# A possible bivoltine development of several bumblebee species in Europe

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This article is devoted to an analysis of the possible bivoltine development of several bumblebee species in Europe. This study is based on materials collected by the authors in European countries and in the European North of Russia. Our records reveal that several bumblebee species may have at least two generations per season. We found the possibility of bivoltine development for the following species: *Bombus hortorum* (Slovakia and France), *B. terrestris* (Slovakia, France and the Isle of Crete off the east coast of Greece), *B. pratorum* (France and European North of Russia), and *B. jonellus* (European North of Russia).

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**Abstract**

This article is devoted to an analysis of the possible bivoltine development of several bumblebee species in Europe. This study is based on materials collected by the authors in European countries and in the European North of Russia. Our records reveal that several bumblebee species may have at least two generations per season. We found the possibility of bivoltine development for the following species: *Bombus hortorum* (Slovakia and France), *B. terrestris* (Slovakia, France and the Isle of Crete off the east coast of Greece), *B. pratorum* (France and European North of Russia), and *B. jonellus* (European North of Russia).

**Keywords** Bumblebees, two generations, Europe, climatic conditions

## Introduction

The study of life cycles of different bumblebee species is one of the important topics of modern bumblebee research (Stelzer et al., 2010). The study of bumblebee phenology at the global scale permits revealing general patterns of bumblebee life cycles in different landscape-zonal conditions.

A relatively small number of published papers has been dedicated to this subject. The majority of studies describe the life cycle of one or two typical species for a particular study region (Meidell, 1968; Rasmont, 1985; Prŷs-Jones & Corbet, 1987). Only a few publications summarize information on the life cycles of bumblebees, one of which is a book by Radchenko & Pesenko (1994). This work is dedicated to the biology of bees and in one of the sections there are descriptions of examples of bumblebee life cycles in various climatic conditions. Further, a review by Sakagami (1976) describes the life cycles of bumblebees in different climatic zones.

The aim of the present study was to analyze our field observations of bumblebees from different areas of Europe, with a special focus on the possibility of bivoltine development of bumblebee families in certain taxa.

## Materials and methods

Bumblebees from European North of Russia were studied in Solovetsky Archipelago during a period of long-term research during 2001-2010 (Kolosova & Podbolotskaya, 2010; Bolotov et al., 2013). For the present research, 119 individuals were studied.

Bumblebees from European countries were collected in 2011. These are south-eastern Slovakia, southern France and the Isle of Crete. Bumblebees were caught with an entomological net. In summary, from Europe 55 individuals were collected and 3 were observed.

Bumblebees were identified by following Løken (1973), and Rasmont & Terzo (2010). In this paper, we used the taxonomic status of species according to Williams (2017). Three females of *Bombus terrestris* (L., 1758) from the Isle of Crete were dissected by using a micro-scalpel for the investigation of their crops (Alford, 1975). The specimens of bumblebees are deposited in the Russian Museum of the Biodiversity Hotspots (RMBH), Federal Center for Integrated Arctic Research, Arkhangelsk, Russia.

Sampling on the Russian Federation territory (Solovetsky Archipelago) was permitted within the framework of the special grants of the Russian Foundation for Basic Research (RFBR, no. 16-05-00854), the Ministry of Science and Education of Russia (no. 6.2343.2017), and the President of Russia Grant Council (no. MD-7660.2016.5). Additionally, sampling on the Solovetsky Archipelago was permitted by the Directorate of the Federal State Cultural Institution

"Solovetsky State Historical and Architectural Museum-Reserve" (scientific agreement no. 111-p). Sampling from the European counties was permitted by scientific agreement of 01.01.2011 between the Institute of Ecological Problems of the North of the Ural Branch of Russian Academy of Sciences and the Institute of Hydrology of the Slovak Academy of Science.

## Results

Description of the studied localities and records of bumblebees are presented in Table 1.

## Discussion

Our novel records reveal that several bumblebee species may have at least two generations per season. In summary, we found some evidence of possible bivoltine development for the following species: *B. hortorum* (Slovakia and France), *B. terrestris* (Slovakia, France and Isle of Crete), *B. pratorum* (France and European North of Russia), and *B. jonellus* (European North of Russia).

