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Review of the Icelandic bee fauna (Hymenoptera: Apoidea: Anthophila)

Anselm Kratochwil

Abstract

Only one species of the Hymenoptera Apoidea Anthophila is native to Iceland: *Bombus jonellus* (Kirby, 1802). A second species, *Andrena tarsata* Nylander, 1848, is mentioned by Schmiedeknecht (1882–1884), but there is reasonable doubt of an existence in Iceland. Four bumblebee species were introduced: *B. hortorum* (Linnaeus, 1761), first detection in 1959; *B. lucorum* (Linnaeus, 1761), first detection in 1979; *B. hypnorum* (Linnaeus, 1758) and *B. pascuorum* (Scopoli, 1763), first detections in 2010. Furthermore *B. terrestris* (Linnaeus, 1761) was introduced for tomato pollination in greenhouses (after 2002). Personal observations in 2014 yielded the result of large extensions of *B. lucorum* primarily in the north-east region of Iceland. The distribution of all bumblebee species in Iceland is summarised, their taxonomical status, habitat preferences, special adaptations and colonisation history are discussed. Based on a differential evaluation, probable trends of their future development are examined. Global warming effects may reduce *B. jonellus* populations and promote those of introduced *Bombus* species. *B. lucorum* may expand in many regions of Iceland far from settlements, but also into cultivated and settlement areas. *B. hortorum* is restricted to settlement areas with gardens (preferring long-tubed flowers), but *B. lucorum* will compete strongly with *B. hortorum*. *B. hypnorum* is also restricted to settlement areas, due to special nesting behaviour. The further development of *B. pascuorum* is likely to be positively supported by global warming effects and competitive effects. *B. terrestris* seems to be not adapted to live outside greenhouses in Iceland.

Keywords: *Bombus*, *Andrena*, Iceland, global warming, introduced species, flower visits.

Zusammenfassung

Nur eine Art unter den apoiden Hymenopteren ist in Island heimisch: *Bombus jonellus* (Kirby, 1802). Eine zweite Art, *Andrena tarsata* Nylander, 1848, wurde von Schmiedeknecht (1882–1884) erwähnt; ihr Vorkommen erscheint sehr zweifelhaft. Vier Hummelarten wurden bisher eingeführt: *B. hortorum* (Linnaeus, 1761), erster Nachweis 1959; *B. lucorum* (Linnaeus, 1761), erster Nachweis 1979; *B. hypnorum* (Linnaeus, 1758) und *B. pascuorum* (Scopoli, 1763), erste Nachweise 2010. Ferner wird *B. terrestris* (Linnaeus, 1761) zur Bestäubung von Tomaten in Gewächshäusern in Island eingesetzt (seit 2002). Beobachtungen im Jahr 2014 erbrachten das Ergebnis einer starken Ausbreitung von *B. lucorum* besonders im Nordosten Islands. Die heutige Verbreitung aller in Island vorkommenden Hummelarten wird vorgestellt und Angaben über ihren taxonomischen Status, Habitat-Präferenzen, besondere Anpassungen und Besiedlungsgeschichte angeführt. Über eine vergleichende Analyse wird die zukünftige Entwicklung diskutiert. Die Auswirkungen der globalen Erderwärmung sollten *B. jonellus* zurückdrängen und einzelne eingeführte *Bombus*-Arten fördern. *B. lucorum* wird sich weiter ausbreiten (sowohl außerhalb des Bereichs der Siedlungen und des kultivierten Gebietes als auch innerhalb). *B. hortorum* ist auf Siedlungsgebiete mit Gärten beschränkt (Bevorzugung tiefkroniger Blüten). Jedoch wird *B. lucorum* mit *B. hortorum* um Nektarquellen stark konkurrieren. *B. hypnorum* ist aufgrund seines spezifischen Nistverhaltens ebenfalls weitgehend auf Siedlungsgebiete beschränkt. Die weitere Entwicklung von *B. pascuorum* wird wahrscheinlich ebenfalls durch die Effekte der globalen Erwärmung und die höhere Wettbewerbsfähigkeit positiv beeinflusst werden. *B. terrestris* kann außerhalb von Gewächshäusern in Island derzeit langzeitig nicht überleben.

Contents

1 Introduction

Within the Hymenoptera Apoidea Anthophila only a single species of the genus *Bombus* is native to Iceland: *Bombus (Pyrobombus) jonellus* (Kirby, 1802), see Klinckowström (1913) and Prŷs-Jones et al. (1981). This is also documented in a chronological bibliographical study from ca. 1680 to 1980 concerning bumblebee observations in Iceland by Prŷs-Jones et al. (1981).

Another bee species is being discussed as possibly native: *Andrena tarsata* Nylander, 1848 (oligolectic to *Potentilla* species), see Gusenleitner & Schwarz (2002). But there is only one reference 'Auch in Island ist sie gefunden worden [also found in Iceland]' without further comments (Schmiedeknecht 1882–1884: 769). No other observation of *A. tarsata* has been detected for Iceland, so that there is reasonable doubt of the existence of this species there.

In contrast to the obviously native *B. jonellus*, Prŷs-Jones et al. (1981) detected two other new *Bombus* species for Iceland, both of which can be classified as introduced: *B. (Megabombus) hortorum* (Linnaeus, 1761) and *B. (Bombus) lucorum* (Linnaeus, 1761). *B. hortorum* was found in the Reykjavík region and surroundings and has been represented in insect collections since 1959. *B. lucorum* occurs also in the vicinity of Reykjavík, where it was first observed on June 29, 1979. Prŷs-Jones et al. (1981) summarise the state of knowledge of the distribution and foraging behaviour of the three bumblebee species.

In IceNews (2010) an article with the title 'More new bees in Iceland' was published and it was reported that two further bumblebee species are meanwhile present in Iceland: *B.* (*Pyrobombus) hypnorum* (Linnaeus, 1758) (Keflavík, Hafnarfjörður and Reykjavík) and *B. (Thoracobombus) pascuorum* (Scopoli, 1763) (Hveragerði, Akureyri). In 2010, the first queens were found, indicating a successful establishment of both species. So until now the Islandic bee fauna comprises one native and four introduced bumblebee species (IceNews 2010). There is another *Bombus* species, *B. (Bombus) terrestris* (Linnaeus, 1758), which was introduced for tomato pollination in greenhouses (after 2002). No information is yet available as to whether *B. terrestris* individuals escaped and live in free nature.

