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Latitudinal Temperature Characteristics of Arrival, Nesting, and Departure of Passerine Birds (Passeriformes, Aves) in the North of Western Siberia

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Abstract—Temperature indicators of the presence of passerine birds in the near-Ob forested tundra and tundra of Yamal Peninsula are considered, with special reference to latitudinal variability. When moving from the forested tundra to the Arctic tundra, a significant decrease in average arrival temperatures and a temperature decrease at the beginning of oviposition are observed, with no temperature effect revealed on the timing of departure. Climate warming in the north of Western Siberia causes a shift in the timing of the beginning of arrival and the beginning of reproduction to earlier dates and a shift in the boundaries of habitats.

Keywords: Arctic, passerine birds, temperature, arrival, egg-laying, departure, climate

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INTRODUCTION

The relationship between bird distribution and temperature boundaries is a well-known phenomenon for the Far North (Uspenskii, 1969). Most passerine birds of Northern Eurasia, migrants from low latitudes, arrive to their breeding range during the period of sustained increase in air temperature, nest during the period of constantly positive temperatures, and depart to their wintering ground during a sustained decrease in air temperature. For the north of Western Siberia, the timing of seasonal phenomena (arrival, egg laying, hatching of chicks, and departure) for different bird species, without any connection to a specific temperature, was considered by Boikov (1965), Leonovich and Uspenskii (1965), and Golovatin and Paskhalny (2003). Zhukov (2013) revealed the similarity of the southern or northern boundaries of the ranges of a significant number of northern species of Western Siberia with the isotherms of the summer months. Studies performed in recent decades have shown the influence of current climate changes on the timing of seasonal phenomena of a number of northern bird species (Jonsen et al., 2006; Zalakevicius et al., 2006; Soloviev et al., 2012; Ryzhanovskiy and Gilev, 2020; Volkov and Pozdnyakov, 2021).

For temperate latitudes, ornithologists in attempt to explain annual variations in the timing of reproduction identify temperature thresholds for the start of egg-laying (Haartman, 1954; Bolotnikov et al., 1973; Anorova, 1976; Hecke, 1979; Zimin, 1988). It is also known that, in the northern parts of the range, these thresholds are lower than in the southern ones (Wiehe, 1979; Järvinen and Linden, 1980; Khokhlova and Golovan, 1981; Zimin, 1988). However, the timing of departure from temperate latitudes is practically not related to the temperature regime in autumn (Sokolov, 2010), and there is no significant correlation between the departure or passage of long-distance and medium-distance migrants in the Baltic region and average monthly temperatures.

The territory of North-Western Siberia, where our observations were performed, is characterized by a relatively short period of positive temperatures, decreasing to the north, and a decrease in daily summer temperatures to the north (Shiyatov and Mazepa, 1995). At the same time, an increase in the average annual surface air temperature has been noted since the end of the last century (Pavlov and Gravis, 2000), which is not decreasing today, which is associated with global warming. Positive long-term trends in the shift of the terms of arrival and nesting to earlier dates are noted due to an increase in spring–summer temperatures in the forest-tundra (Ryzhanovskiy and Gilev, 2020). The purpose of this work is to specify the temperature of arrival, egg-laying, and departure of songbirds in the Lower Ob region and the Yamal Peninsula during the years of our research.

MATERIALS AND METHODS

Field observations covered the territory from the latitude of Labytnangi (66°30′ N, 66°25′ E) in the Ob forest-tundra to the latitude of the Sabetta Village (71°10′ N, 72°40′ E) in Northern Yamal. The main materials were obtained in the forest-tundra at the Oktyabrsky and Kharp field stations in the vicinity of Labytnangi and directly within the city, where the greatest number of observations were conducted in the period from 1971 to 2020. In 1974–1976 and 1982–1988, the Khanovei field station operated in the Middle Yamal near the Mys Kamennyi settlement (68°40′ N, 73°50′ E). In 1975 and 1989–1994, observations were performed in Northern Yamal, in the area of the Sabetta Village (Yaibari station, 71°04′ N, 72°40′ E).

