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Short communication

Case study on forage plants of the heath bumblebee (*Bombus jonellus*) in southwest Iceland

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INTRODUCTION

Bumblebees (*Bombus* spp.) are pollinators of especially high conservation interest. They have behaviours (pollen-gathering, buzz pollination), morphological structures (branched body hairs well-adapted for retaining pollen), and endothermic capabilities, that make them well-adapted for transporting large amounts of pollen in subarctic regions (Heinrich & Vogt 1993, De Luca & Vallejo-Marín 2013). Recent findings indicate that 23.6% of bumblebee species in Europe are threatened with extinction, and that 45.6% of Europe's bumblebee species are in decline (Nieto et al. 2014). These declines are likely due to multiple threats acting synergistically, but the primary threat is the loss and fragmentation of foraging and nesting resources (Kosior et al. 2007, Potts et al. 2010, Goulson et al. 2015). In Iceland, the aggressive spread of invasive non-native plant species such as Nootka lupine (*Lupinus nootkatensis* Donn) and cow parsley (*Anthriscus sylvestris* L.) (Magnússon 2011, Icelandic Institute of Natural History 2016) represents a serious threat to native forage-plant communities. Recent research suggests that Iceland's only native bee, the heath bumblebee (*B. jonellus* Kirby), is at risk of serious declines in Iceland due to the spread of invasive plant populations (Willow 2016).

To protect *B. jonellus* in Iceland, we need to not only manage invasive plant species, but also improve our knowledge of the native food plants that *B. jonellus* visits (Willow 2016). A range of flowering plant species used by *B. jonellus* in Iceland is given in Prŷs-Jones et al. (1981, 2016), with estimates of their significance as forage resources. However, further systematic observations of foraging preferences are required, as the plant-pollinator network throughout Iceland is undergoing changes, particularly due to the spread of invasive plant populations and the introduction of exotic bumblebee species (Magnússon 2011, Icelandic Institute of Natural History 2016, Prŷs-Jones et al. 2016). The primary aim of this study was to determine the significance of various plant species, across the forage season, as forage for *B. jonellus* in relatively natural environments in south-west Iceland. The importance of each forage plant species was estimated from the number of observed *B. jonellus* visits.

MATERIALS AND METHODS

The study was conducted at three sites, two within Heiðmörk, a nature reserve on the south and south-east outskirts of Reykjavík. One of these sites is the heath adjacent to Lake Vífilsstaðavatn, at the west end of Heiðmörk, where flowering plants included dense stands of both woody and herbaceous flora. The other site is located at the east end of Heiðmörk, in and around Rauðhólar, a mosaic of hills and pseudocraters, with a mosaic of bare rock, rock covered by lichens and mosses, and patches of flowering herbaceous plants. The third site is the heath surrounding Lake Reynisvatn in Grafarholt, a suburb in the east of Reykjavík. Here, the flowering plant network is primarily a dense herbaceous flora. All three of these sites have abundant species-rich wildflower communities across the summer.

Sampling took place under full sun in warm, low-wind conditions during the summer of 2016, from 14 June (first *B. jonellus* observation) to 7 August (last *B. jonellus* observation). Overall, sampling took place on ten different days. The two sites in Heiðmörk were each sampled three times, and the heath surrounding Lake Reynisvatn was sampled four times. Sampling sites were rotated to avoid bias, and the number of days between sampling events ranged from 3 to 10, depending on weather conditions. All sampling took place between 10:00 AM and 6:00 PM.

Sampling consisted of walking in a meandering fashion throughout the site, looking for *B. jonellus* visiting the wildflower species present. The paths walked varied between sampling days. As expected, different flowering plant species ranged from being present in small isolated populations to being very abundant. However, attempts were made to make observations on all plant species that were flowering, and care was taken to minimize bias towards any plant species. When *B. jonellus* was observed, the species on which the individual was observed foraging was recorded.

From 14 June to 13 July, if a *B. jonellus* worker carrying a large corbicular pollen load was observed, the individual was euthanized in a jar containing a cotton ball soaked with 100% acetone. From each specimen, a single hindleg with the pollen load attached was removed and mounted in silicon oil for analysis by light microscopy. The purpose was to determine if pollen loads contained pollen from plant species other than that which the individual was observed foraging on. For identification purposes, a reference collection of pollen slides was prepared by the author, and corbicular pollen identity was determined by comparison with reference slides of pollen from each plant species flowering in the study area.