Observations of bumblebees in the year 2014 along a transect from east to west coast of Iceland should bring new information about the present situation of the bumblebee distribution, including preferred foraging plants, with special interest in the introduced bumblebee species. The development of mega databases concerning *Bombus* species deposited in collections of museums or recorded represent a further source of information. Since the publication of Prŷs-Jones et al. (1981) no approach was taken to summarise the bumblebee colonisation in Iceland. A provisional evaluation is provided here.

Some questions about the observed introduced individuals and species, their present distribution, hypotheses of future development including potential effects of global warming and competition between species will be discussed.

Acknowledgements

I thank Erwin Scheuchl (Ergolding, Germany) for the literature source of *Andrena tarsata*, John Asher (American Museum of Natural History, New York, USA) for support and fruitful discussion and Kristján Kristjánsson (Reykjavik University, Iceland) for cooperation. Rainer Prosi (Crailsheim, Germany) introduced me in QGIS within a meeting of the research group 'Wildbienen-Kataster Baden-Württemberg' (Stuttgart, Germany). Lars Krogmann (Stuttgart State Museum of Natural History) and Hans Richard Schwenninger (Stuttgart, Germany) kindly read the manuscript and provided valuable comments. The improvement of the English text by Ann Thorson (Oxford, United Kingdom) is much appreciated.

2 Material and methods

The observation in Iceland was carried out from June 3 to June 18 in 2014, also including the northeast region with former scarce bumblebee detections (see Fig. 1, Prŷs-Jones et al. 1981). 26 specimens (IS1–IS26) were collected. The route covers the following localities: Seyðisfjörður, Nardvík, Borgarfjörður, Svartiskógur, Burstafell, Porshöfn, Raufarhöfn, Húsavík, Mývatn, Akureyri, Námafjall, Goðafoss, Breiðavík, Látrabjarg, Reykjavík, Seljalandsfoss, Skógafoss, Djúpivogur. Information about flower visits is added, and observations in gardens are indicated (botanical terminology according to Kristinsson 2010 and www.iceland-nh.net 2015: 'Plants of Iceland').

The data of Prŷs-Jones et al. (1981) were digitised and, using Natural Earth (Free vector and raster map data; www.naturalearthdata.com 2015) as base map, the distribution data of Prŷs-Jones et al. (1981), my own data and all available further data were compiled with QGIS version 2.8.1 Wien (www.qgis.org 2015) in the WGS84/Pseudo-Mercator reference system. The distribution maps show a UTM grid of 50 × 50 kilometer squares. One grid point covers an area of 25 × 25 km.

The following internet data bases were used: Global Biodiversity Information Facility (Copenhagen, Denmark [GBIF] including Naturalis Biodiversity Center [Leiden, Netherlands] and Lund Museum of Zoology [Sweden]; www.gbif.org 2015). Specimens from the collections in the National Museum of Natural History (RMNH; Rijksmuseum voor Natuurlijke History), later National Museum of Natural History, Naturalis in Leiden and the Zoological Museum Amsterdam (ZMA) and further acquisitions were examined. One record is from the American Museum of Natural History, New York (AMNH).

The data on the observed and collected specimens are arranged as follows: code number, worker/queen, locality, date, latitude, longitude, elevation, flower visit. The arrangement of the GBIF data is: identity number, worker/queen, locality, date, further comments.

3 Results and discussion

3.1 *Bombus (Pyrobombus) jonellus subborealis* Richards, 1933

Status

B. jonellus was described by Kirby (1802). Primarily shown by Vogt (1911), *B. jonellus* varied geographically in morphology. Vogt (1911) differentiated three varieties (var. geogr.): 1) *martes* Gerstaecker, 1869: Alps; 2) *typicus*: England, Germany (but not the Bavarian Alps) and southern Ural; 3) *atrocorbiculosus*: Scotland, Orkney Islands, Iceland, Norway, Amur region. Within the group 3 Vogt (1911) differentiated two further groups: a) 'Forma nova' *sparreschneiderianus* and b) 'Forma nova' *horsleyi* (only northern Scotland, Orkney Islands). Today different subspecies were classified. In Iceland the subspecies *subborealis* Richards, 1933 is distributed (Richards 1933, Løken 1973).

Richards (1933) differentiated the following subspecies: 1) *Bombus jonellus jonellus* (Kirby, 1802): England, Scotland (including Orkneys but not Hebrides), Ireland, Belgium, France, Germany, Austria (except Alps), probably Southern Scandinavia and South Russia; 2) *B. j. vogtii* Richards, 1933 (*B. j. atrocorbiculosus* [Vogt, 1911] pars parte): Shetland; 3) *B. j. hebridensis* (Wild, 1931): Hebrides; 4) *B. j. suecicus* (Friese, 1911) (*B. j. atrocorbiculosus* [Vogt, 1911] pars parte): Sweden; 5) *B. j. subborealis* Richards, 1933 (*B. j. atrocorbiculosus* [Vogt, 1911] pars parte): Norway, Iceland; 6) *B. j. martes* (Gerstaecker, 1869): higher levels of Bavaria (Germany) and Alps.

