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INSUFFICIENT COLD RESISTANCE AND THE EASTERN BOUNDARY OF THE DISTRIBUTION RANGE OF ANT *LASIUS FULIGINOSUS* (HYMENOPTERA: FORMICIDAE)

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Summary. The hypothesis of insufficient cold resistance as a factor limiting the distribution of the dendrophilous ant *Lasius fuliginosus* eastward of the city of Novosibirsk is proposed and partially tested; this species has colonies of two million individuals and therefore has a significant biocenotic role. The cold resistance and wintering conditions of this ant species in the vicinity of Novosibirsk are studied. The mean supercooling point in three nests was –14.6 to –18.1°C, down to –23.9°C in the most resistant individuals. The lower lethal temperature does not exceed –12°C. The temperatures in the nests (with 55 cm snow-cover height above it) did not decrease below –1.5°C at 50–60 cm depth during the winter, which indicates wintering temperature conditions comfortable for the ants. The cause of absence of this species in Yakutia, foothills of the Western and Eastern Sayan Mountains, and Tuva, as established by myrmecologists, is likely climatic, initially associated with a decrease in the amount of solid precipitation under the condition of similar or lower air temperatures from Western to Central Siberia, in particular by a third in the vicinity of the city of Krasnoyarsk in comparison to the vicinity of Novosibirsk.

Key words: supercooling point, lower lethal temperature, wintering temperature, Novosibirsk, Siberia, Russia.

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Резюме. Предложена и частично проверена гипотеза о недостаточной холодостойкости как факторе, ограничивающем распространение на восток от Новосибирска дендрофильного муравья *Lasius fuliginosus*, имеющего семьи в 2 млн. особей и потому обладающих значительной биоценотической ролью. Рассмотрены холодостойкость и условия зимовки этого муравья в окрестностях Новосибирска. Средняя температура максимального переохлаждения в трех гнездах составила –14.6…–18.1°C, у наиболее устойчивых особей до –23.9 °C. Длительно переносимые температуры не превышают –12°C. Температуры в гнездах (при мощности снежного покрова над ними в 55 см) не опускались в течение зимы на глубине 50-60 см ниже –1.5 °C, что свидетельствует о

складывавшихся комфортных для муравьев температурных условиях зимовки. Причина констатируемого мирмекологами отсутствие вида в Якутии, предгорьях Западного и Восточного Саян и в Туве, вероятно, климатическая, изначально связанная (при близких или более низких температурах воздуха) с уменьшением количества твердых осадков от Западной к Средней Сибири, в частности, в окрестностях Красноярска – на треть относительно окрестностей Новосибирска.

INTRODUCTION

The jet black ant *Lasius fuliginosus* (Latreille, 1798) is a mass dendrophilous species inhabiting the south of the forest and forest–steppe zones of Europe and the Caucasus; in Asia, the distribution range extends along the south of Western Siberia to the Altai and the mountainous part of the Irtysh River basin. It forms the largest colonies among species of the genus, as more than two million individuals can be found in nests. It even competes with the red wood ants for space and resources (Radchenko, 2016). The facts above suggest a significant biocenotic role of the jet black ant in forest communities.

This easily found species has never been recorded by the myrmecologists (Dmitrienko & Petrenko, 1976; Zhigulskaya, 1968) working east of Novosibirsk. In particular, it was never found during extensive studies of Yakutia and Buryatia, in the Angara River basin and above its mouth in the Yenisei River basin through to its upper reaches (Tuva depressions). The causes of the absence of *L. fuliginosus* eastward of Western Siberia are unknown and are not discussed in the literature.

The increasing continentality and severity of climate in general from west to east suggests that the possible cause is the insufficient cold resistance of the species, as demonstrated for other species of ants (Berman et al., 2010). However, the ecology of wintering in *L. fuliginosus* remains unstudied. To test the hypothesis, previously unknown cold resistance of the discussed ants and the temperature conditions of their wintering in the vicinity of the city of Novosibirsk are studied. A comparison of the cold resistance of ants and the soil temperatures during winter months allows us to partially answer the posed question.

MATERIALS AND METHODS

We collected the ants for the experiments in park forests in the vicinity of Novosibirsk on August 31 – September 2, 2018. The air temperature reached 30°C, the ants were active in a way typical for summer, they were found in large numbers on birches (*Betula pendula*) and in underground tunnels leading to other trees. Some of the insects were in wintering chambers located in the soil among the roots of birches. To compare the cold resistance, we caught over 1000 individuals in such chambers in three nests and the active ants, which were probably collectors of aphid honeydew on the tree trunks. Since the excavation of winter chambers in the soil is associated with cutting the roots and, eventually, the destruction of the tree (which is unacceptable in a forest park), we estimated the cold resistance of ants from a layer of 20–40 cm. It is known that the cold resistance does not depend on the location of wintering chambers (Berman et al., 1984). The galleries were traced to a depth of at least 60 cm.