Everywhere we sought to register the beginning of arrival (first record, first song, first catch with nets and traps), found and then controlled nests to establish the dates of the start of egg-laying. The total number of control nests exceeded 3700. In high latitudes, the arrival and egg-laying usually occur in a short time. Therefore, the first spring records of birds and finds of the first nests usually reflect the beginning of the seasonal phenomenon. The dates of departure of birds were recorded mainly in the forest-tundra. The temperature of the dates of the beginning of arrival, egg-laying, and the beginning of departure were determined on the basis of data from meteorological stations closest to our stations.

The source of information on the air temperature in the forest-tundra was the average daily data from the Salekhard weather station (66°31′ N, 66°36′ E); the temperature in the Middle Yamal was taken from the average daily data from the Mys Kamenny weather station (68°29′ N, 73°30′ E). Since we do not have data from the Tambei weather station (71°45′ N, 71°81′ E), which is the closest to the Yaibari station, the temperature at this station was considered to be the average value between the temperature at Mys Kamenny and the data from the Belyi Island weather station (73°24′ N, 72°30′ E). The temperature of the beginning of arrival, egg-laying, and end of departure were determined by the dates of the first spring record, the dates of laying the first egg, and the dates of the last record of individuals of a given species. Since there is little data on the Yaibari station, data on tundra stations were pooled to calculate the significance of temperature change trends from forest-tundra to tundra.

The data were processed using statistical methods; data on the temperatures of occurrence of various phenomena in the life of birds were compared using analysis of variance methods. Linear regression analysis was used to assess the long-term temperature dynamics and to construct the trends. Data were processed using the Statistica v. 6.0 (StatSoft Inc., 1984–2003) and Microsoft Excel 2010 software.

RESULTS

Arrival. Long before the onset of spring warming, at temperatures below –20°C in some years, hooded crows (*Corvus cornix*) and snow buntings (*Plectrophenax nivalis*) arrived at the latitude of the Arctic Circle. The average long-term temperature of the onset of arrival for these species was –8.9 ($n = 42$) and –9.7°C ($n = 39$), respectively. The arrival of other species, common in the forest-tundra in spring, began at an average long-term temperature above 0°C, but in years with late springs, some species began their arrival at subzero temperatures. The temperature of the onset of arrival of passerines in Yamal was lower than in the forest-tundra; i.e., the further northwards, the lower the temperatures of arrival (Table 1). In the forest-tundra, these are more often above-zero temperatures; in Yamal, more often subzero temperatures.

For the majority of species of the Ob forest-tundra, the temperature of the beginning of arrival gradually increased in the period 1971–2020, simultaneously with an increase in spring temperatures in these years (Ryzhanovskiy and Gilev, 2020). Significant positive long-term trends in arrival temperature were revealed for the eastern yellow wagtail (*Motacilla tschutshensis*) and white wagtail (*M. alba*), willow warbler *(Phylloscopus trochilus*), fieldfare (*Turdus pilaris*), little bunting (*Ocyris pusillus*), snow bunting, and Lapland longspur (*Calcarius lapponicus*). Positive though nonsignificant trends are characteristic of other forest-tundra species.

The period of research in the Middle and Northern Yamal was shorter. Nevertheless, in 1974–1976 and 1982–1994, an increase in the temperature of the beginning of arrival was also noted in the period from 1974 to 1994. In the Middle Yamal, the trends in the temperature of the beginning of arrival were also positive for the horned lark (*Eremophila alpestris*), meadow pipit (*Anthus pratensis*), red-throated pipit (*A. cervinus*), white and yellow-headed (*M. citreola*) wagtails, willow warbler, chiffchaff (*Phylloscopus collybita*), redwing (*Turdus iliacus*), and little bunting; in the Northern Yamal, the trends in the temperature of the beginning of arrival were also positive for the red-throated pipit, white wagtail, bluethroat (*Cyanecula svecica*), Lapland bunting, and redpoll. Figure 1 shows the trends of arrival temperatures for the white wagtail and the willow warbler as an example. It is evident that the trend lines in the forest-tundra and tundra for these species are parallel, and the increase in arrival temperatures in these subzones is similar.