Observed specimens

Eight queens and four workers were detected. — IS2: queen, 4.VI.2014, east of Borgarfjörður, 65°30′56.20″N, 13°47′33.00″W, 5 m, *Salix lanata*; IS3: queen, 4.VI.2014, Svartiskógur, 65°30′46.75″N, 14°33′54.75″W, 74 m, *Salix lanata*; IS4: queen, 4.VI.2014, Svartiskógur, 65°30′46.75″N, 14°33′54.75″W, 74 m, *Salix lanata*; IS5: queen, 4.VI.2014, Svartiskógur, 65°30′46.75″N, 14°33′54.75″W, 74 m, *Salix lanata*; IS6: worker, 6.VI.2014, Porshöfn, 66°11′54.88″N, 15°19′41.87″W, 9 m, *Salix lanata*; IS12: queen, 7.VI.2014, Snartastaðakirkja, Kópasker, 66°17′43.62″N, 16°25′29.77″W, 12 m, *Salix callicarpaea*; IS13: queen, 7.VI.2014, Snartastaðakirkja, Kópasker, 66°17′43.62″N, 16°25′29.77″W, 12 m, *Salix callicarpaea*; IS16: queen, 7.VI.2014, Skinnastaðir, Jökulsá á Fjöllum, 66°2′9.96″N, 16°26′16.54″W, 39 m, *Salix phylicifolia*; IS17: queen, 7.VI.2014, Ásbyrgi, 66°0′5.88″N, 16°30′49.61″W, 85 m, *Taraxacum officinale* agg., *Salix lanata*; IS19: worker, 9.VI.2014, Akureyri, 65°40′29.85″N, 18°5′39.04″W, 60 m, *Taraxacum officinale* agg.; IS24: worker, 9.VI.2014, Akureyri, 65°40′29.85″N, 18°5′39.04″W, 60 m, *Lupinus polymorpha* (garden); IS26: worker, 17.VI.2014, Svinafellsjokul, 64°0′29.92″N, 16°52′46.07″W, 135 m, *Lupinus nootkatensis*.

GBIF and AMNH records

30 GBIF and one AMNH records are available. — AMNH_BEE00163546: worker, Blaskogabyggo, Árnessýsla, Pingvellir National Park, 64°15′28.98″N, 21°7′30.00″W, 24.VII.1971, R. G. Goelet, *Bombus jonellus* (Kirby, 1802); GBIF335156422, GBIF335156423: Syntypes, Skagafjord?, Steineke, *Bombus (Pyrobombus) jonellus subborealis (atrocorbiculosus)* Vogt, 1911; GBIF335156424, GBIF335156425, GBIF335156426, GBIF335156428: Syntypes, Skagafjord?, 30.VII.1896, W. Lundbeck, *Bombus (Pyrobombus) jonellus subborealis (atrocorbiculosus)* Vogt, 1911; GBIF335156427: Syntype, Skagafjord?, 1.VIII.1881, W. Lundbeck, *Bombus (Pyrobombus) jonellus subborealis (atrocorbiculosus)* Vogt, 1911; GBIF335156429, GBIF335156430: Syntypes, Hallormsstadhur, 9.VIII.1907, *Bombus jonellus subborealis (atrocorbiculosus)* Vogt, 1911; GBIF335156431, GBIF335156432, GBIF335156433, GBIF335156434, GBIF335156435: Syntypes, Akureyri, *Bombus (Pyrobombus) jonellus subborealis (atrocorbiculosus)* Vogt, 1911; GBIF335156437, GBIF335156438: Syntypes, *Bombus (Pyrobombus) jonellus subborealis (atrocorbiculosus)* Vogt, 1911; GBIF335156439: Syntype, Steineke, *Bombus (Pyrobombus) jonellus subborealis (atrocorbiculosus)* Vogt, 1911; GBIF335156860: Syntype, *Bombus (Pyrobombus) jonellus subborealis (sparreschneiderianus)* Vogt, 1911; MZLU.Ent.247626: 7 specimens, *Bombus jonellus* (Kirby, 1802); RMNH.INS.592439: worker, 1.I.1870, Bottema, *Bombus (Bombus) hortorum* (Linnaeus, 1758); RMNH.INS.598901: worker, 1.I.1870, Bottema, *Bombus (Bombus) terrestris* (Linnaeus, 1758); RMNH.INS.604974: worker, Skaftafell, 19.VII.1980, *Bombus jonellus* (Kirby, 1802); RMNH.INS.607337: *Bombus (Pratobombus) jonellus* (Kirby, 1802); RMNH.INS.612347: Skaftafell, 19.VII.1980, *Bombus jonellus* (Kirby, 1802); ZMA.INS.764078, ZMA.INS.774622: workers, Morsárdalur (Morsaadalen), 4.VIII.1908, *Bombus (Pyrobombus) jonellus* subsp. *subborealis* Richards, 1933; ZMA.INS.947791: Syntype, female, 9.VIII.1908, *Bombus (Pyrobombus) jonellus subborealis* f. *sparreschneiderianus* Vogt, 1911; ZMA.INS.947807, ZMA.INS.947811: Syntypes, workers, *Bombus (Pyrobombus) jonellus subborealis* f. *atrocorbiculosus* Vogt, 1911.

R e m a r k : Concerning '*atrocorbiculosus*' and '*sparreschneiderianus*' see section 'Status'. The determinations of RMNH.INS.592439 (*B. hortorum*) and RMNH.INS.598901 (*B. terrestris*) are not correct, both specimens can be classified as *B. jonellus*. The syntype status of the specimens of the Zoological Museum Amsterdam (ZMA, included also in GBIF) is related to the collection of Vogt (1911) concerning the classification in '*atrocorbiculosus*' and '*sparreschneiderianus*'.