The insects were delivered to the Institute of Biological Problems of the North, Far East Branch of the Russian Academy of Sciences (the city of Magadan) and acclimated in WT-64/75 temperature test chambers (Weiss, Germany) by sequentially keeping them at temperatures of +5, –1, and –5°C for a month each. This procedure equalized the conditions of preparation for the wintering for ants from the two collected groups with different degrees of physiological preparation: still active ants, collected on tree trunks, and the ants already wintering in underground chambers**.** At the end of the study, a control group from thermostats with a temperature of –5℃ was consecutively transferred to +1 and +5°C. All insects came to life, indicating that the acclimation scheme was correct and confirming that the characteristics of cold resistance were obtained on living ants.

The cold resistance of ants was evaluated by the supercooling point (*SCP*) and freezing temperatures (*TF*). These values characterize the ability of insects to endure short–term cooling below zero without freezing of the body fluids. Along with the mean *SCP* we used the minimum values, which, being on the edge of the distribution, indicate the limit capabilities of ants *L. fuliginosus*. The measurement of *SCP* were taken by standard methods (Berman *et al*., 2010).

The temperature conditions of wintering were estimated according to the data from loggers set in one of the nests for the winter at a depth of 20–30 and 50–60 cm. We also used the measurements of soil thermometers and other climatic data (Reference book..., 1965–1969).

RESULTS AND DISCUSSION

In areas with a relatively mild climate, judging by the findings in Estonia, (Maavara, 1971), *L. fuliginosus* winters in nests made in the trunks of weakened trees, often in the hollows (Radchenko, 2016). In cold regions, the wintering part of the nest is located under the roots of the populated tree (Zakharov, 2015), but we could not find any information on the nature and arrangement of wintering chambers in the literature.

Two found nests were located in birches without visible damage. The third nest was also located in a birch (40 cm in diameter), but on the southern side of its trunk; 50 cm from the ground to a height of 2 m, there was a 0.5–6 cm wide and 3–7 cm deep crack filled with dried bore-dust from ants making galleries in the wood. Aphids and ants were under the bore-dust. **In the underground part** of all three nests, galleries were close to the bark of large roots and in the adjacent soil layer no more than 35 cm wide. The galleries went vertically down deeper than 60 cm, where we could not reach without damaging the tree roots. In all soil chambers located along the undamaged roots, we found attached root-sucking aphids forming a continuous layer. In the soil galleries that were not adjacent to the roots, only ants were found.

Cold resistance of the wintering *L. fuliginosus* in three studied nests is expectedly different (Table 1). Active ants that collect honeydew from aphids had an average *SCP* of –9°C (with a minimum value of –14.7℃). The highest average *SCP* or the insects from the three nests that were in the wintering chambers at the time of collection was twice lower *SCP* of the honeydew collectors (–18.1°C, with a minimum of –23.9°C in the dataset). *TF* in the compared groups differed even more significantly: –3.7°C in the active insects versus –12.6°C in the insects from wintering chambers. Thus, *L. fuliginosus* ants collected on tree trunks were not prepared for the wintering. It was earlier shown that individuals from other species (*Formica aquilonia, F. pratensis, Camponotus ligniperda,* and *Lasius niger*) that start the wintering last have lower *SCP* and *TF* (Maavara, 1971).

However, datasets from the wintering chambers of the three nests were also found to differ by physiological state. The average *SCP* of the datasets of specimens from these nests form a smooth series from –14.9 to the aforementioned –18.1°C (Table 1). Differing degree of preparation for the wintering is also reflected in the distribution pattern of *SCP* within each dataset (Fig. 1), ranging from normal with weak asymmetry (nest no. 3, *SCP* of –18.1°C) to sharply asymmetric (nest no. 2, *SCP* of –15.2°C). With better preparation for the wintering, the average *SCP* can decrease to the values observed in the most cold-resistant individuals from the studied nests (–22.3 to –23.9°C), similar to the pattern observed in other species of ants; the right sides of the *SCP* distribution indicate the existence of reserve capabilities in the species (Berman *et al*., 2010).

Table 1. Cold resistance characteristics (°C) of *Lasius fuliginosus* in three nests from the vicinity of Novosibirsk.