An analysis of latitudinal differences in the temperature of arrival in the forest-tundra and Yamal using analysis of variance showed that, for the species common to the entire territory, the decrease in average temperatures when moving from the forest-tundra to the arctic tundra is significant: $F = 4.00$, $p = 0.05$ for red-throated pipit; $F = 4.06$, $p = 0.05$ for Lapland bunting; $F = 4.84$, $p = 0.03$ for white wagtail; $F = 5.22$, $p = 0.003$ for horned lark; $F = 7.94$, $p = 0.01$ for bluethroat; and $F = 13.06$, $p = 0.001$ for wheatear (*Oenanthe oenanthe*). Differences were nonsignificant only

Table 1. Minimum, maximum, and mean air temperature (°C) on the first day of arrival of birds in the Ob forest-tundra (66°30′) and in the Middle (68°40′) and Northern (71°04′) Yamal

Species	Latitude, deg		
	66°30′	68°40′	71°04′
Eremophila alpestris	−4.5–15.1 / 1.1 ± 0.9 (28)	−5.6–0.6 / −2.2 ± 1.2 (6)	−7.0... −0.8 / −3.4 ± 1.5 (4)
Anthus pratensis	−10.7–17.2 / 2.5 ± 1.0 (26)	−4.5–0.8 / 2.2 ± 1.0 (6)	X
Anthus cervinus	−2.8–5.4 / 2.5 ± 0.6 (21)	−4.4–2.6 / −0.3 ± 1.0 (6)	−0.4–5.0 / 1.6 ± 0.9 (5)
Motacilla tschutshensis	−0.8–20.0 / 5.1 ± 1.1 (22)	X	X
Motacilla citreola	3.3–5.3 / 4.3 (2)	−0.7–1.3 / 0.4 ± (8)	2.6 (1)
Motacilla alba	−8.8–12.2 / 0.3 ± 0.6 (42)	−6.4–0.5 / −3.0 ± 1.3 (6)	−8.0–1.0 / −2.5 ± 2.0 (4)
Prunella montanella	−1.1–6.8 / 2.7 ± 0.7 (12)	−0.4–1.4 / 0.4 (3)	X
Phylloscopus trochilus	−3.6–12.2 / 3.4 ± 0.6 (29)	−1.6–2.8 / 0.8 ± 0.5 (9)	X
Phylloscopus collybita	−0.6–7.8 / 3.6 ± 0.6 (17)	−0.6–3.7 / 1.7 ± 0.5 (10)	X
Phylloscopus borealis	0.8–21.5 / 7.4 ± 1.0 (27)	X	X
Acrocephalus schoenobaenus	−0.4–13.6 / 8.7 ± 1.6 (9)	0.5–5.3 / 3.8 ± 0.8 (7)	X
Oenanthe oenanthe	−1.5–9.9 / 3.6 ± 0.8 (15)	−5.8–3.1 / 1.1 ± 1.2 (7)	−1.0–0.9 / 0.1 ± 0.4 (4)
Cyanecula svecica	−1.8–14.3 / 4.1 ± 0.7 (27)	−3.1–3.2 / −0.1 ± 0.7 (8)	−1.0–6.0 / 1.6 ± 1.5 (4)
Turdus pilaris	−8.5–11.8 / 1.3 ± 1.0 (26)	–	X
Turdus iliacus	−1.6–11.9 / 2.4 ± 0.5 (32)	−2.5–2.8 / 0.2 ± 0.7 (7)	X
Fringilla montifringilla	−2.8–10.3 / 2.4 ± 0.6 (34)	X	X
Acanthis flammea	−7.5–4.9 / −1.0 ± 0.9 (18)	–*	−2.2 – 1.0 / 0.1 ± 0.6 (6)
Schoeniclus schoeniclus	−3.6–14.1 / 3.1 ± 1.1 (21)	−3.9... −0.3 / −2.2 ± (3)	X

Table 1. (Contd.)