In temperate latitudes, a bumblebee family typically exists for only one season (Alford, 1975; Goulson, 2010). Bumblebee families live from spring to autumn, on the average 3 to 6 month, the duration of their life depends on the different species (Goulson, 2010). One reproductive generation emerged towards the end of summer. Since the beginning of autumn, bumblebees from nests die, except young females of the new generation (Goulson, 2010). Hence, the majority of bumblebees of temperate latitudes are characterized by an annual life cycle (Sakagami, 1976). However, some species of bumblebee in temperate latitudes can transform life

cycles. They are capable of producing two generations in one season (Radchenko & Pesenko, 1994).

*B. terrestris* has no obligate diapause. In laboratory conditions, this species can breed throughout the year (Radchenko & Pesenko, 1994). According to Rasmont et al. (2008), "In N. Europe, the phenology of *Bombus terrestris* is similar to that of other bumblebee species, but the same is not true in the Mediterranean regions, where colony foundation may occur in autumn and winter". Examples of two generations in one season for this species are known from S France, S England, Corsica, and Sardinia (Stelzer et al., 2010; Rasmont, 1985; Rasmont et al., 2008). According to our materials, at least bivoltine development of *B. terrestris* is possible in S France, near Toulouse, where a single worker of this species was collected in the month of January. On the Isle of Crete, the male and females of *B. terrestris* were recorded in late November, which may also indicate two generations per season. Based on the observations of flowering plants and the study of bumblebee crops, we suggest that the winter activity of *B. terrestris* on the Isle of Crete is not a common phenomenon, likely because limited food sources may lead to their mortality.

Both *B. hortorum* and *B. pratorum* have a short life cycle (Prŷs-Jones & Corbet, 1987), which explains the presence of males of these species in SE Slovakia and S France in late May. According to Prŷs-Jones & Corbet (1987), *B. hortorum* and *B. pratorum* may produce two generations per season in Britain, because the short life cycle allows these species "to complete a second nesting cycle in some years". Hence, the same can be assumed for SE Slovakia and S France.

The ability of *B. jonellus* to produce two generations per season is well-known (Alfken, 1913; Meidell, 1968; Douglas, 1973; Prŷs-Jones & Corbet, 1987; Kolosova & Podbolotskaya,

2010). The possibility for two generations of *B. jonellus* and also *B. pratorum* during the summer months is apparent on the Solovetsky Islands. Entomological research on the Solovetsky Archipelago was carried out annually in the summer months of the period of 2001-2010 (repeated twice for 7-10 days each summer season: late June – early July and late July – early August) (Kolosova & Podbolotskaya, 2010; Bolotov et al., 2013). The location of the Solovetsky Islands in the south-west of the White Sea leads to short cool summers, which are shorter than on the mainland (Shvartsman & Bolotov, 2007). The emergence of overwintered females here is in mid-June, workers have been recorded since the end of June and reach maximum abundance by mid-July, young females and males emerge towards the end of July – early August. However, in years 2003 and 2009, we have observed males of *B. jonellus* and *B. pratorum* in late June – early July, that can be assumed to be two generations per season for these species on the Solovetsky Archipelago.

## Conclusions

Finally, the problem of studying bivoltine development for bumblebee species presents potential for further research. Climate warming, the global impact of which on bumblebees has had multiple consequences (Kerr et al., 2015), can also lead to rapid shifts in the number of possible generations per season, which may have a negative influence on agricultural crops across Eurasia.

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Fig 1. Habitats and bumblebees. (A) Oak-maple forest with herb-celandine plant cover on a slope of the Marečková Mountain, 20.05.2011, Slovakia. (B) Female of *B. terrestris* with specific searching behaviour on a slope of the Marečková Mountain, 20.05.2011, Slovakia. (C) Worker of *B. terrestris* on flowers of common ivy in the Imbras Gorge, 23.10.2011, Isle of Crete. (D) Common ivy thickets on a rocky outcrop, a single available nectar source in the Imbras Gorge, 23.10.2011, Isle of Crete. (E) Sparse mixed fir-beech forest with juniper-grass-herb plant cover on the foothill of the Neouville Mountain, 26.05.2011, Pyrenees, France. (F) Grass-herb meadow near pine-birch forest in the village of Isakovo, Solovetsky Archipelago of Russia. (G) Grass community near coast in the Bolshoy Zayatskiy Island, Solovetsky Archipelago. Photos: Yu.S. Kolosova.