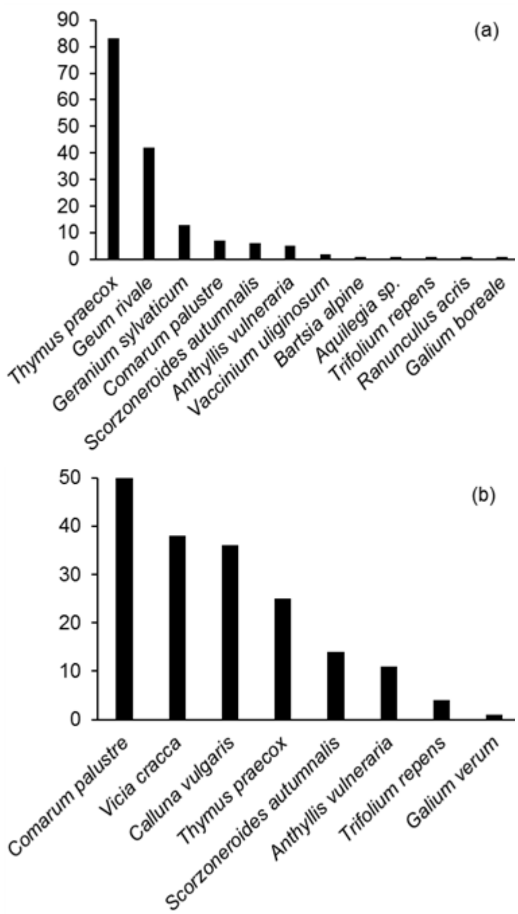

Figure 1. Number of *B. jonellus* foraging observations for various wildflower species. Shown separately are data for (a) 14 June – 18 July and (b) 21 July – 7 August, 2016.

RESULTS

A total of 342 floral visits by *B. jonellus* were recorded during the study. The number of observations on any single day ranged from 1 to 82. *B. jonellus* was recorded visiting the flowers of 15 plant species during the study. The most frequently visited species were wild thyme (*Thymus praecox* Opiz), marsh cinquefoil (*Comarum palustre* L.), water avens (*Geum rivale* L.), tufted vetch (*Vicia cracca* L.), and common heather (*Calluna vulgaris* (L.) Hull). These species were collectively the site for 82% of foraging observations in this study, 32% of all observations occurring on *T. praecox*.

Pollen loads of 38 *B. jonellus* workers were examined. These individuals were collected on ten different plant species. For all pollen loads analysed, the only plant species detected was that which the individual was collected on. For this reason, and because Icelandic *B. jonellus* populations are increasingly at risk of decline, pollen load analyses were discontinued after 13 July in order to avoid further mortalities.

Separation of the data into two time periods revealed a separation of dominant species assemblages in *B. jonellus*'s diet. From 14 June to 18 July, *T. praecox* was the most visited species, representing 51% of all floral visits during this time period, followed by *G. rivale* (26%) and wood crane's-bill (*Geranium sylvaticum* L.) (8%) (Fig. 1a). From 21 July to 7 August, *C. palustre* was the site of 28% of recorded visits, followed by *V. cracca* (21%), *C. vulgaris* (20%), *T. praecox* (14%), autumn hawkbit (*Scorzoneroides autumnalis* (L.) Moench) (8%), and kidney vetch (*Anthyllis vulneraria* L.) (6%) (Fig. 1b). It is noteworthy that *B. jonellus* was recorded visiting *S. autumnalis* and *A. vulneraria* mostly during the transitional period when foraging observations on *G. rivale* and *T. praecox* began to decline, and before *V. cracca* and *C. vulgaris* became dominant forage species. Additional species visited by *B. jonellus* during the study include bog bilberry (*Vaccinium uliginosum* L.), alpine bartsia (*Bartsia alpine* L.), white clover (*Trifolium repens* L.), a species of columbine (*Aquilegia* sp.), meadow buttercup (*Ranunculus acris* L.), northern bedstraw (*Galium boreale* L.), and lady's bedstraw (*Galium verum* L.).

DISCUSSION

This study revealed clear relationships between *B. jonellus* and numerous flowering plant species in south-west Iceland. Two dominant and temporally separate forage-species assemblages were observed (Fig. 1). Taking into consideration both major and minor forage species, *T. praecox*, *G. rivale*, *C. palustre*, *V. cracca*, *C. vulgaris*, *G. sylvaticum*, *S. autumnalis*, and *A. vulneraria* appear to be very significant forage species for *B. jonellus* populations in south-west Iceland. These results both compare and contrast with estimations of forage significance suggested by Prŷs-Jones et al. (1981, 2016), who do not emphasize the importance of *G. rivale*, and do not mention *C. palustre* or *V. cracca*. They highlight the importance of *V. uliginosum*, bearberry (*Arctostaphylos uva-ursi* (L.) Spreng), *C. vulgaris*, *T. praecox*, various willow species (*Salix phylicifolia* L., *S. lanata* L., *S. arctica* Pall, *S. herbacea* L.), and *G. sylvaticum*. Contrasting results may reflect differences in plant community composition at sampled locations. It is suggested here that the results of the present study as well as previous studies should be taken into consideration, especially since overlap exists among the results of the present study and the work of Prŷs-Jones et al. (1981, 2016). Moreover, the use of floral resources among pollinators can vary considerably from year to year (Alarcón et al. 2008).

The fact that only a single plant species was detected in each examined pollen load suggests that, although *B. jonellus* is a polylectic species at the population level, at the individual level they specialize in their foraging behaviour. Restoring optimal forage habitat for *B. jonellus* in Iceland may require that major and important minor forage species are present in restored habitats. Maximizing the diversity of *B. jonellus*'s preferred forage species should benefit *B. jonellus* populations, allowing individuals within these populations to specialize within the range of plant species available. Indeed, differences in floral specialization among *B. jonellus* individuals may be an adaptation for reducing competition within or between populations, and thus should be encouraged. Similar studies in other regions of Iceland should further enhance our knowledge of *B.*

jonellus's foraging preferences throughout its range in Iceland.

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