.17	−0.20
May, II decade (average air temperature)	−0.08	−0.18	−0.22	0.35	0.57	0.38
May, III decade (average air temperature)	0.19	0.43	−0.13	−0.08	0.35	−0.01
T FAD	−0.29	**−0.60**	−0.11	0.25	−0.14	0.06
T FED	0.19	−0.09	0.14	−0.40	−0.46	−0.49
T MLD	0.29	−0.03	0.37	−0.26	−0.06	−0.16
T mean FAD-FED	0.34	−0.29	−0.36	0.17	0.06	−0.11
T sum FAD-FED	−0.26	0.44	**−0.69**	0.45	−0.03	0.08
T breed	0.14	0.02	0.13	0.09	**−0.62**	−0.41
T win	0.19	0.03	−0.14	−0.45	−0.16	−0.40
T mig	0.25	0.30	0.21	−0.35	0.34	0.12
NAO	0.09	−0.09	−0.08	−0.43	−0.05	−0.3
EA/WR	0.04	0.04	0.24	−0.2	0.53	0.33

Note. Bold — $p < 0.05$.

Table 2. Timing of breeding stages

Year	First egg X ± SD, n	Hatching X ± SD, n	Fledgling X ± SD, n	B
2006	126 ± 1.53 (37)	148 ± 1.2 (28)	168 ± 1.3 (27)	42
2007	126 ± 3.4 (48)	151 ± 0.6 (34)	159 ± 0.9 (34)	33
2008	126 ±1.1 (47)	144 ± 0.7 (32)	158 ± 0.6 (32)	32
2009	132 ±1.0 (55)	149 ± 0.7 (35)	163 ± 0.8 (33)	31
2010	134 ± 1.0 (54)	150 ± 1.0 (40)	164 ± 1.2 (31)	30
2011	135 ± 1.2 (36)	155 ± 1.3 (30)	167 ± 1.1 (24)	32
2013	128 ± 1.8 (16)	147 ± 1.5 (13)	161 ± 1.5 (12)	33
2014	123 ± 1.3 (20)	143 ± 1.2 (19)	157 ± 1.4 (16)	34
2015	139 ± 5.0 (15)	155 ± 3.1 (11)	172 ± 5.7(4)	33
2016	127 ± 1.3 (20)	146 ± 1.3 (17)	159 ± 1.7 (10)	32
2017	132 ± 1.8 (15)	149 ± 1.1 (15)	163 ± 1.5 (9)	31
Average	129.82 ± 1.48 (363)	148.82 ± 1.17 (274)	161.91 ± 1.44 (232)	33

Note. 01 January = 1. B — length of the breeding cycle in days; n —number of clutches.

Laying period

The first-egg date between April 23 (2006) and May 5 (2017) (table 2). The median laying date for all years was 1 May.

The date of commenced egg differs between nesting seasons ($F_{(10.361)} = 10.973$, $p < 0.001$). The date of first egg laying is relate to local temperatures: the date of transition of the average daily temperature through +10 °C (positive), with the date of average temperature of the second ten-days of April, and also with the T_{FAD} — the average temperature 5 days before the arrival date (negative) (table 1, n = 11). The average temperature of the date of first egg ranges from + 9 °C (2007) to + 21.5 °C (2009); averages + 15.0 ± 1.24 °C.

The median of the egg-laying period for all the years was between the 8th and the 21st of May.

Indicators such as the data of transition of the average daily temperature through the value of + 5 °C, date of accumulation of the sum of effective temperatures up to 130 °C, 150 °C and 170 °C positively correlate with the dates of the median of the laying period. Indicators of the sum of average daily effective temperatures between the date of arrival and the date of laying the first egg ($T_{sum\ FAD\text{-}FED}$) negatively correlate with the dates of the median of the laying period (table 1).

Modelling

Using Generalised Linear Models (GLMs) made it possible to obtain a set of models of the dependence of first egg day (FED) on temperature parameters. For further analysis, sixteen were selected for which ΔAICc < 2 (table 3).

Of the 24 temperature parameters used as independent variables, the selected models contain 17. All selected models are used to determine the relative importance of each parameter used in the models. For this, the average model value for each parameter was calculated (fig. 3).

According to the obtained models, the first egg date correlates with a set of temperature indicators, including the:

— average daily temperature of the third ten-days of April,

— the date of accumulation of effective temperatures of 150 °C,

— the air temperature on the migration routes (T_{mig}),

— the average value of five average daily temperatures before the arrival date (T_{FAD}).

The best model (with the lowest AICc value) includes only these four independent variables (fig. 3).