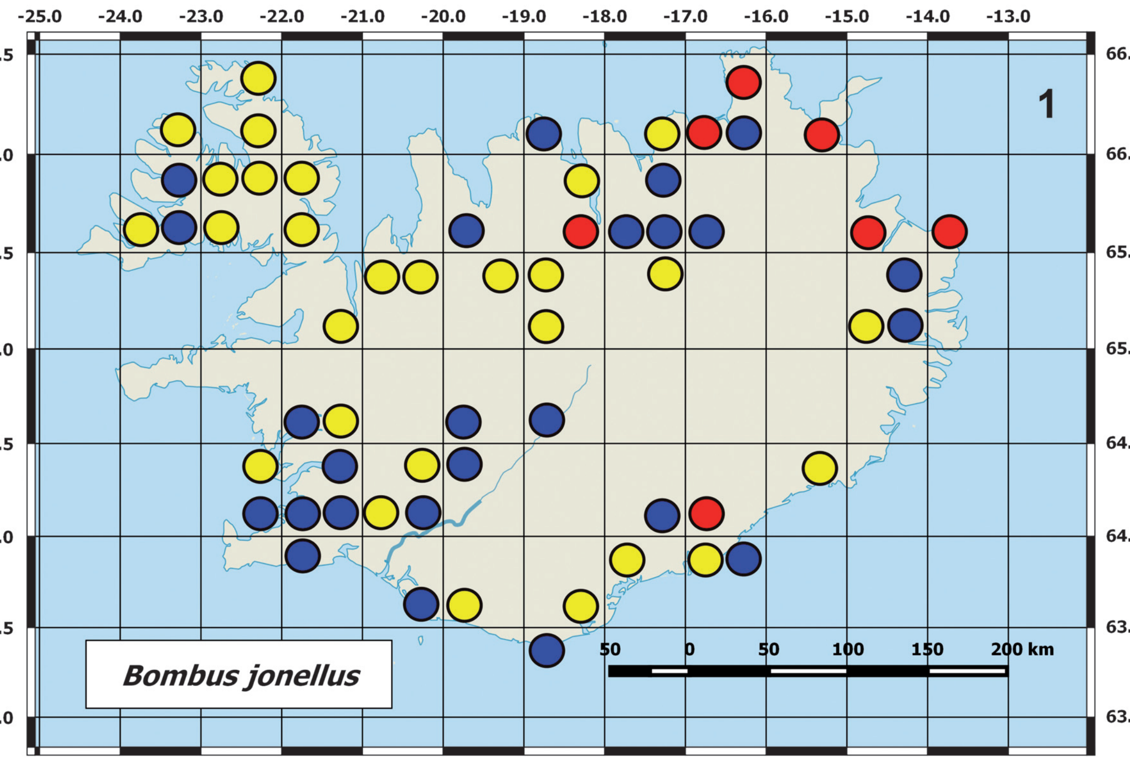
Body length

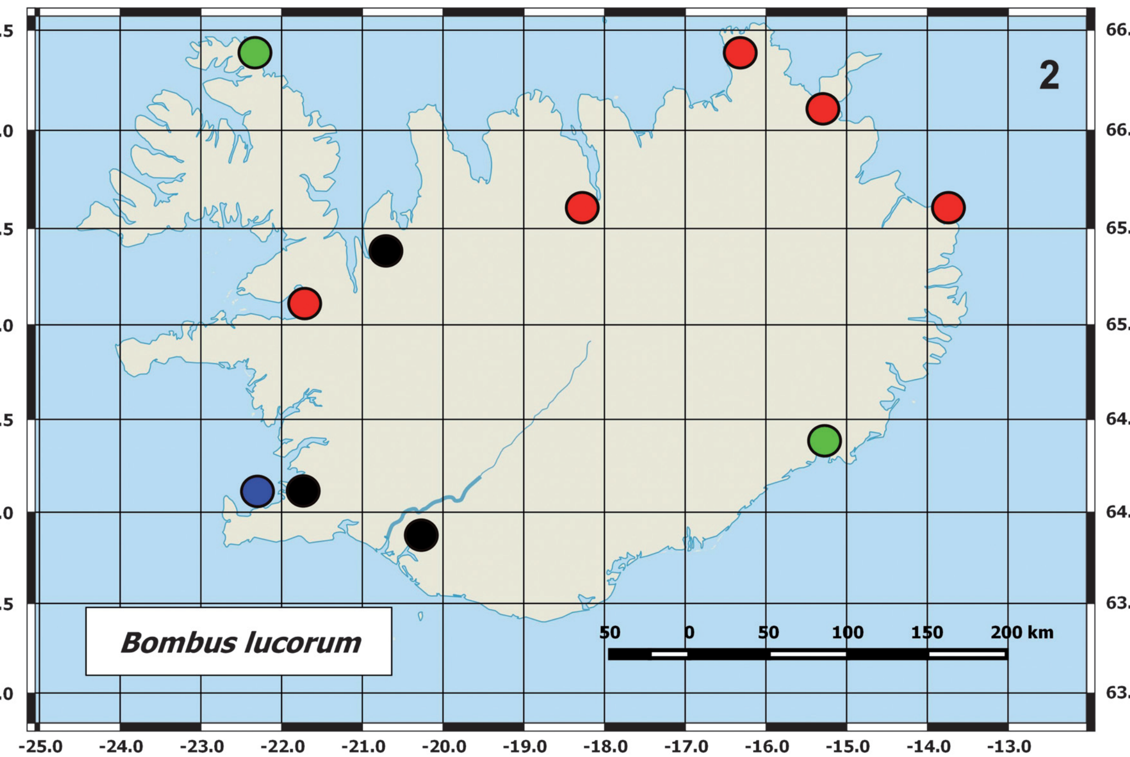
The mean body length in queens was 17.11 mm (SD ± 0.67) (N = 8), in workers 11.68 mm (SD ± 2.33) (N = 4).

Distribution and habitat selection

Fig. 1 documents the distribution of *Bombus jonellus* in Iceland (Prŷs-Jones et al. 1981: 77 grid records before 1960, 35 grid records between 1960 and 1980, 12 grid records added from 2014).

B. jonellus is widespread in Iceland and occurs as a dominant *Bombus* species in nearly all habitat types with entomophilous plant species from the glacier forefield to the coastal ecosystems. In the highlands specimens are not so frequent. Today the number of *B. jonellus* detections in 25 × 25 km grids of Iceland amount to 58 grids. Iceland covers 197 grids, but about 10 % are covered by ice





Figs. 1–2. Distribution of *Bombus* spp. in Iceland. – **1**. *B. jonellus*. **2**. *B. lucorum*. – Yellow circles: grids with records before 1960 (Prŷs-Jones et al. 1981), blue circles: records between 1960 and 1980 (Prŷs-Jones et al. 1981), green circles: records of Ólafsson (2008, 2009), red circles: own data 2014, black circles: 3 records of GBIF 2014. Older detections were replaced by more recent ones.