Species	Latitude, deg		
	66°30′	68°40′	71°04′
Ocyris pusillus	$\frac{-5.9\text{–}11.7}{2.5 \pm 0.7(29)}$	$\frac{-0.3\text{–}3.1}{1.4 \pm 0.4(9)}$	X
Calcarius lapponicus	$\frac{-10.9\text{–}8.1}{1.0 \pm 0.8(23)}$	$\frac{-3.9\text{–}2.8}{-1 \pm 0.7(7)}$	$\frac{-3.9\text{–}0.9}{-0.3 \pm 0.9(5)}$

X—the species does not nest; * the species (redpoll) began arriving before the beginning of our observations; in parentheses—the number of years of observations; dash—no data.

for the redpoll (*Acanthis flammea*). Post-hoc analysis showed that the temperatures of the beginning of the arrival of species to Northern Yamal (in the arctic tundra) and to Middle Yamal (in the subarctic tundra) do not differ significantly. The temperatures of arrival in the forest-tundra are significantly higher than in the subarctic and arctic tundras.

Egg-laying. In the Ob forest-tundra, egg-laying began at temperatures above zero for all species (Table 2), with average values ranging from 5 (fieldfare) to 13°C (Arctic warbler (*Phylloscopus borealis*)). In the Middle and Northern Yamal, egg-laying began at average temperatures close to 0°C. A decrease in the temperature at which egg-laying begins with moving northwards can be noted when comparing both the minimum values (thresholds) and mean values (Table 2, Fig. 2). A comparison of samples including the nests in the forest-tundra with the nests in Yamal using analysis of variance showed that, for nearly all species, the decrease in average temperatures with moving from the forest-tundra to the tundras is highly significant (from $F = 8.46$, $p = 0.01$ for the redpoll to $F = 88.45$, $p = 0.001$ for the white wagtail). Latitudinal differences in the temperature of the onset of egg-laying were not found only in the wheatear, possibly due to the small sample size.

In some years, the first eggs of the season in the Yamal tundra were laid at temperatures below 0°C. This is due to the fact that the egg is formed for 4–5 days (Zimin, 1988), and a short-term cold snap, which is common in the north, does not stop oogenesis and egg laying. At the same time, the air temperature in the preceding 3–5 days, as well as the average temperature for 5 days, was always positive.

