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SHORT COMMUNICATION

Description of nest architecture and ecological notes on the bumblebee *Bombus* (*Pyrobombus*) *lapponicus* (Hymenoptera: Apidae: Bombini)

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Abstract
Little information is known about the nesting behaviour of arctic and boreal bumblebee species. The arctic is an environment with hard eco-climatic constraints notably for bumblebees. Here, we describe the nest of a common circum boreal species, *Bombus lapponicus*. A natural nest was discovered from an abandoned rodent nest (*Microtus oeconomus*) at 560 m. at Björkliden (Sweden) on June 14, 2021. The nest was 10 cm under the ground and at the end of a 1-meter-long sinuous tunnel. When discovered, the nest was wrapped in rodent straw and consisted of a nectar pot and 11 cells. The architecture of the brood had a horseshoe shape, consistent with other bumblebee nests already described. Before nest excavation, we observed the queen's comings and goings during a whole day to determine the time spent inside the nest to take care of the brood and the time spent outside to collect nutritive resources. The development of the brood was continued in the laboratory until the emergence of sexuates.

Keywords Bumblebee · Circum arctic species · *Bombus* (*Pyrobombus*) *lapponicus* · Nest · Description

Introduction

Bombus lapponicus (Fabricius 1793) belongs to the large subgenus *Pyrobombus* Dalla Torre 1880 that includes more than 50 species over the world (Williams 2021). The habitat of *Pyrobombus* is very diversified including mountains, open environments such as meadows, tundra, grass fields, forests and even jungle (Williams 2006). The biodiversity hotspot of this group is in Asia, but *Pyrobombus* is well represented in North America and Europe (reviewed in Rasmont et al. 2021; Williams 2021). Some so-called "bivoltine" species have more than one generation per year (e.g. *B. jonellus* (Kirby 1802)) (Skyrm et al. 2012). The nesting behaviour of *Pyrobombus* species is only known from some species but are consistent among bumblebees with underground nest (Hobbs 1967; Sakagami 1976; reviewed by Liczner and Colla 2019). The provision of eggs in the first cell arrangement for *B.* (*Pyrobombus*) *impatiens* Cresson 1863 is generally two eggs at the center and three on each side, forming three rows. The new egg cells would be laid on top of the previous cells (Szabo and Pengelly 1973). The queen deposits multiple eggs into a single egg cell, the larvae develop together before becoming separated into single larval cells (Szabo and Pengelly 1973).

In bumblebees, three classical categories exist to describe the nest architecture (Sladen 1912; Alford 1975; reviewed by Rasmont et al. 2021): (1) pollen-storers, refers to bumblebees that intermixed pollen and nectar pots with brood cells (e.g., *B. terrestris* (L. 1758), *B. jonellus*); (2) pocket-makers refers to species that lay a pocket of pollen at the base of the brood cell (i.e., *B. pascuorum* (Scopoli 1763))

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and (3) honeycomb builder (i.e. *B. mendax* Gerstäcker 1869) refers to species which store of lot of pollen and nectar only in cells of pure wax (empty cocoons are not used for that storing) (Haas 1976). After emergence of adults, cocoons can be destroyed, and new pollen and nectar pots are built or as in most bumblebee species pupal cocoons are re-used as food storage and the architecture of the nest is composed of food pots and brood cells intermixed. However, separate food pots have also been observed in some American *Thoracobombus* Dalla Torre 1880 species (Hobbs 1966; Cameron et al. 1999).

Here, we report behavioural and ecological observations of the nesting biology of *B. lapponicus*, and we provide a detailed description of natural nest development and brood composition of one of the most common circum arctic bumblebee species (Williams et al. 2014; Martinet et al. 2019; Rasmont et al. 2021).

