

RESEARCH ARTICLE

The study of circadian activity of bumblebees (Hymenoptera: Apidae, *Bombus* Latreille) of the Middle Ob lowlands

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Using the example of two mass species of bumblebees in the Middle Ob lowland, it is shown that the change in bumblebees activity during the day is a species-specific indicator. *B. distinguendus* in the conditions of the Middle Ob lowlands are characterized by the morning-evening rhythm of activity, in *B. lucorum*, the activity is relatively uniform throughout the day. The optimal temperature for active foraging of both species varies within 19–25°C. The total duration of bumblebees diurnal activity at the beginning of the flight is 11–12 hours. In the period of the mass bumblebees flight, the duration increases to 18–19 hours.

Keywords: *Bombus*; circadian activity; bumblebees; optimal temperature; Middle Ob; *Bombus lucorum*; *B. distinguendus*

Almost all animals adapt their physiological and behavioral processes to the daily fluctuations of abiotic parameters. Diurnal or circadian rhythm enables living beings to prepare for environmental changes. The study of diurnal rhythms of social insects is of great interest to scientists. Bumblebees, as pollinators of many plants, are the most important ecological component of natural and natural-anthropogenic ecosystems. The seeds harvest of many cultivated plants depends on their activity. In addition, the bumblebees diurnal rhythm is of sufficient interest in connection with the impact of all groups of abiotic and biotic factors on it, which are able to influence foragers.

Many studies have confirmed that bumblebees adapt their activity time to the alternating light and dark phases of the day. Since the bumblebees forage flights take place during almost the entire daylight hours (and sometimes at bright nights), therefore, light is an important factor determining the bumblebees activity.

It is noted that the daily bumblebees activity outside the nest usually begins long before the sunrise, with large females dominating in the morning, and from 12 o'clock small and mobile workers appear in mass (Alekseev, 1982). Bumblebees activity reaches a maximum at around 11 o'clock in the morning; then from 12 to 14 in the afternoon most bumblebees are in the nests; from 14 o'clock departures from the nest are increasing, reaching a maximum at approximately 18 hours (Panfilov et al., 1960; Tyumaseva, 1988, etc.). There is still no reliable explanation for this behavior strategy for foraging bumblebees during the day.

The dependence of the diurnal activity of bumblebees from the ambient temperature was studied by D.V. Panfilov, V.F. Shamurin and V.A. Jurcev (1960). They revealed that bumblebees are able to maintain their body temperature 20-30 degrees higher than the ambient temperature.

Having analyzed the factors determining the bumblebees activity and features of adaptation to the north conditions, I.A. Bogacheva and E.V. Shalaumova (1990) suggested that the decrease in the intensity of the foraging activity of bumblebees in the middle of the day is due to the direct effect of high temperatures on the bumblebees. Bumblebees produce a large amount of heat during the flight, and if they cannot give it out to the environment, this reduces their flight activity. The daily break can be also caused by the indirect effects of high temperatures, manifested through a decrease in nectar secretion in plants.

The purpose of our research is to study the peculiarities of the bumblebees circadian activity in the conditions of the Middle Ob lowland and its dependence on various environmental factors

Materials and methods

The the bumblebees circadian activity was studied in July (period of bumblebees mass flight) in 2007–2008 in two localities: a country road in the mixed forest in the vicinity of the village Salym in the Nefteyugansky district, and a grassy meadow with

anthropogenic load (trampling down, cattle grazing) in the vicinity of the village of Saygatina in the Surgut region. The study areas were selected so that they were more or less homogeneous over an area of at least 0.1 ha.

To determine the nature of bumblebees circadian activity, we used classical methods (Palij, 1970). The surveys were carried out at regular intervals, every three hours (at 6, 9, 12, 15, 18, 21, 24 o'clock), in triplicate. The detailed studies of circadian activity were conducted on two model objects: *Bombus distinguendus* – when foraging on *Vicia cracca* L. (Fabaceae) in the vicinity of Salym, and *B. lucorum* – when foraging on *Trifolium repens* L. (Fabaceae) in the vicinity of the village of Saygatina. To interpret the obtained results, the data were recalculated into a percentage and into the average number of pollinators per flower of a particular plant over one hour.