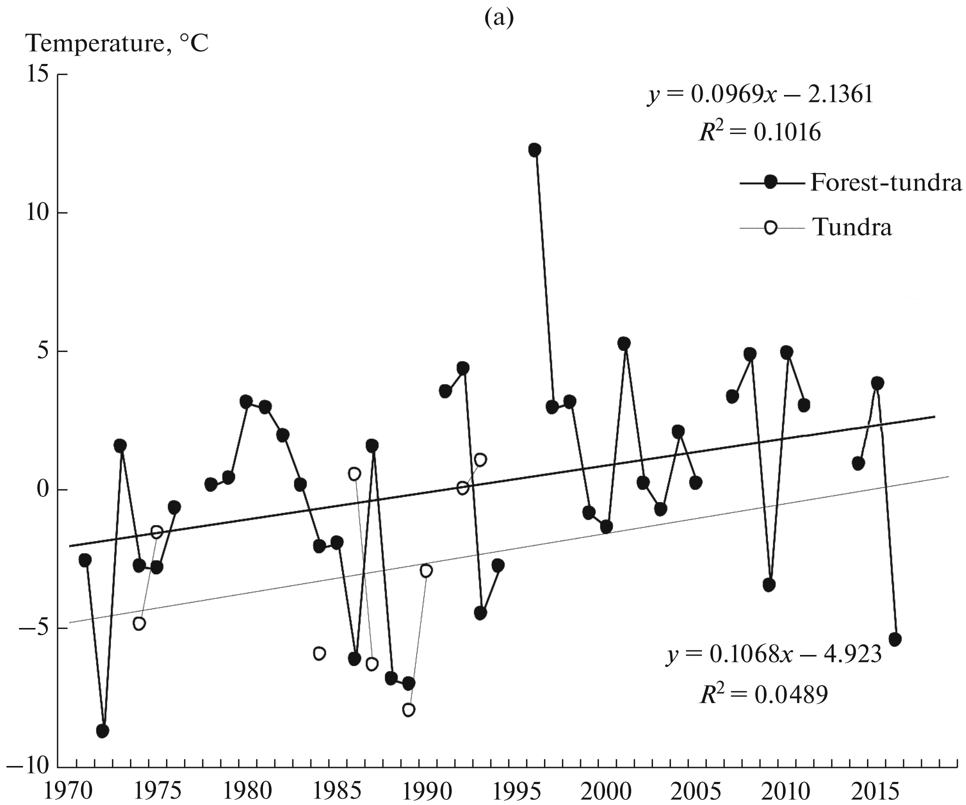
Departure. Autumn migration of passerine birds in the Ob forest-tundra begins in the first to second ten-day periods of August and ends in the third ten-day period of October to the first ten-day period of November (Ryzhanovskiy, 1997; Paskhalny and Golovatin, 2018). The departure is started by yellow wagtails and arctic warbler and is finished by snow buntings. The temperature at the beginning of the departure of birds from the forest-tundra is always above-zero, since the average temperature in August at the latitude of the Arctic Circle is 11.2°C, lim 7.5–15.1°C (Shiyatov and Mazepa, 1995).

The temperature at which the departure ends is also positive for some species. However, horned larks, meadow pipits, white wagtails, fieldfares, bramblings (*Fringilla montifringilla*), and common reed buntings (*Schoeniclus schoeniclus*) in some early autumn years (1981 and 1984) ended their migration with the first snowfall and at subzero temperatures. The range of temperatures of the last record is large and is 10–15 (sometimes 20°C) for nearly all species, which apparently indicates the absence of temperature restrictions for departure.

According to S.V. Shutov (personal communication), in 1989 the departure from the tundras of the Middle Yamal (Bovanenkovo Village) ended in the third ten-day period of August for yellow-headed wagtails, willow warblers, and little buntings at a temperature of 6–15°C, whereas bluethroats, red-throated pipits, and white wagtails completely departed at the beginning of September at a temperature of 1–5°C. In the same days, at the end of August–September, snow buntings migrating to the south were observed; however, they appeared in the forest-tundra at the beginning of winter, in October–November (Paskhalny and Golovatin, 2018), at subzero temperatures. In this species, molting ends in mid–late September (Ryzhanovskiy, 1997), then the migratory state is formed and fattening begins, but the departure from the tundra is delayed until the cold weather.

DISCUSSION

An analysis of long-term data (Ryzhanovskiy and Gilev, 2020) showed that, in the forest-tundra, short-term rises and falls in temperature may not have a significant effect on the beginning of bird arrival. Of greater importance is the general course of spring, which can be characterized by average temperatures for a certain period. Significant negative correlations were found between the dates of the beginning of arrival and average monthly temperatures in May: as expected, the higher the temperatures, the earlier the arrival begins.