## Table 1(on next page)

New records of bumblebees indicating a possible bivoltine development

Materials of bumblebees from the studied localities

1 Table 1 New records of bumblebees indicating a possible bivoltine development

| Species | Locality | Date | Records | Data collectors |
|---|---|---|---|---|
| *B. hortorum* (L., 1761) | SE Slovakia, Vihorlatské Vrchy Region, slope of the Marečková Mountain [48°49'40"N, 21°59'19"E, 350-400 m alt.], oak-maple forest with herb-celandine plant cover (Fig 1A) | 19-20.05.2011 | 4 males and 41 workers were collected | Bolotov & Kolosova |
| | S France, close to La Carole Village [42°54'35"N, 1°49'8"E, approx. 600 m alt.], beech forest, near travertine terraces | 25.05.2011 | 3 males were collected | Bolotov & Kolosova |
| *B. terrestris* (L., 1758) | SE Slovakia, Vihorlatské Vrchy Region, slope of the Marečková Mountain [48°49'40"N, 21°59'19"E, 350-400 m alt.], oak-maple forest with herb-celandine | 20.05.2011 | A female with specific searching behaviour was recorded. The female was looking around a mouse hole and seems to be a new generation, with | Bolotov & Kolosova |

| | | | | |
|---|---|---|---|---|
| | plant cover (Fig 1A) | | brilliant, bright hair cover (Fig 1B) | |
| | SE Slovakia, Vihorlatské Vrchy Region, forest road near Vinné village [48°48'36"N, 21°58'46"E, 195 m alt.], mixed broadleaf forest with herb plant cover | 21.05.2011 | 2 females with specific searching behaviour were recorded*. The females are likely looking for nesting sites and they appear to be a new generation, with brilliant, bright hair cover | Bolotov & Kolosova |
| | S France, near Toulouse, garden | 15.01.2011 | A worker was collected | Pokrovsky & Shirokova |
| | Greece, Crete Island, entrance to the Imbras Gorge, near café [35°14'53" N, 24°10'3" E, alt. 770 m], on the flowerbed | 23.10.2011 | A male was collected | Bolotov & Kolosova |
| | Greece, Isle of Crete, the Imbras Gorge, mountain | 23.10.2011 | 2 live and 1 dead females were | Bolotov & |

| | | | | |
|---|---|---|---|---|
| | valley [35°14'36" N, 24°10'2" E, alt. 700 m], on flowers of the common ivy (*Hedera helix* L.) | | collected and a worker was observed (Fig 1C). Females were very sluggish, with empty crops (dissected), most likely because ivy provides imperfect nectar source, but other flowering plants were lacking along the valley on that date (Fig 1D) | Kolosova |
| *B. pratorum* (L., 1761) | S France, Pyrenees, foothill of the Neouville Mountain, near boundary of Pyrenees National Park [42°48'05"N, 00°13'50"E, 1330 m alt.], sparse mixed fir-beech forest with juniper-grass-herb plant cover on a mountain slope in a river valley (Fig 1E). The early- | 26.05.2011 | A male was collected | Bolotov & Kolosova |

| | | | | |
|---|---|---|---|---|
| | summer phenological aspect was recorded there, with flowering of *Anemone* sp. | | | |
| | European North of Russia, Solovetsky Archipelago, Isakovo village [65°05'42"N, 35°36'57" E, approx. 11 m alt.], grass-herb meadow near pine-birch forest (Fig 1F). | 29.06.2009 | A male was collected | Kolosova & Podbolotskaya |
| *B. jonellus* (Kirby, 1802) | European North of Russia, Solovetsky Archipelago, Savvatyevo village [65°07'03"N, 35°36'20" E, approx. 5 m alt.], grass-herb meadow near pine-birch forest. | 26.06.2003 | 12 males were collected | Kolosova & Podbolotskaya |
| | European North of Russia, Solovetsky Archipelago, Bolshoy Zayatskiy Island [64°58'05"N, 35°39'42" E, approx. 2 m alt.], grass | 20.06.2009 | 20 males were collected | Kolosova & Podbolotskaya |

| | | | | |
|---|---|---|---|---|
| | community near coast (Fig. 1G). | | | |
| | European North of Russia, Solovetsky Archipelago, Isakovo and Savvatyevo villages. | 29.06.2009 | 86 males were collected | Kolosova & Podbolotskaya |