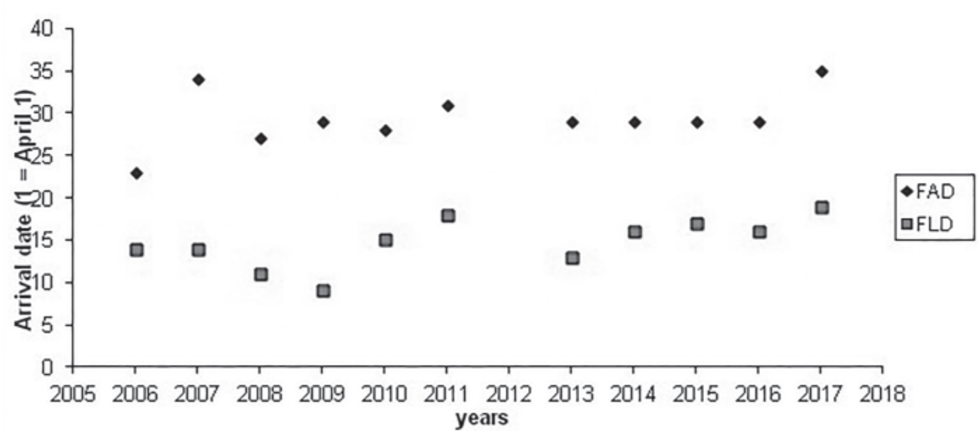

Fig. 2. First spring records and first-egg day of Collared Flycatcher at investigation plots in 2006–2017.

Clutch size

The size of the clutch of the Collared Flycatcher (eggs) negatively correlates with the date the average daily temperature passes through + 5 °C (n = 11, table 1, fig. 4).

Modelling

When analyzing a set of models of the dependence of the size of the clutch on the temperature parameters, it was found that the size of the clutch is directly related to:

— the date of transition of daily average temperatures through + 5 °C,

— the date of accumulation of effective temperatures of ∑130°,

— the air temperature on the migration routes (T_{mig}).

The best model (with the lowest AICc value) includes only these three independent variables (fig. 5, tables 4 and 5).

The egg-laying period's duration

The egg-laying period of a Collared Flycatcher in the study area can take from 30 to 45 days (2006, 2010, 2011, 2013, 2015, 2016); in certain years (2007, 2008, 2009, 2014), a period is clearly distinguished when up to 90 % of clutches is created. So, in 2007, the egg-laying period took 12 days and ended, in fact, on May 15.

Table 3. Top-ranked models (i. e. with ΔAICc < 2) used to test the effect of temperature parameters on the first egg date (FED)

No	Model	AICc	Weights
1	FED ~ 1 + ∑T150 + april3 + TFAD + Tmig	2373.196	0.05664735
2	FED ~ 1 + ∑T150 + april3 + TFAD + Tmig + NAO	2373.584	0.04666312
3	FED ~ 1 + ∑T150 + may1 + TFAD + Tmig	2373.741	0.04314636
4	FED ~ 1 + ∑T150 + april3 + june1 + TFAD + Tmig	2373.856	0.04073443
5	FED ~ 1 + ∑T150 + april3 + may1 + TFAD + Tmig	2373.875	0.04034008
6	FED ~ 1 + ∑T150 + april3 + TFAD + Tbreed + Tmig	2373.927	0.03931396
7	FED ~ 1 + ∑T150 + april3 + TFAD + TMLD + Tmig	2373.989	0.03811487
8	FED ~ 1 + ∑T150 + april3 + TFAD + Tmig + EAWR	2374.069	0.03661495
9	FED ~ 1 + ∑T150 + ET170 + april3 + TFAD + Tmig	2374.155	0.03508035
10	FED ~ 1 + ∑T150 + april2 + may1 + TFAD + Tmig	2374.264	0.03321866
11	FED ~ 1 + ∑T150 + april3 + may3 + TFAD + Tmig	2374.269	0.03313093
12	FED ~ 1 + ∑T150 + april3 + TFAD + TsumFAD-FED + Tmig	2374.865	0.02459804
13	FED ~ 1 + ∑T150 + april3 + june3 + TFAD + Tmig	2374.868	0.02455389
14	FED ~ 1 + T5 + ∑T150 + april3 + TFAD + Tmig	2374.872	0.02450862
15	FED ~ 1 + ∑T150 + april2 + april3 + TFAD + Tmig	2375.170	0.024111634
16	FED ~ 1 + T10 + ∑T150 + april3 + TFAD + Tmig	2375.172	0.02109086