Figs. 3–4. *Bombus lucorum* queens visiting flowers in Iceland. – **3**. *Salix lanata* (Bakkagerði, Höfn, 4.VI.2014). **4**. *Lupinus nootkatensis* (Húsavik, Laxá, 8.VI.2014). – Photos: A. Schwabe.

and snow. If we suppose that 177 grids are not ice- or permanently snow-covered, until today *B. jonellus* has been observed in 58 grids (33 %).

Phenology and flower visits

From June 3 to June 18 queens and workers could be observed to prefer *Salix* species: *S. callicarpaea*, *S. lanata*, *S. phylicifolia*. Further plant species visited by *B. jonellus* are *Taraxacum officinale* agg. and two introduced *Lupinus* species: *L. nootkatensis* and *Lupinus* hybrid (garden). At this time more queens than workers could be observed; that means that the foundation of colonies was not advanced.

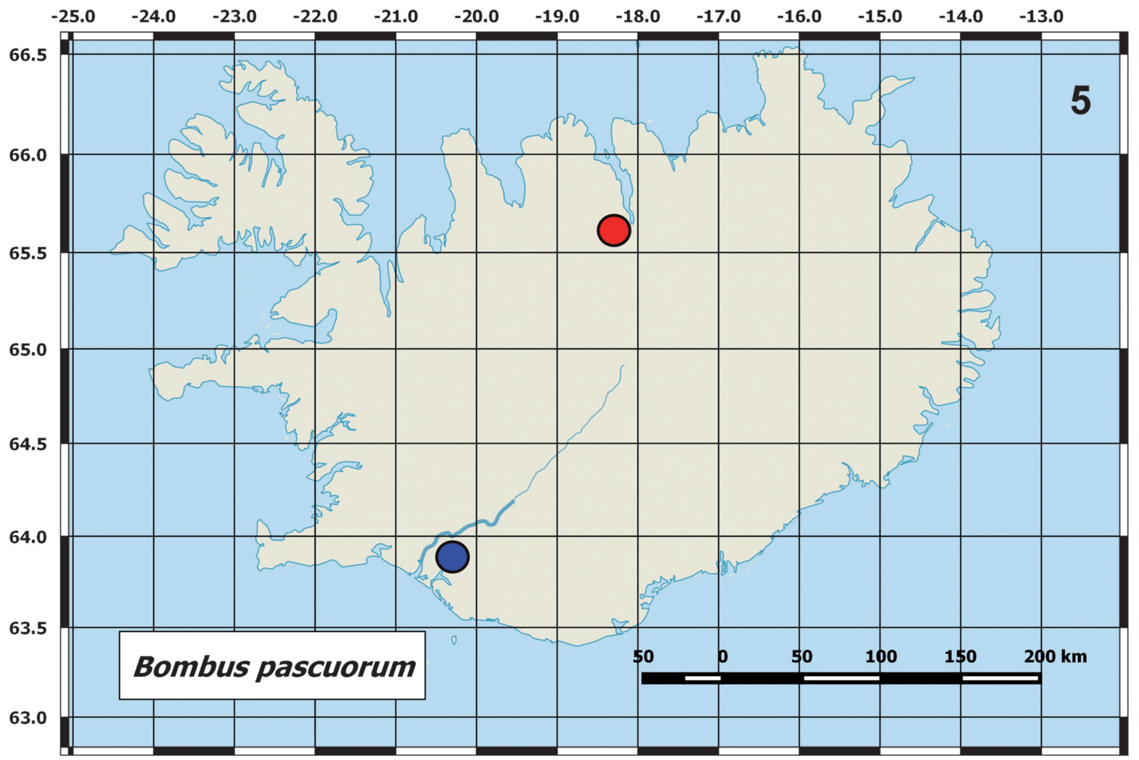
Prŷs-Jones et al. (1981) documented the plant species spectrum visited by *B. jonellus* and emphasise that in June primarily *Salix* species are available. Among the most important foraging plants other than *Salix* species are: *Geranium sylvaticum*, *Vaccinium uliginosum*, *V. myrtillus*, *Calluna vulgaris*, *Thymus praecox* subsp. *arcticus*, *Trifolium repens* and *Arctostaphylus uva-ursi*. Fairly important are: *Rhinanthus minor*, *Dryas octopetala*, *Geum rivale*, *Leontodon autumnalis* and *Potentilla palustris*.