On the days of observation, the temperature, cloudiness and lighting were recorded. Thus, when studying the circadian activity of *B. distinguendus*, the average temperature at the time of recording was following: at 0.00 – 12–14°C, 6.00 – 16–18°C, 9.00 – 20–21°C, at 12.00 – 26–27°C, 15.00 – 25–26°C, 18.00 – 22–24°C, 21.00 – 18–19°C. The average cloudiness for all recordings was 30–40%, wind – 2–5 m/s, lighting – from 50 to 75 Klx. When studying the circadian activity of *B. lucorum*, the average temperature at the time of recording was following: at 0.00 – 11–14 °C, 6.00 – 16–18°C, 9.00 – 20°C, 12.00 – 25–26°C, 15.00 – 25–26°C, 18.00 – 22°C, 21.00 – 17–19°C. The average cloudiness for all recordings was 40 %, wind – 2–5 m/s, lightning from 55 to 75 Klx

Results and discussion

In the Middle Ob lowlands, 26 bumblebees species of the genus *Bombus* Latr. (Demidova, Tyumaseva, 2008, 2011; Demidova et al., 2018) are currently registered. Phenological studies have shown that the beginning of the bumblebees flyout from wintering vary in different species. However, in all species, the bumblebee females are the first to appear, which indicates their greater tolerance in contrast to working foragers. After the winter diapause, the first are the females of *Bombus lucorum*. Their flyout falls on the third decade of April – first decade of May, depending on the year. The females of *B. distinguendus* fly out in the first decade of June. The total duration of bumblebee diurnal activity in this period (early summer) is 11–12 hours. During the mass flight of bumblebees, the duration increases to 18–19 hours.

During the period of mass flight, the activity peak of *B. distinguendus* bumblebees is in the morning, from 8.00 to 10.00, and in the evening from 16.00 to 19.00 (Fig.1). Early in the morning at 6.00, the activity is low, as well as at lunchtime. The bumblebees of *B. distinguendus* are insects with a morning-evening rhythm of activity.

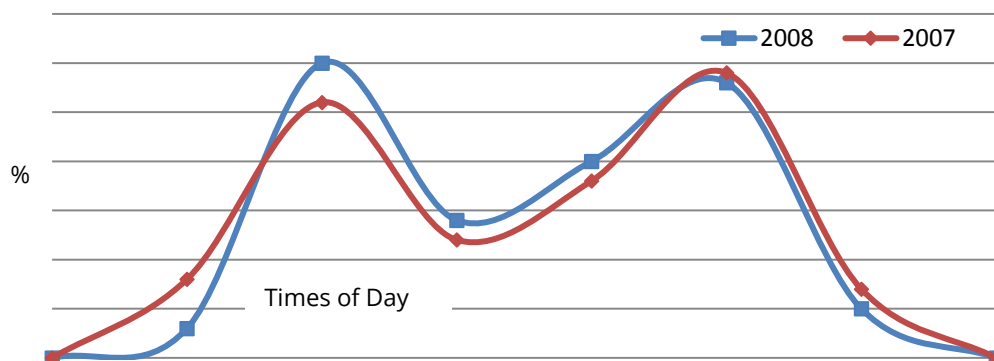


Figure 1. Circadian activity of *Bombus distinguendus* on *Vicia cracca* L., July, 2007–2008

Studying the dependence of the bumblebees activity on the air temperature, we confirmed that the intensity of the pollinators work depends on temperature (Fig. 2). According to the graph of *B. distinguendus* activity dependence on the temperature, it is clear that the limiting factors of bumblebee foraging activity are low air temperatures – less than 15°C, as well as very high ones – more than 25°C. The optimal temperature for *B. distinguendus* in the study region is 19–24 °C.

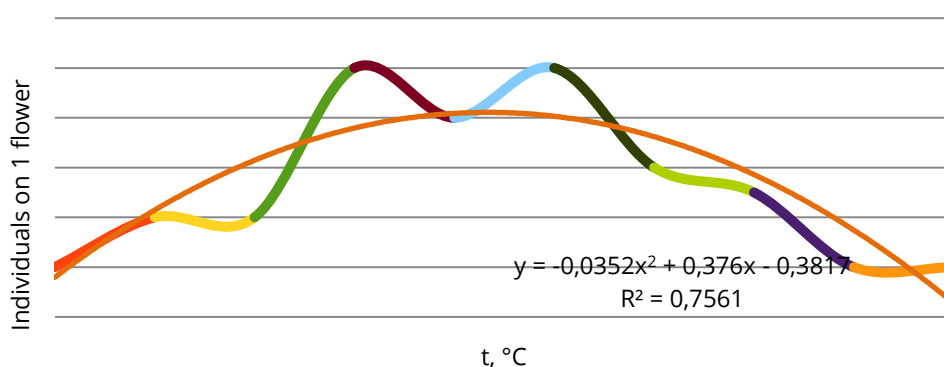


Figure 2. Activity of *Bombus distinguendus* Mor. depending on temperature (optimal temperature for bumblebees)

Fig. 3 shows that *B. lucorum* are almost evenly active during daylight hours, a small peak of activity is observed in the morning at 9.00–10.00 hours.