Nest no.	Collection site	Collection depth, cm	*SCP* *m±SE**	Min *SCP*	*TF* *m±SE***	*n*
1a	From tree trunk	-	–9.0±0.6	–14.7	–3.7±0.6	18
1b	In soil around a root	20–40	–14.6±0.5	–20.1	–8.4±0.5	52
2	as above	20–40	–15.2±0.6	–22.3	–9.8±0.7	57
3	as above	20–40	–18.1±0.4	–23.9	–12.6±0.6	55

**SCP,* supercooling point, ***TF*, freezing temperatures.

The lack of living material made it impossible to determine the resistance of *L. fuliginosus* to prolonged exposure to low temperatures close to *SCP* or resistance to a state of supercooling. However, this characteristic can be preliminarily estimated based on the data for closely related species. For *Lasius niger* and *L. alienus*, at *SCP* equal to –23.7 and –20.6°C, the maximum tolerated temperatures were close: –13 and –14°C, respectively (Zhigulskaya *et al*., 2018). Comparison of *SCP* in these species with *L. fuliginosus* suggests that the latter species can endure temperatures no lower than –12°C long-term.

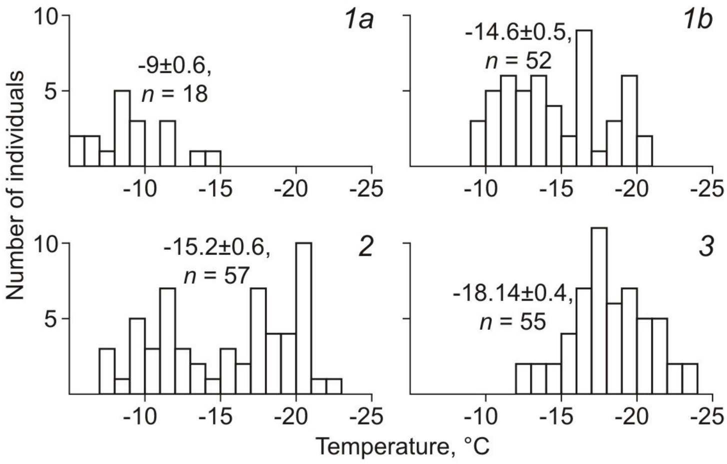

Fig. 1. Supercooling points (*SCP)* distributions of the *Lasius fuliginosus* from 3 nests from the environs of the Novosibirsk. In the right upper corner of the picture there is a number of the nest.

Wintering conditions. According to the data of the loggers installed in the nest (Fig. 2), the minimum temperatures at 20–30 cm depth decreased only to –1.9°C for 3 days (from February 15 to February 17, 2019), and at 50–60 cm depth, to –1.5°C and only for two days (February 19–20, 2019). The snow cover depth over the nest was about 55 cm from February 15 to February 20. However, even with the snow-cover in the vicinity of the city of Novosibirsk, which was close to the multiyear background (32 cm in the "field" and 60 cm in the "forest"), temperatures in the soil at 20 cm depth could not fall below –6.4°C on average (Table 2). It should be taken into account that the ant galleries and chambers were also found deeper than 60 cm. At this depth, even at the "coldest" stations in the south of Western Siberia (Aleiskaya, Barnaul-Agro), where the snow cover depth does not exceed 20 cm according to the permanent snow stake and the field snow surveys, the soil temperatures at 80 cm depth do not decrease below –6°C (Reference book..., 1965). Thus, the temperatures in the nests should be higher than the lower lethal of the studied ants within the range of –12 to –8°C.

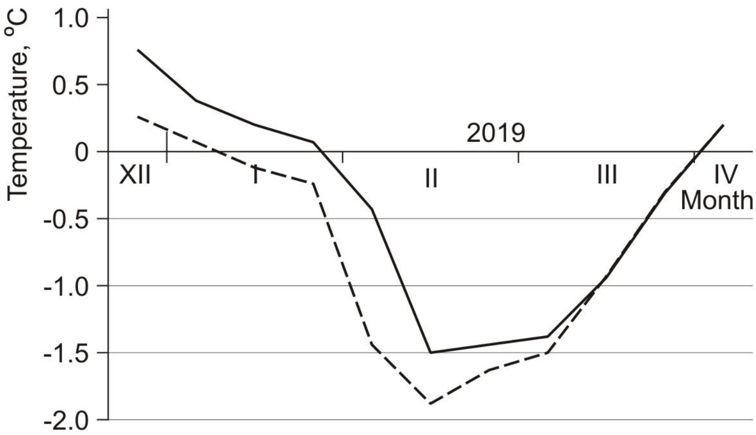

Fig. 2 Dynamics of the minimal decade temperatures of 2018–2019 in the nest of the *Lasius fuliginosus* at the depth 20–30 cm (dotted line) and 50–60 cm (solid line) in vicinity of Novosibirsk.