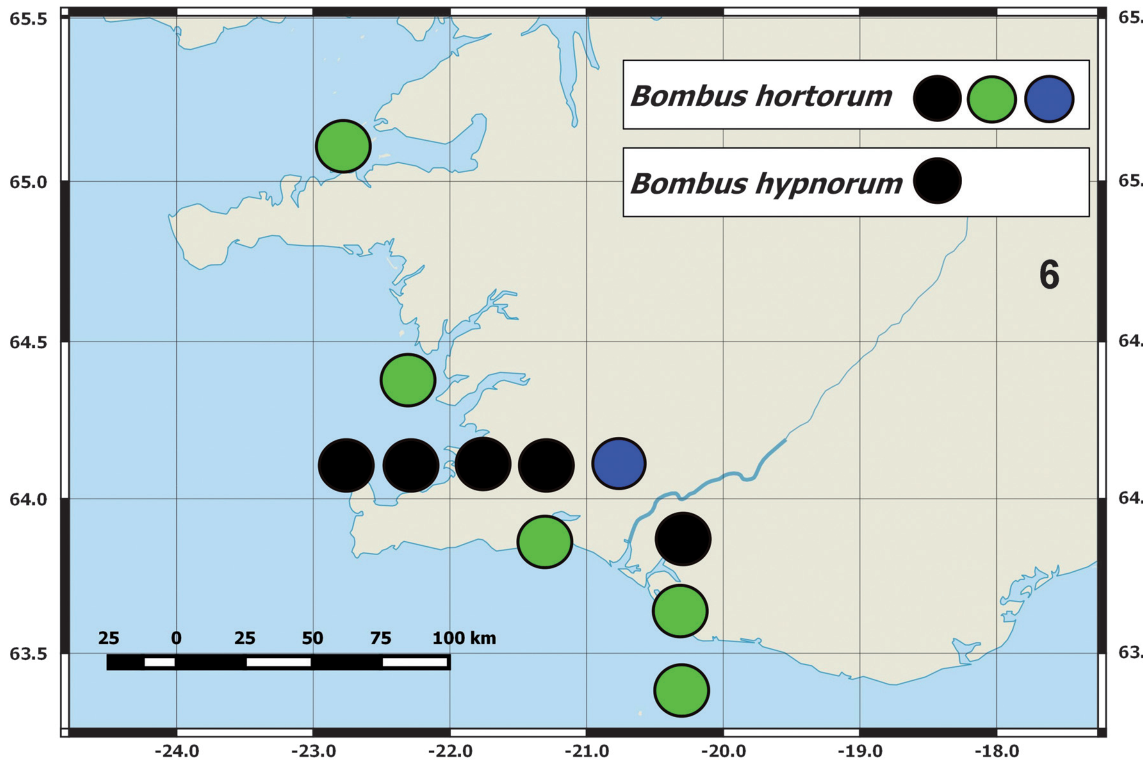
Ecological characterisation

Subspecies as geographic taxa are characterised by adaptations evolved under the special regional environmental conditions. In the following for a comparison only the ecological characters of the subspecies *subborealis* should be considered. In Norway *B. j. subborealis* is widely distributed from the south to the Arctic coast with a preference for heather (*Calluna*) and adjacent meadows from coast to the alpine region (Løken 1973). For eastern Scandinavia *B. jonellus* prefers biotopes with boreal character (Pekkarinen et al. 1981). In the Abisco region (Norway) nesting sites were found in subalpine heath birch forest habitats (Svensson & Lundberg 1977). Cultivated areas are avoided (Løken 1973).

In the terminology of Pittioni & Schmidt (1942) *B. jonellus* can be classified as stenoecious-hylophilous (small ecological amplitude and preferring humid regions).

On Solovetskii Island (White Sea) Bolotov et al. (2013) studied the population dynamics of *B. jonellus*, *B. lucorum*, *B. pascuorum*, *B. pratorum*, *B. hypnorum* and some other species under different environmental conditions. Changes in species abundance reflected changes





Figs. 5–6. Distribution of *Bombus* spp. in Iceland. – **5**. *B. pascuorum* ssp. *sparreanus*. Blue circle: grid with records of Ice-News (2010) and of Ólafsson (2010), red circle: own data 2014 including 3 GBIF records. **6**. *B. hortorum* in Southwestern Iceland. Blue circle: grid with records between 1960 and 1980 (Prŷs-Jones et al. 1981); green circles: grids with records of Ólafsson (2013a); *B. hortorum* and *B. hypnorum*: black circles: grids with records of Ólafsson (2010, 2013b). Older detections were replaced by more recent ones.

in weather and climate conditions. The superdominance of *B. jonellus* was positively correlated with a high frequency of winter-thaws and negatively correlated with summer heat supply (Bolotov et al. 2013). Thaws from January to March were unfavourable for bumblebees and resulted in high mortality rates. But in contrast to other species *B. jonellus* is better adapted to these unfavourable conditions and has the competitive advantage of early nest founding, small colony size and rapid colony development, which allows two generations in some years (Meidell 1968, Douglas 1973). Under winter-thaw conditions and reduced population sizes of the other bumblebee species *B. jonellus* benefits from free resources. The same situation exists in Iceland. Frost in Iceland is frequent, but thaws are common and a peculiarity of Icelandic weather (Einarsson 1984). High population densities in *B. jonellus* are present in cold summer seasons (Bolotov et al. 2013). *B. jonellus* colonises successfully the Subarctic (forest tundra, hypoarctic tundra) with nesting preferences along sea coast and in river deltas within the drier conditions of well-drained sandy soils (Bolotov et al. 2013).

3.2 *Bombus (Bombus) lucorum* (Linnaeus, 1761)

Observed specimens

Eight queens and two workers were detected. — IS1: queen, 4.VI.2014, east of Borgarfjörður, 65°30′56.20″N, 13°47′33.00″W, 5 m, *Salix lanata*; IS7: queen, 6.VI.2014, Porshöfn, 66°11′54.88″N, 15°19′41.87″W, 9 m, *Salix lanata*; IS8: worker, 6.VI.2014, 66°11′54.88″N, 15°19′41.87″W, 9 m, *Salix lanata*; IS9: queen, 7.VI.2014, Snartastaðakirkja, Kópasker, 66°17′43.62″N, 16°25′29.77″W, 12 m, *Salix lanata*; IS10: queen, 7.VI.2014, Snartastaðakirkja, Kópasker, 66°17′43.62″N, 16°25′29.77″W, 12 m, *Salix lanata*; IS11: queen, 7.VI.2014, Snartastaðakirkja, Kópasker, 66°17′43.62″N, 16°25′29.77″W, 12 m, *Salix lanata*; IS14: queen, 7.VI.2014, Snartastaðakirkja, Kópasker, 66°17′43.62″N, 16°25′29.77″W, 12 m, *Salix phylicifolia*; IS15: queen, 7.VI.2014, Snartastaðakirkja, Kópasker, 66°17′43.62″N, 16°25′29.77″W, 12 m, *Lupinus nootkatensis*; IS23: worker, 9.VI.2014, Akureyri, 65°40′29.85″N, 18°5′39.04″W, 60 m, *Corydalis solida*; IS25: queen, 10.VI.2014, Saelingsdal, 65°14′52.30″N, 21°48′9.92″W, 92 m.

GBIF records

Four GBIF records are available. — GBIF1038537544: Gauksmyrartjörn, 65°20′48.71″N, 20°48′28.71″W, 12.VII.2014, *Bombus lucorum* (L.); GBIF1038538694: Reykjavík, Fossvogscemetery, 64°07′21.40″N, 21°54′43.55″W, 6.VII.2014, *Bombus lucorum* (L.); http://www.inaturalist.org/observations/744552: Hvolsvöllur, 63°45′7.57″N, 20°13′14.04″W, 19.VI.2014, *Bombus lucorum* (L.); MZLU.ENT.225391: Iceland, 18.X.2011, *Bombus lucorum* (Linnaeus, 1761).