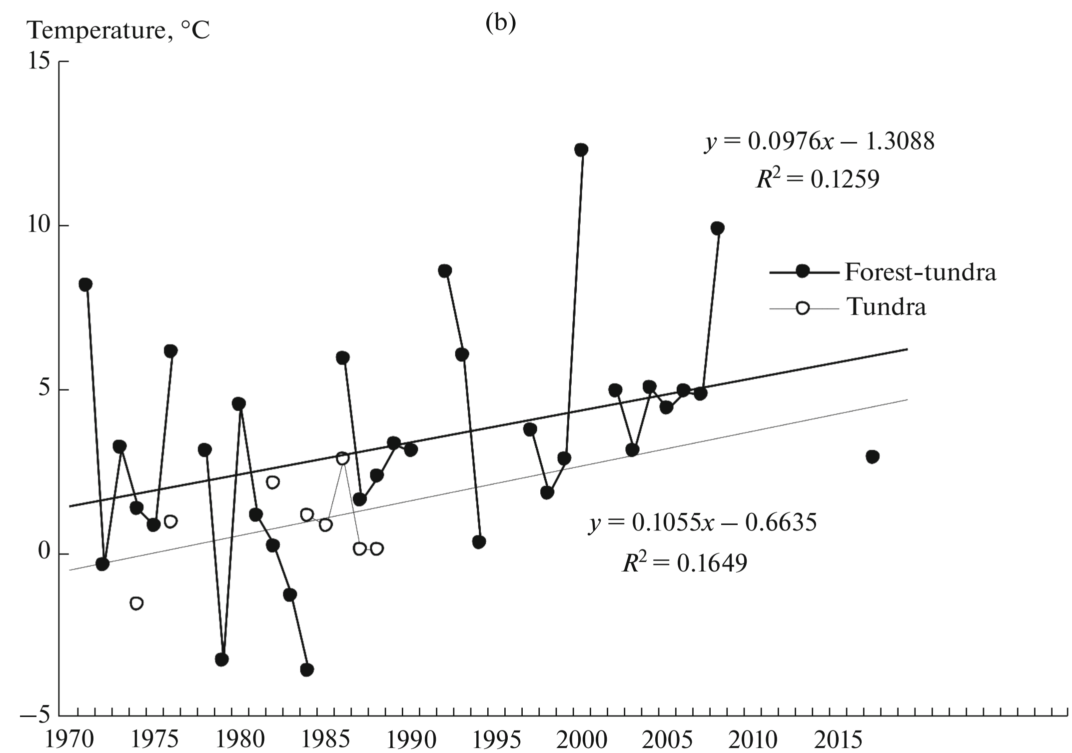


Fig. 1. Arrival temperatures and long-term trends for the white wagtail *M. alba* (a) and the willow warbler *Ph. trochilus* (b) in the forest-tundra and tundra of Yamal.

Table 2. Minimum, maximum, and mean air temperature (°C) on the first day of the beginning of egg-laying in the Ob forest-tundra (66°30′) and in the Middle (68°40′) and Northern (71°04′) Yamal