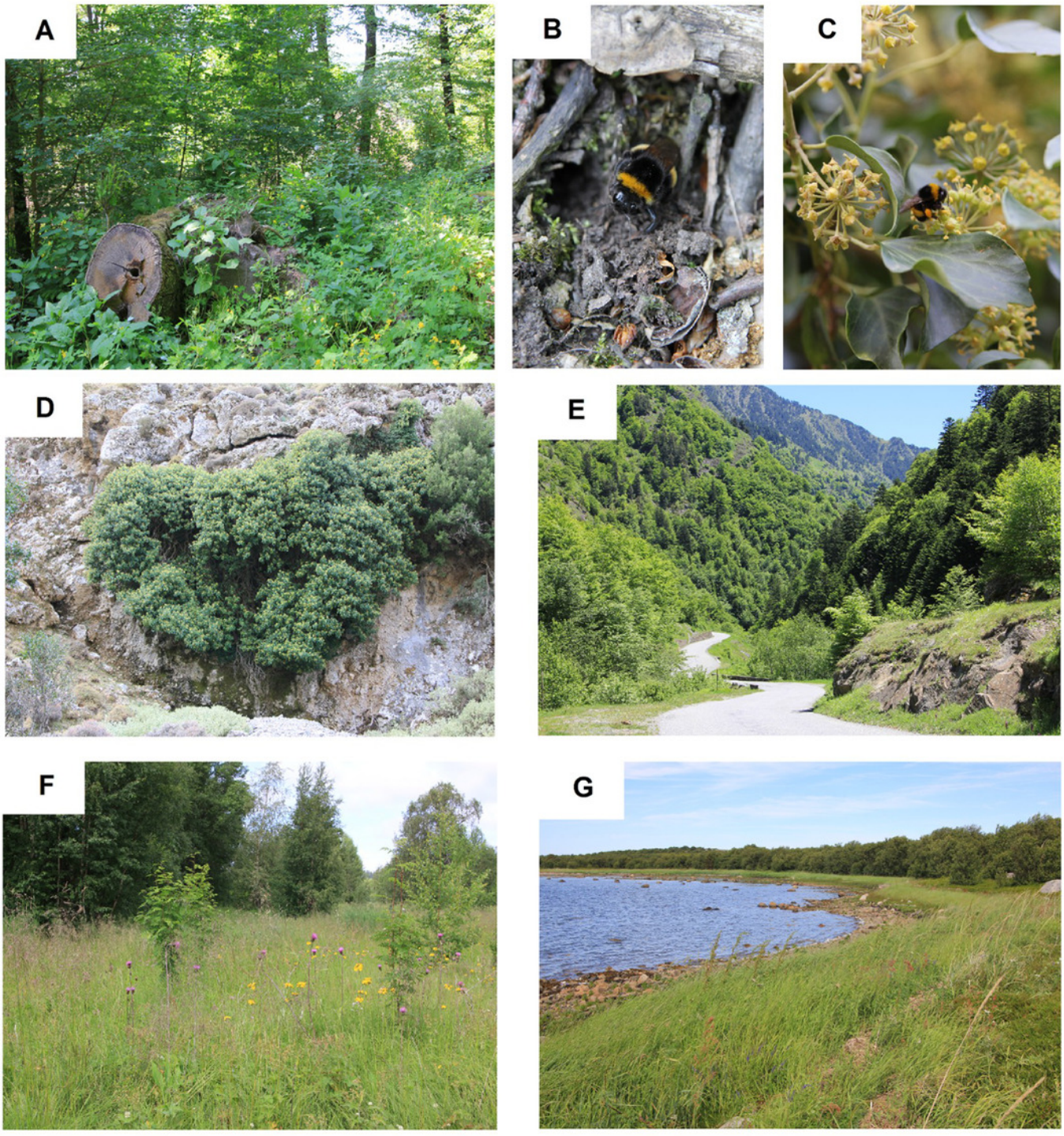
*They were visually identified as *B.* cf. *terrestris*.

# Figure 1

## Habitats and bumblebees



(A) Oak-maple forest with herb-celandine plant cover on a slope of the Marečková Mountain, 20.05.2011, Slovakia. (B) Female of *B. terrestris* with specific searching behaviour on a slope of the Marečková Mountain, 20.05.2011, Slovakia. (C) Worker of *B. terrestris* on flowers of common ivy in the Imbras Gorge, 23.10.2011, Isle of Crete. (D) Common ivy thickets on a rocky outcrop, a single available nectar source in the Imbras Gorge, 23.10.2011, Isle of Crete. (E) Sparse mixed fir-beech forest with juniper-grass-herb plant cover on the foothill of the Neouville Mountain, 26.05.2011, Pyrenees, France. (F) Grass-herb meadow near pine-birch forest in the village of Isakovo, Solovetsky Archipelago of Russia. (G) Grass community near coast in the Bolshoy Zayatskiy Island, Solovetsky Archipelago. Photos: Yu.S. Kolosova.

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