Body length

The mean body length in queens was 20.90 mm (SD ± 1.82) (N = 8), in workers 12.30 mm (SD ± 2.69) (N = 2).

Distribution

Fig. 2 documents the distribution of *B. lucorum* in Iceland (4 grid records between 1960 and 1980, 7 grid records added from 2014). Today the number of detections in 25 × 25 km grids of Iceland amounts to 9 grids (5 %). It is remarkable that *B. lucorum* has expanded the distribution area not only to the whole north and northeast but also occurs in the southern parts of Iceland. Concerning introduced *Bombus* species *B. lucorum* shows the largest distribution and seems best adapted to the environmental conditions.

Phenology and flower visits

From June 4 to June 10 queens could be observed to prefer *Salix* species: *S. lanata* (Fig. 3) and *S. phyllicifolia*, although they also visited *Lupinus nootkatensis* (Fig. 4). Workers could be detected on *S. lanata* and *Corydalis solida*. At this time, more queens than workers could be observed; that means that the foundation of colonies was not advanced. In contrast to all other species *B. lucorum* competes in flower visiting exclusively with *B. jonellus*.

Introduction history

The first detection was in June 1979 in the region of Reykjavík (Heiðmörk, Reykjavík), in 1980 in Hafnarfjörðurs. The introduction seems not to have been intended.

Ecological characterisation

In Norway *B. lucorum* is abundantly distributed, but only occasionally observed in alpine regions (Løken 1973). In Scandinavia the preferred biotopes are e. g. habitats rich in *Salix*, meadows, gardens, orchards, *Calluna*- and *Vaccinium*-heath (Løken 1973). In the terminology of Pittioni & Schmidt (1942) *B. lucorum* can be classified as euryoecious-hylophilous (broader ecological amplitude with preference in humid regions). In contrast to *B. terrestris* the colonies are not so rich in individuals and the diapause is longer, therefore this species is not domesticable.

Bolotov et al. (2013) has shown that in contrast to *B. jonellus*, in the course of overwintering the abundance of *B. lucorum* is negatively influenced by thaws from October to January and positively correlated with the thickness of the snow cover and with dry weather conditions in summer. The snow cover is largest in northern and northeastern Iceland during December and through March (Einarsson 1984).

B. lucorum has one of the shortest tongue lengths in North European *Bombus* species, and therefore nectar robbing by biting a hole in the tube is a special resource strategy (Pekkarinen 1979, Teräs 1985). *B. lucorum* is very competitive in flower utilisation; this is shown in contrast to *B. hypnorum* e. g. by Teräs (1985).

It is remarkable that both *B. lucorum* and *B. pratorum* (Linnaeus, 1761) have recently established themselves on the Faroe Islands in 2007 (Madsen & Jensen 2011, Jensen & Madsen 2013). Both species were probably introduced via ship transport and both live in settlements with gardens. Only one bumblebee specimen had previously been reported from the Faroe Islands, but with doubtful provenance: *Bombus lapponicus* (Fabricius, 1793), see Madsen & Jensen (2011).

3.3 *Bombus (Thoracobombus) pascuorum sparreanus* (Løken, 1973)

Status

B. pascuorum (Scopoli, 1763) exhibits a large diversity after the last taxonomic revision, three allopatric and 21 parapatric subspecies (Lecocq et al. 2015). The introduced species can be classified as *B. p. sparreanus* (Løken, 1973) from central Fennoscandia (distribution from the west coast of Norway across the mountains eastwards throughout the conifer forest to the Gulf of Bothnia). This subspecies occurs also in Finland except Lapland (see fig. 2 in Lecocq et al. 2015).

Observed specimens

One queen and three workers were detected. — IS18: queen, 9.VI.2014, Akureyri, 65°40′29.85″N, 18°5′39.04″W, 60 m, *Lamium maculatum* (garden); IS20: worker, 9.VI.2014, Akureyri, 65°40′29.85″N, 18°5′39.04″W, 60 m, *Lupinus nootkatensis*; IS21: worker, 9.VI.2014, Akureyri, 65°40′29.85″N, 18°5′39.04″W, 60 m, *Vicia sepium* (garden); IS22: worker, 9.VI.2014, Akureyri, 65°40′29.85″N, 18°5′39.04″W, 60 m, *Vicia sepium* (garden).

Body length

The mean body length in queens was 17.5 mm (N = 1), in workers 10.9 mm (SD ± 0.61) (N = 3).

Distribution

Fig. 5 documents the distribution in Iceland (2 grid records). The introduction (two colonisation events?) seems not intended. *B. pascuorum* avoids colder regions and is absent from most of all Arctic islands (Orkney, Shetland Faroe Islands).

Flower visits

Flower visits of a queen on *Lamium maculatum* and workers on *Lupinus nootkatensis* and *Vicium sepium* could be observed by the author.

Ecological characterisation

Bombus pascuorum is a highly polytypic taxon (Lecocq et al. 2015). The origin of the documented introduced specimens is Norway. Bolotov et al. (2013) has shown that in the course of overwintering the abundance is negatively influenced by thaws from January to March. It is not clear to which subspecies the results of Bolotov et al. (2013) can be referred: *Bombus p. smithianus* or *B. p. sparreanus* (the authors had not differentiated to subspecies level). *B. pascuorum* can be classified as euryoecious-hylophilous (Pittioni & Schmidt 1942).

3.4 *Bombus (Megabombus) hortorum* (Linnaeus, 1761)

Distribution

Fig. 6 documents the distribution in Iceland (12 grid records; Prŷs-Jones et al. 1981; further observations according Ólafsson 2009, 2010). The first detection was in 1959 in Reykjavík, Heiðmörk (Prŷs-Jones et al. 1981). It seems that the restriction to south-west Iceland has remained until today. Anthropogenic influences (gardening) promote this long-tongued bumblebee species.

Ecological characterisation

B. hortorum is distributed in the entire Fennoscandia from the southern coast northwards, from the sea level to the subalpine/alpine zone (Løken 1973). In Fennoscandia the habitats enclose gardens, orchards, fields with Fabaceae, and sites of many flowers with deep corolla tubes (e. g. *Aconitum*, *Galeopsis*, *Vicia*). Anthropogenic influences (gardening) promote this long-tongued bumblebee species. *B. hortorum* can be classified as euryoecious-hylophilous (Pittioni & Schmidt 1942).