Materials and methods

The nest was discovered near a lake at 560 m above the sea level in the lesser tundra stage near Björkliden in Sweden (68° 24′ 46″ N, 18° 39′ 09″ E) on June 14, 2021, in early spring as it is often the case in alpine zone (Hobbs, 1967) (Fig. 1) by carefully observing the flight of *B. lapponicus* queens and their entry into a potential nest. During our observation, the weather conditions were partly cloudy with an air temperature of 12 °C (Fig. 1). In spring, this tundra is dominated by several flowering species of *Salix* (L. 1753), *Saxifraga oppositifolia* (L. 1753), *Loiseleuria procumbens* (L. 1753), *Arctostaphylos uva-ursi* (L.) Spreng 1825 and *Vaccinium vitis-idea* (L. 1753). In the area and at the time the nest was found, the snow cover had partially melted, and the plants mentioned here were in flower. The nest was found in a discontinuous permafrost zone under deep snow cover in winter, just melted at that time (see nest details below). After excavation, the brood and the founding queen were bred in laboratory with controlled parameters (22 °C, 50–60% of humidity) until emergence of sexuates. The nest was placed in complete darkness at 22 °C with 50–60% humidity and were fed with commercial honey as sugar resources and pollen of *Salix* sp. as lipid/protein resources (assumed as a highly suitable diet) (Vanderplanck et al. 2019). Frozen pollen loads were purchased from the "Ruchers de Lorraine" company.

Fig. 1 Nest entrance. Photograph of the nest entrance (diameter = 1.5 cm). The nest was established in peat moss little bank oriented to the east in the tundra alpine level, in an abandoned rodent nest (*Microtus oeconomus*) (Photo K. Przybyla)

Results

Nest description

The nest was established in dry peat moss bank oriented to the east in the tundra alpine level, in an abandoned rodent nest (*Microtus oeconomus* (Pallas, 1776)) (Fig. 1). Hobbs (1967) has indicated that the subspecies *sylvicola* in North America is particularly versatile in the nest-selecting habits compared to other *Pyrobombus* species. Dried mosses, lichen and *Empetrum nigrum* (L. 1753) bush hid the small opening of the nest (diameter = 1.5 cm). Before excavation, we observed the flight behavior (e.g., entry and exit of the nest) of the queen during 2 consecutive days for a total observation time of 10 h. In total, we observed the female leaving and returning to the nest eight times. During the nest development period, bumblebees experience 24-h sunlight ("polar day"), and we observe the queen foraging on flowers until 01.00 am (time when we stop observations to excavate the nest). On average, the queen spent 15 min (± 4 min) outside the nest to collect resources and 30 min (± 6 min) inside to feed the larvae and warm up the brood.

The entrance tunnel (1 m long) reached a small spheroid cavity diameter = 4–6 cm), at 10 cm below the soil surface. The former rodent nest had two other entrances, but these were not exploited by the queen of *B. lapponicus*. The brood was kept warm there insulated in the rodent bedding without nest canopy (wax involucrum). In the cavity, the brood was crowded with agglomerate straw, and we found two pollen loads inside the cavity (Fig. 2A). Near the brood inside the cavity, one wax isolated nectar pot (Fig. 2B) was present, but this pot (height = 19 mm; diameter = 7 mm) was empty when we excavate the nest. There was no pollen pot at this step. We excavated the nest at an early stage of

Fig. 2 Excavated nest. **A** Top view of the entire structure of the nesting cavity and the bumblebee brood closely crowded with straw used as bedding by the rodent. **B** View of the first nectar pot built by the queen during the initiation phase of the nest (Photos B. Martinet)

development and there were no emerged individuals except the founding queen. The brood was in a classical shape built by bumblebees at this stage, *i.e.,* horseshoe-shaped (Alford 1975). The pupal cocoons were organized into four clusters of 2 (center), 3 (lateral), 3 (lateral) and 3 (above) cocoons (Fig. 2A), respectively; (height = 8 ± 1.5 mm; diameter = 5 ± 0.6 mm) corresponding to the first and only batch of workers. In bumblebees and notably in *Pyrobombus*, often the numbers of eggs recorded in the first batch were less than the numbers of pupae, indicating that the queens added egg cells to the basic groups of eight (Hobbs 1967).

Nest composition

After excavation, the nest was directly transported to a laboratory rearing chamber at Abisko Research station until the emergence of the sexuates. We reared the nest in a plastic box (9*11*16 cm) provided by Biobest NV (Westerlo, Belgium) (Fig. 3). From a behavioral point of view, it is interesting to observe that the queen (and the individuals produced) were not sensitive to the variations of lights (no alarm, no buzzing or anormal activity) whereas they were very sensitive to any vibrations. The individuals were very calm during rearing and easily handled with no defensive behaviour. In total, 1 batch of 11 workers, 14 virgin queens (or gynes) and 13 males were produced. Directly after emergence, workers go to the honey pot to have their first drink, then after they return to their cocoon to be heat by the queen and acquire the odour of the nest and finally, they incubate the brood for thermoregulation (Fig. 3). Worker emerged 7 (first)-10 (last) days after the excavation of the nest. We observe first virgin queens on July 10 and first males on July 15. The total body length is given as additional information: worker total length = 9 ± 1.5 mm (n = 11); male total length = 11 ± 0.8 mm (*n* = 13); virgin queens total length = 16.5 ± 1 mm (*n* = 14). Several post-emergence pupal cells were found to have been reused for nectar or pollen storage. Moreover, workers built very atypical large (height = 5–6 cm) nectar pots made with pure wax attached at one side of the brood (Fig. 3).