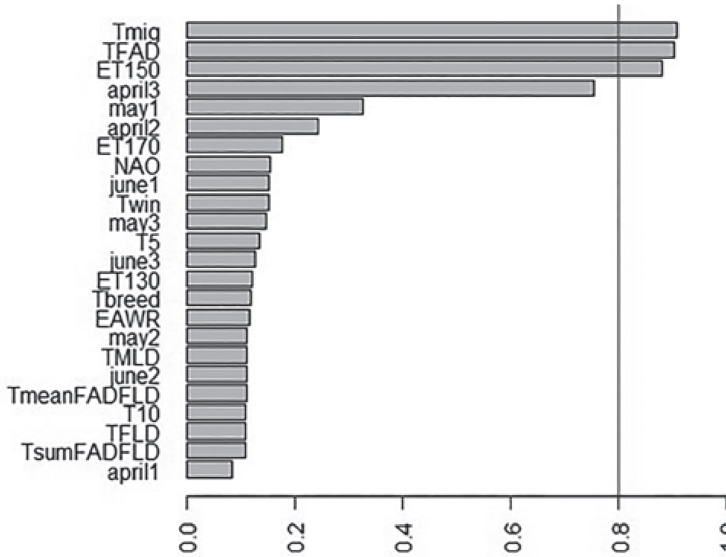

Fig. 3. Model-averaged importance of the predictor variables from the subset of best-fitting models for the first egg date (FED).

Egg lying usually occurred in the first and second ten-days of May. However, in some years (2006, 2008, 2014, 2016), the beginning of egg lying began earlier (table 6).

The minimum egg-laying period is in the date range with the sum of effective temperatures from 250 °C to 440–560 °C (2008 and 2014); maximum — in the range from 148 °C to 541 °C (2006); the median of the egg-laying period in all years falls on the range of the sum of effective temperatures 354–490 °C.

Table 4. Top-ranked models (i. e. with ΔAICc < 2) used to test the effect of temperature parameters on the clutch size (eggs)

No	Model	AICc	Weights
1	Eggs ~ 1 + ∑T130 + Tmig	1343.055	0.0734167108
2	Eggs ~ 1 + Tmig	1343.227	0.0673501432
3	Eggs ~ 1 + ∑T150 + Tmig	1343.261	0.0662041805
4	Eggs ~ 1 + ∑T130 + april2 + Tmig	1343.314	0.0644817471
5	Eggs ~ 1 + ∑T130 + june2 + Tmig	1343.835	0.0496889456
6	Eggs ~ 1 + ∑T130 + april1 + Tmig	1343.863	0.0490031275
7	Eggs ~ 1 + T5 + ∑T130 + Tmig	1344.619	0.0335875298
8	Eggs ~ 1 + ∑T130 + Tbreed + Tmig	1344.682	0.0325469350
9	Eggs ~ 1 + may3 + Tmig	1344.700	0.0322553737
10	Eggs ~ 1 + ∑T130 + may2 + Tmig	1344.918	0.0289166064
11	Eggs ~ 1 + ∑T130 + TsumFAD-FED + Tmig	1344.965	0.0282422003
12	Eggs ~ 1 + ∑T130 + ∑T170 + Tmig	1345.031	0.0273342477
13	Eggs ~ 1 + ∑T130 + TMLD + Tmig	1345.038	0.0272409779
14	Eggs ~ 1 + T10 + ∑T130 + Tmig	1345.044	0.0271460994

Table 5. Best Generalized Linear Model for the clutch size (eggs)

Coefficients	Estimate	Std. Error	z value	Pr (> |z|)
(Intercept)	1.89961	0.02116	89.788	< 2e-16 ***
ET130	−0.04228	0.02832	−1.493	0.135
Tmig	−0.02573	0.02821	−0.912	0.362

Signif. codes: ‘***’ 0.001.