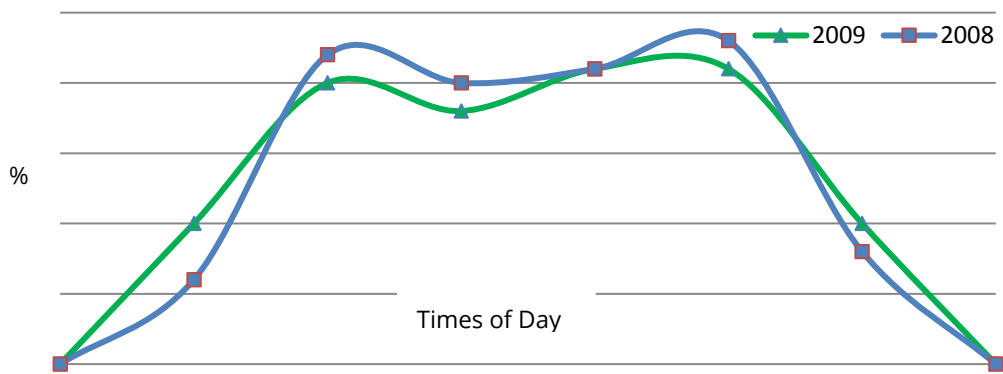


Figure 3. Circadian activity of *Bombus lucorum* L. on *Trifolium repens* L., July, 2008–2009

The uniform activity of *B. lucorum* during the day is clearly visible, depending on the temperature (Fig. 4). Its peak of activity is observed at 19 °C – 23 °C. However, at +23 °C and higher, there is some decline in the activity of these insects.

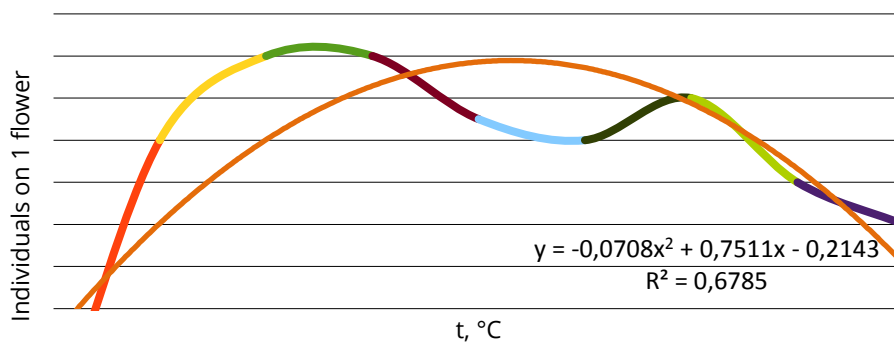


Figure 4. Activity of *Bombus lucorum* L., depending on temperature (optimal temperature for bumblebees)

We should not forget that the bumblebees activity depends not only on temperature, but also on the complex sum of factors, and, in addition to climatic conditions, it is necessary to take into account the peculiarities of the plants nectar excretion and the pollinators biology.

As *B. lucorum* is an «operator» (a pollinator biting through the flower tube at the nectary), so the plants nectar excretion minimally affect its activity. This is probably why there are minor differences in the temperature activity of this pollinator.

Conclusions

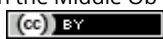
On the example of two mass bumblebee species of the Middle Ob lowlands, we have shown that the change in bumblebees activity during the day is a species-specific indicator. *B. distinguendus* in the conditions of the Middle Ob lowlands are characterized by the morning-evening rhythm of activity, in *B. lucorum*, the activity is relatively uniform throughout the day. The optimal temperature for active foraging of both species varies within 19–25 °C. The total duration of bumblebees diurnal activity at the beginning of the flight is 11–12 hours. In the period of the mass bumblebees flight, the duration increases to 18–19 hours.

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