Discussion

The nest of *B. lapponicus* was found in abandoned rodent nest as it has often been observed (Svensson and Lundberg 1977; Liczner and Colla 2019). The rodent-bumblebee

Fig. 3 Lateral view of the bumblebee nest. 30-day-old *Bombus lapponicus* nest. The photograph shows (1) founding queen; (2) incubating workers with extended abdomen to thermoregulate the brood; (3) workers managing food resources and the brood; (4) large cocoons of new virgin queens; (5) pollen pot made by former cocoon; (6) nectar pots made by former cocoons; and (7) large nectar pots build on purpose and made de novo of pure wax (Photo P. Rasmont)

association is known to facilitate the spontaneous nesting of bumblebee queens (Djegham et al. 1994; McFrederick and Lebuhn 2006). Moreover, the use of a part of the litter seems to stimulate egg-laying in other wild bumblebee queens that we managed to breed in the same room of the laboratory (i.e., queens of *B. lapponicus*, *B. jonellus* and *B.* (*Alpinobombus*) *balteatus* Dahlbom, 1832). It is hypothesized that the smell of rodent urine stimulated egg-laying behaviour, as demonstrated by Djegham et al. (1994) for *Bombus terrestris*. No camouflage has been observed at the entrance of the nest as observed in some *Pyrobombus* species in North America (Hobbs 1967). The architecture of the examined nectar pots of *B. lapponicus* nest resembles that of the high mountain species *B.* (*Mendacibombus*) *mendax* and that one of *B.* (*Mendacibombus*) *handlirschianus* Vogt 1909 which is known as "honeycomb builder" species (Haas 1976; De Meulemeester et al. 2011). These species store lots of pollen and nectar in large cells of pure wax while the empty cocoons are not used for that storing but are destroyed after emergence (Haas 1976; Aichhorn 1976). The development of the brood has allowed us to observe large neo-formed nectar pots (pure wax) and pots from recycled emergence cells. However, in *B. mendax* and *B. handlirschianus*, these large nectar pots made on purpose are built outside of the comb and even outside of the insulating straw. Here in *B. lapponicus*, these nectar pots built on purpose are lumped with the brood inside the comb. Such large nectar stocks in the three species could be related to the scarce food resources in Arctic and alpine biotope. Our observations show that *B. lapponicus*, is a pollen storer species like its nearly related species *B. monticola* Smith 1849 (Sladen 1912; Cameron et al. 2007) and all *Pyrobombus* species for which we have nest description (Sakagami 1976; reviewed in Rasmont et al. 2021; Williams 2021). In southern Alberta, Hobbs (1967) described nest establishment, nesting initiation and brood development in 11 *Pyrobombus* species including *B. lapponicus sylvicola* in artificial devices. Hobbs (1967) indicated *Pyrobombus* are good producers of wax and particularly the taxon *sylvicola* considering the numbers of honey pots produced built with wax-pollen.

The coloration of the founding queen of *B. lapponicus* was typical of the species with dark red hairs on the first tergites of the abdomen and light red on the last. However, there were differences in coloration in the newly produced virgin queens which could indicate intranidal colour polymorphism as found in *B. handlirschianus* (De Meulemeester et al. 2008). There is great variability in the coloration of *B. lapponicus* throughout its distribution and to be certain of the conspecific status across the entire range of both forms additional study of the population genetic structure are required.

During the rearing and handling of the brood, it was surprising to see that the individuals were very insensitive to white light unlike numerous other bumblebee species that we experienced. This insensitivity to white light may be related to the life beyond the Arctic Circle marked by the absence of night ("polar day" from early May to late August). We assume that this note of the nesting of the most common artic bumblebee species is enlarging the knowledge about this species and could help to understand the ecological and behavioural features of other bumblebee species living in hardest habitat such as tundra.

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Availability of data and material All data are available in the main text or the supplementary materials including full data sets and photographs.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare no competing financial interests.

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