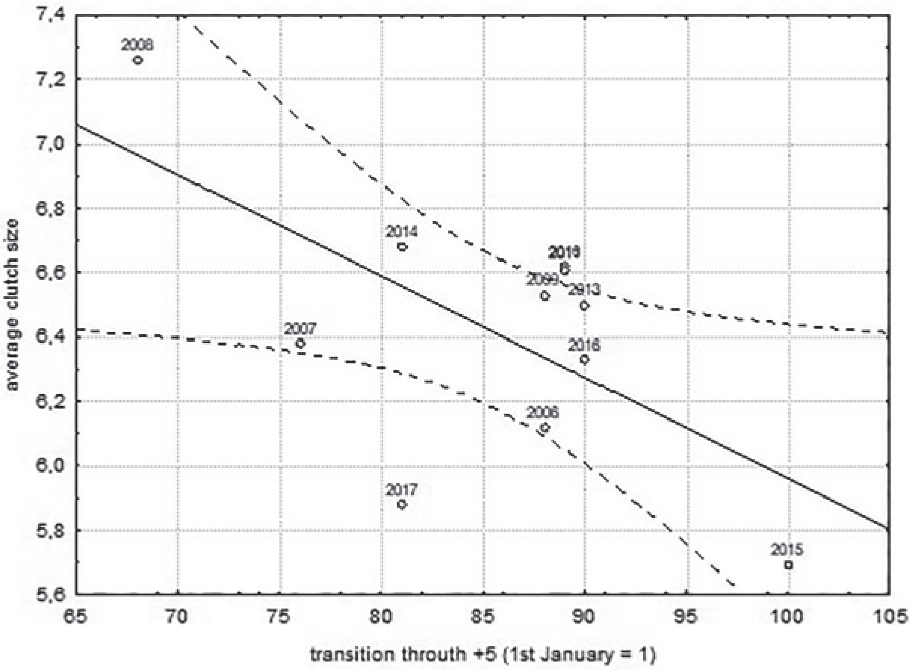

Fig. 4. Clutch size of Collared Flycatcher and a date of transition of average temperature through +5 °C (meteorological spring beginning).

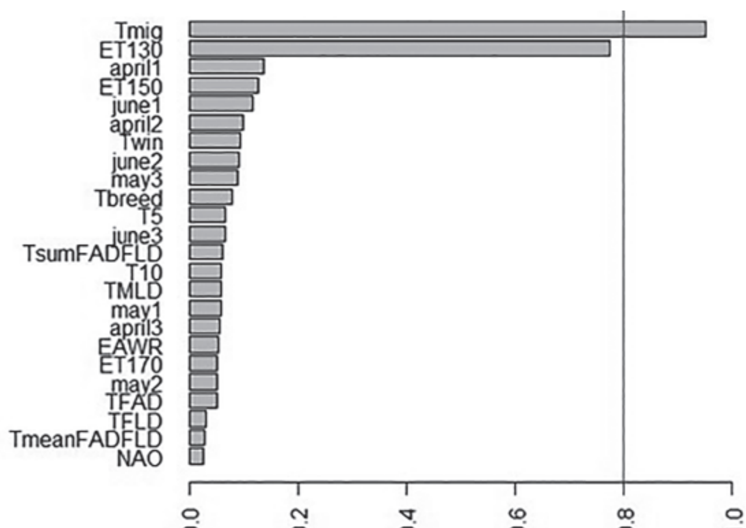

Fig. 5. Model-averaged coefficients of the predictor variables from the subset of best-fitting models for the clutch size (eggs).

Table 6. Distribution (% of clutches) of first egg laying in the third (III) ten days period of April. First (I). Second (II) and third (III) ten days period of May. First (I) ten days period of June numbers of clutches

	2006	2007	2008	2009	2010	2011	2013	2014	2015	2016	2017	total
3^{d}April	13.51	0.0	42.55	1.82	7.41	0.0	12.5	20.69	0.00	20.00	0.0	11.57
1^{st}May	18.92	75.00	46.81	60.00	18.52	38.89	56.25	39.73	33.33	55.00	66.67	46.28
2^{d} May	51.35	16.67	6.38	30.91	64.81	50.00	25.0	10.34	33.33	25.00	26.67	33.33
3^{d} May	16.22	2.08	4.26	7.27	9.26	11.11	6.25	0.0	33.33	0.00	6.67	7.99
1^{st} June	0.00	6.25	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.00	0.00	0.83

Breeding success

The breeding success negatively correlated with the average temperature of the 30-day interval until the median date of the laying period (T_{breed}) (table 1).

Discussion

Our results revealed that the breeding characteristics of the Collared Flycatcher are generally depend on local temperatures, as is the case in a number of works in Central Europe. This is true for the first egg date and median laying date.

The dates of onset of egg-laying for the Collared Flycatcher in the Homilshanski Lisy were similar to those recorded in south-western Germany, where the earliest date of first egg-laying was “the end of April” (Löhrl, 1976). An arrival date of the start of egg-laying for the Collared Flycatcher in NE Ukraine (1 May) was more similar to S Poland, where the earliest first egg date was 3 May (Głowaciński, 1973) and earlier than in Bialowieza Forest, where it is on the 2nd decade of May (Mitrus, 2003). Overall, the distribution of first egg dates in the different ten-day periods of April, May and June demonstrated the shift of the main egg-laying period in northeastern Ukraine a ten days earlier than in Bialowieza Forest (Mitrus, 2003).