Species	Latitude, deg		
	66°30′	68°40′	71°04′
Eremophila alpestris	–	0.4–4.0 / 1.5(3)	–0.8–2.2 / 0.7(2)
Anthus pratensis	5.5–13.1 / 7.8 ± 1.3(4)	1.2–1.3 / 1.3(2)	–
Anthus cervinus	4.9–12.3 / 8.1 ± 1.5(5)	–0.8–3.5 / 1.3 ± 0.4(11)	1–1.8 / 1.4(2)
Motacilla tschutshensis	1.8–15.4 / 7.4 ± 2.2(6)	X	X
Motacilla alba	2.8–12.9 / 4.5 ± 1.4(7)	1.3–2.8 / 2.0(3)	0.5–1.6 / 1.0(2)
Phylloscopus trochilus	3.2–18.7 / 9.9 ± 1.2(14)	0.2–6.1 / 1.9 ± 0.8(9)	X
Phylloscopus collybita	3.5–22.6 / 11.5 ± 2.7(7)	0.2–5.3 / 3.6 ± 1.0(5)	X
Phylloscopus borealis	5.6–22.6 / 13.4 ± 2.4(7)	X	X
Cyanecula svecica	1.4–15.6 / 8.1 ± 1.4(11)	–0.8–2.3 / 1.3 ± 0.5(6)	–
Turdus pilaris	0–13.2 / 5.1 ± 1.6(8)	–	X
Turdus iliacus	2.9–11.4 / 6.1 ± 0.1(7)	–	X
Oenanthe oenanthe	4.2–5.9 / 5.1(2)	0–9.3 / 3.4 ± 1.3(7)	5.6 (1)
Acanthis flammea	1.6–13.3 / 6.4 ± 0.9(15)	1.8–4.7 / 4.2 ± 1.3(9)	1.6–9.0 / 5.3(2)
Ocyris pusillus	4.7–19.6 / 10.7 ± 1.4(11)	–0.7–4.3 / 1.8 ± 1.0(5)	X
Calcarius lapponicus	7.8–18.2 / 10.9 ± 2.0(5)	0.5–2.9 / 1.2 ± 0.5(5)	0–3.8 / 1.4 ± 0.6(6)

X— the species does not nest; in parentheses—the number of years of observations; dash—no data.

The average temperatures of the onset of egg-laying in the forest-tundra and in Yamal differ quite significantly. In the forest-tundra, these temperatures are not lower than 5 (more often, about 10°C), whereas in the north of Yamal whey are usually 1–3°C (Table 2, Fig. 2). It should be noted that, in closely related species (belonging to the same genus), the temperatures of the onset of egg-laying are very similar. For example, in the forest-tundra, they are 8–9°C for pipits, almost the same (7.45°C) for wagtails, 10–13°C for warblers, and 5–6°C for thrushes (Table 2). Possibly, this is due to the similarity of the physiological characteristics of these birds. It can be assumed that these are the temperatures at which birds of these species prefer

Table 3. Minimum, maximum, and mean air temperature (°C) on the last day of departure from the Ob forest-tundra

Species	Temperature	Species	Temperature
Eremophila alpestris	−4.4–9.0 / 1.1 ± 0.9 (12)	*Luscinia svecica*	1.8–13.9 / 6.9 ± 1.3 (10)
Anthus pratensis	−1.6–10.3 / 3.6 ± 0.9 (20)	*Turdus pilaris*	−4.3–4.3 / 0.2 ± 0.7 (14)
Anthus cervinus	0.3–14.6 / 6.0 ± 1.2 (13)	*Turdus iliacus*	1.1–8.5 / 5.4 ± 1.3 (5)
Motacilla tschutshensis	7–15.2 / 9.7 ± 1.2 (6)	*Fringilla montifringilla*	−0.8–21.0 / 6.2 ± 1.4 (14)
Motacilla alba	−1–9.1 / 3.5 ± 0.7 (14)	*Emberiza pusilla*	1.1–14.3 / 6.3 ± 0.8 (15)
Phylloscopus trochilus	1.7–14.5 / 6.4 ± 1.1 (14)	*Emberiza schoeniclus*	−3.9–10.2 / 2.9 ± 0.7 (22)
Phylloscopus collybita	2.6–14.6 / 8.0 ± 1.4 (8)	*Calcarius lapponicus*	1.1–10.1 / 5.7 ± 1.1 (7)
Phylloscopus borealis	2.7–12.7 / 6.7 ± 0.9 (6)	*Plectrophenax nivalis*	−9.6–1.2 / −2.6 ± 0.9 (15)

The number of years of observation is given in parentheses.

to start egg-laying. The sharp decrease in the temperature of the onset of egg-laying begins with moving to the north of Subarctic reflects harsher conditions and the need to start egg-laying earlier, practically as soon as the temperature becomes slightly above 0; otherwise, there is a high probability to have no time to hatch offspring.