3.5 *Bombus (Pyrobombus) hypnorum* (Linnaeus, 1758)

Distribution

Fig. 6 documents the distribution in Iceland (5 grid records). The introduction (first observed in 2008) seems not intended.

Ecological characterisation

B. hypnorum is widely distributed throughout Norway from the sea level to the subalpine region, and in the north concentrated to conifer forests. The natural nesting sites are cavities in trees (Anasiewicz 1971). Preferred habitats are meadows, gardens, orchards, road sites and pastures, but primarily *B. hypnorum* is a Siberian fauna element of the taiga region (Løken 1973) (according Reinig 1965: sub-boreal taiga element). *B. hypnorum* can be classified as euryoecious-hylophilous (Pittioni & Schmidt 1942). Williams (1991) has shown that *B. hypnorum* is associated with the cool temperate forest zone in the north and the upper montane forests in the south, and Løken (1973) demonstrated a stronger preference for areas inhabited by man. It was also shown by Svensson & Lundberg (1977) that the distribution of *B. hypnorum* in Fennoscandia is positively influenced by man-made habitats and sites in the neighbourhood of villages (see also Postner 1951, Wagner 1971). This is due to the specialised nesting behaviour. The nests are generally established aboveground in tree hollows, abandoned swallow nests, bird boxes in trees, or house walls (Løken 1973).

Bolotov et al. (2013) has shown that in the course of overwintering the abundance is negatively influenced by thaws from January to March.

Since one century *B. hypnorum* seems to have expanded to the west; e. g. increase in Belgium and Germany during the twentieth century probably as a result of increasing urbanisation (Rasmont 1988, 1989). *B. hypnorum* colonised England in 2001 (Goulson & Williams 2001).

3.6 *Bombus (Bombus) terrestris* (Linnaeus, 1758)

Ecological characterisation

Bombus terrestris is imported to Iceland for tomato pollination in greenhouses. This species occurs in the north only in the southern part of Fennoscandia, sporadically observed in southern Norway, but widely distributed in southern Sweden, concentrated in coastal regions (Løken 1973). *B. terrestris* is a more continental species, preferring dryer and warmer habitats and producing large colonies. *B. terrestris* can be classified as a hypereuryoecious-intermediary species (Pittioni & Schmidt 1942).

4 Bumblebees in Iceland: Summarising notes and aspects for the future

A consequence of social life of bumblebees is the long seasonal activity. Therefore the temperature plays an important role in their distribution. Normally the limits of *Bombus* distribution correlate with the isotherms of effective temperature sums (Pekkarinen et al. 1981).

The climate of Iceland is characterised by large interdecadal variations of temperature which are synchronic to the Atlantic multidecadal oscillation. Over longer periods the climate has become warmer: in the last 200 years about 0.7 °C per century, in the last 100 years about 0.5 °C. From 1975 to 2008 Iceland has warmed by about 1.2 °C (about 0.35 °C per decade; global average trend about 0.2 °C per decade); see Björnsson & Jónsson (2009).

As a consequence of warming up, species react with extension. This phenomenon is not new. Kaisila (1962) demonstrated that the phases of extensions and abundances of Lepidoptera in Finland correspond precisely to the periods of warm summers in this century. Extensions of *B. sylvarum* and *B. subterraneus* in Finland are associated with the warming up of the climate (Pekkarinen et al. 1981). *B. terrestris* has also extended its range northwards in Scandinavia (Løken 1973). *B. terrestris* and *B. lapidarius* colonised Northern Scotland (Macdonald 2001) and the possible role of climate change was discussed (Macdonald 2001). In 2014 *B. terrestris* was detected in Shetland (Macdonald & Harvay 2014), 2014 in Orkney (Prŷs-Jones & Williams 2015) and Fair Isle probably *B. magnus* (Vogt, 1911). All were introduced through human agency, in cargo, perhaps hibernating and probably by sea using ferry ships (Prŷs-Jones & Williams 2015).

The response of nature to recent climate change is complex (Parmesan 2006). Species adapted to colder conditions will reduce their populations or in extreme will inevitably go extinct if there is no possibility to reach higher mountain regions or northern latitudes. This process can be accelerated if competitors adapted to higher temperatures interact (Menéndez 2007). In Iceland global warming effects may reduce *B. jonellus* populations adapted to cooler summer temperatures and promote those of introduced *Bombus* species with higher temperature preferences. *B. lucorum* may expand in many regions of Iceland far from settlements but also into cultivated and settlement areas.

A similar situation is observed in northern Britain (Plowright et al. 1997, Plowright & Plowright 2009). The authors come to the conclusion that global warming effects are decisive. *B. muscorum* tolerate cold and damp weather conditions and gave evolutionary responses such as late phenology, large body size and dense body hairs. Under such weather conditions *B. pascuorum* is not able to compete. Under global warming *B. pascuorum* expanded northwards and – better adapted – provided the decline of *B. muscorum* suffering now under ecological disadvantages. The further development of *B. pascuorum* is also positively promoted by global warming effects (Plowright et al. 1997, Plowright & Plowright 2009).

In Iceland *B. hortorum* is restricted to settlement areas with gardens (preferring long-tubed flowers). But *B. lucorum* may also compete with *B. hortorum*. *B. hypnorum* is also restricted to settlement areas, concerning special nesting behaviour.

B. terrestris seems not to be adapted to survive outside greenhouses in Iceland. There are no impacts of introduced *B. terrestris* as reported from Israel (Dafni & Shmida 1996), Japan (Dafni 1998), Tasmania (Hingston et al. 2002) or New Zealand (Macfarlane & Gurr 1995).

In Iceland the process of a species turnover in Hymenoptera Apoidea Anthophila is going on. The driving forces are two factors, which correlate among themselves: global warming and introduction of non-native species. The rate of change or the consequences, e. g. within the pollinator network, are unknown.

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