According to the statement (Both & Visser, 2001), a long-range migrant Collared Flycatcher, adapting to local climatic conditions, can shift the date of commence of nesting. Thus, these dates in whole are reflect the temperature differences at various parts of area. The role of temperature in breeding cycle was analysed by Mitrus (2003).

However, a simple correlation of the parameters is not sufficient evidence of the influence of local climatic conditions on the nesting parameters of the Collared Flycatcher.

We suggested that the shift in egg-laying time, as well as the size of the masonry and the success of breeding are an adaptive response to a complex of temperature indicators. For example, accumulation dates of the sum of effective temperatures 130° (ΣT 130), 150° (ΣT 150), 170° (ΣT 170) — was used in studies of the Pied Flycatcher (*Ficedula hypoleuca*) in Karelia (Artem’yev 1994; 2015) and is an indicator of the timing of mass nesting of the species at similar latitudes. The dates of transition of daily temperatures through + 5 °C, + 7 °C, + 10 °C also one of the local characteristics (Artem’yev, 2008).

According to the constructed model (fig. 3), the first-egg date related to set of temperature indicators, generally showing not only the degree of air warming at nesting sites (April3, T_{FAD}, ΣT150), but also maintaining a constant level of air temperature (T10) (table 1). The first three indicators characterise the degree of warm air, and T10 — the constancy of this level.

The role of the measure of air temperature on the migration routes (T_{mig}) was the most important for determining the first-egg date (fig. 3). The impact of conditions on migration routes may affect the physical condition of birds arriving at nesting sites (feeding conditions, the waste of additional energy to compensate for the effects of low temperatures). The amount of effective temperatures (as the degree of air warming) is one of the indicators that integrate both the overall dynamics of the transition of average daily temperatures, and the average temperatures of decades, 5-day segments.

The size of the clutch may depend not only on the age of the bird, but also on the climatic conditions of the season (Garamszegi et al., 1998). In the study area the size of the clutch is determined as data of transition though +5 °C (fig. 4), so by two other indicators (T_{mig}, Σ130) (fig. 5). It showing not only sufficient air heating in nesting sites, but also the migration conditions of birds. Optimal (sufficient) air heating determines the high density of forage objects as sources of protein, allowing females to produce large masonry (fig. 5).

However, warm spring conditions do not always contribute to increased reproductive success (Grimm et al., 2015). An increase in temperature in excess of the optimal one has a depressing effect on the vegetation — the feed base of insects and caterpillars, the main food of the flycatcher. Therefore, relatively low temperatures (often with high humidity) are more favorable for the Collared Flycatcher.

Mechanisms influencing air temperature and precipitation act indirectly — both through the availability and abundance of food and the number of predators that ravage nests. (Borgmann, 2013; Adamik & Kral, 2007).

The average daily effective temperature between the date of arrival and the date of delivery of the first egg ($T_{sum\ FAD\text{-}FLD}$) demonstrates the degree of air warming, and therefore the amount and availability of feed, the synchronization of the predator's life cycles and victims, adjusting breeding dates to the needs of nestlings (Potti, 1999; Burger et al., 2012). In our studies, they have a negative meaningful correlation with the median egg lying date (table 1).

The average thirty-day temperatures before the median laying date (T_{breed}), is negatively correlated with the number of nestlings per nesting female (table 1). It can be concluded that such a factor as the increase in air temperature above some optimal level plays an additional role in reducing the success of reproduction.

In the populations of Collared Flycatcher near the southern borders of Wood-and-Steppe zone, where in some years there are early transitions of temperatures through the +5 °C (early onset of phenological spring) and high dryness, there is an effect of local air temperatures on the timing of the beginning and duration of egg-laying, as well as clutch size and reproductive success.

To start nesting, the optimal stable level of air warming should be achieved. In our conditions, it is determined by a set of temperature indicators: T10, ∑T150, the average value of five average daily temperatures before the arrival date (T_{FAD}), the average daily temperature of the second and third decades of April (correlate with the start date eggs). This complex includes such an indicator as the temperature of the air on the migration routes (T_{mig}), which determines the physical condition of birds arriving at nesting sites. The role of the environment conditions on wintering and miation paths, as opposed to local nesting conditions for distant migrants (in the example of the Willow Warbler) is discussed by a number of authors (Wesołowski & Maziarz, 2009).

The early date of the transition of the average temperature through the +5 °C is positively correlated with the size of the clutch. But the large size of the clutch does not always mean the large size of the brood. Reproductive success (the number of nestlings per nesting female) is in feedback with such indicator as the average of 30 average daily temperatures before the median date of lying. Thus, the number of nestlings is associated with the presence of not high, but optimal temperatures in the reproductive period.

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