The timing of the departure of first-year juveniles is determined by the migratory state, which is the result of the implementation of the ontogenesis program and photoperiodic conditions of the second half of summer (Gwinner, 1972; Dolnik, 1975; Noskov and Rymkevich, 2010). The timing of the departure of adult birds is established during spring photostimulation. It is adjusted by mating activity, molting, and photoperiod (Dolnik, 1975; Sokolov, 2006). Air temperature is determined by the seasonality of the climate of high latitudes, and its gradual autumn decrease in some

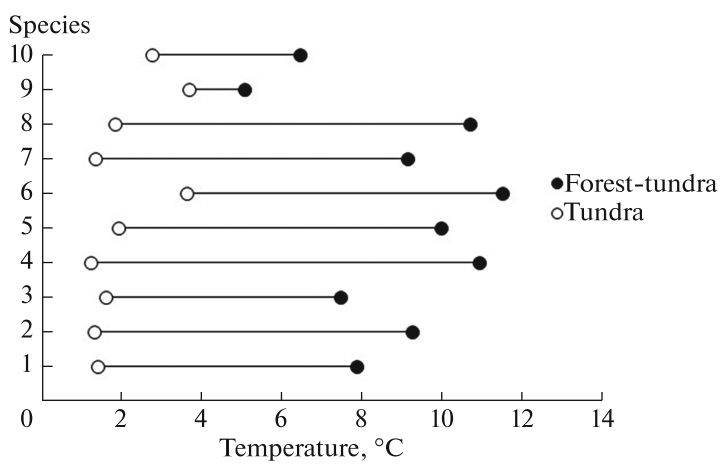


Fig. 2. Temperatures of the onset of egg-laying in the forest-tundra and tundra of Yamal in some bird species: 1—*A. pratensis*, 2—*A. cervinus*, 3—*M. alba*, 4—*C. lapponicus*, 5—*Ph. trochilus*, 6—*Ph. collybita*, 7—*G. svecica*, 8—*O. pusillus*, 9—*O. oenanthe*, 10—*A. flammea*.

years and sharp in other years has little effect on the timing of the end of departure. However, the stimulus for the departure of snow buntings, along with the shortening day, is probably the temperature, in contrast to yellow wagtails, arctic warblers, and reed warblers (*Acrocephalus schoenobaenus*), which complete their departure at the end of summer and definitely do not have temperature limits for departure.

Each bird species, due to the peculiarities of metabolism, is tolerant to a certain temperature range. Therefore the temperature regime of a particular area directly affects the possibility of the existence of this species (Shilov, 1985). There is a general tendency towards an increase in the species composition of birds of the forest-tundra and subarctic tundra against the background of a decrease in the abundance of some species in the forest-tundra, up to their disappearance during nesting. In 1970, at the beginning of our study of the avifauna of the Ob forest-tundra and tundra of the Yamal Peninsula, the list of birds included 116 species. In 1984, in our review for this area (Danilov et al., 1984), 186 species were listed, including 121 species of breeding birds. In 2020, in a new review (Ryabitsev and Ryzhanovskiy, 2022), 227 species were listed, including 163 breeding ones. Most new bird species were initially included in the list of vagrant species, breeding in the northern taiga and southern forest-tundra, moving northwards as the climate warmed. At the same time, subarctic species are shifting northwards. In particular, Lapland buntings and horned larks have practically disappeared from the forest-tundra, the abundance of red-throated pipits in the forest-tundra has decreased, but these birds are as common in the tundra as before. Further climate change will affect the avifauna of high latitudes.

CONCLUSIONS

When moving from the forest-tundra to the arctic tundras, a significant decrease in average temperatures for the arrival of passerine birds and a decrease in temperature for the onset of egg-laying is observed, with no temperature effect on the timing of departure. The current climate change affects the timing of arrival and breeding of birds, shifting them to earlier dates, as well as the movement of the boundaries of ranges.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies on humans or animals that meet the criteria of Directive 2010/63/EU.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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