In the vicinity of Krasnoyarsk ("Opytnoe Pole" meteorological station), despite a very similar background air temperature, temperatures in the soil at 20–80 cm depths are 1.5–2 times lower than those at the corresponding depths in the vicinity of Novosibirsk (Table 2). An obvious initial cause is reduction of solid precipitation by more than a third in the vicinity of Krasnoyarsk: 52 cm versus 79 cm, respectively. Moreover, an important factor is the wind redistribution of snow in the "forest-field" system: both in Novosibirsk and Krasnoyarsk, there is two times less snow in the "field" than in the "forest". However, in the "forest" in the vicinity of Novosibirsk, there is two times more snow than in the "forest" near Krasnoyarsk.

Thus, the differences in the total amount of solid precipitation, reinforced by the redistribution of snow by the wind between the "forest" and the "field" in the vicinity of Krasnoyarsk and Novosibirsk, strongly affect soil temperatures; this appears to be critical for the distribution of *L. fuliginosus,* the ant species with low cold resistance, to the east of West Siberia.

Table 2. Average monthly temperatures (°C) of air, soil under natural cover, and snow cover depth (cm) on the routes (Reference book..., 1965–1969).

Meteorological station	Months	Air temperatures	Soil temperatures at a depth, cm			Snow		
			20	40	80	Precipitation, mm	Snow cover depth on a route, cm	
							Field	Forest
Bugry (Novosibirsk)	XII	–13.9	–4.6	–1.9	0.8	36	23	38
	I	–16.1	–5.8	–3.7	–0.9	25	26	48
	II	–14.3	–6.4	–4.6	–2	18	32	60
Opytnoe Pole (Krasnoyarsk)	XII	–12.4	–5.8	–3.9	–5.9	24	11	22
	I	–15.5	–8.2	–6.7	–3.6	16	11	26
	II	–13.8	–9.6	–8.1	–5.3	12	11	29

The existing estimation of the possible limiting effect of climate on the distribution of the discussed species needs to be corrected, since comparison of the data from only two meteorological stations (Novosibirsk and Krasnoyarsk) is clearly not sufficient. It is possible that it is first necessary to analyze the frequency of winters with weather conditions critical for the ants, especially dry winters. During such winters, giant nests of this species can freeze out, and their restoration takes a long time, perhaps comparable to the period of repetition of the critical years.

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REFERENCES

Berman, D.I., Zhigulskaya, Z.A. & Leirikh, A.N. 1984. Biotopic distribution and cold hardiness of *Formica exsecta* Nyl. (Formicidae) near the Northeast Distribution Boundary (the upper reaches of the Kolyma). *Bulletin of Moscow society of naturalists, Biological Series*, 89(3): 47–63. [In Russian]

Berman, D.I., Alfimov, A.V., Zhigulskaya, Z.A. & Leirikh, A.N. 2010. *Overwintering and cold-hardiness of ants in the Northeast of Asia*. Pensoft, Sofia-Moscow. 294 pp.

Dmitrienko, V.K. & Petrenko, E.S. 1976. *Ants of taiga biocenoses of Siberia.* Nauka, Novosibirsk. 220 pp. [In Russian]

Zakharov, A.A. 2015. *Ants forest communities, its life and role in the forest.* KMK. Scientific Press. Moscow. 404 pp. [In Russian]

Zhigulskaya, Z.A. 1968. Ant (Formicidae) population of steppe Tuva landscapes. P. 115–139. *In*: *Soil fauna in forestless biocenoses of the Altay-Sayan mountain system*. Novosibirsk. [In Russian]

Zhigulskaya, Z.A., Krugova, T.M. & Bulakhova, N.A. 2018. Wintering conditions and cold resistance the ants *Lasius alienus* and *L. psammophilus* (Hymenoptera, Formicidae) in south of Siberia. *Fauna of Ural and Siberia*, 2: 16–24. [In Russian]

Maavara, V.Yu. 1971. On cold-hardiness of some ant species. P. 68–71. *In: Cold-hardiness in insects and mites. Abstracts of the Simposium held in Taru (Estonian SSR) April 19 to 21*. Tartu. [In Russian]

Radchenko, A.G. 2016. *Ants (Hymenoptera, Formicidae) of Ukraine*. Kiev. 480 pp. [In Russian]

Reference book on the USSR climate. 1965. Leningrad: Gidrometeoizdat; No 20. Part 2. 396 pp; 1966. No 21. Part 4. 110 pp.; 1967. No 21. Part 2. 504 pp.; 1969. No 20. Part 4. 331 pp. [In Russian]