Changes in the bumblebee fauna of Iceland: Will *Bombus lucorum* replace *Bombus jonellus*? (Hymenoptera: Apoidea)

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Abstract: This publication gives new records for all bumblebee species living in Iceland: *B. hortorum, B. hypnorum, B. jonellus, B. lucorum, B. pascuorum, B. pratorum* and *B. terrestris*. *B. terrestris* was detected outside the greenhouses for the first time. At 23 locations 217 specimens were collected. *B. pratorum* was only seen. The known strong expansion of *B. lucorum* (Kratochwil 2016) could be confirmed. The relation between *B. jonellus* and *B. lucorum* has constantly changed at the expense of of *B. jonellus* since *B. lucorum* occurred in Iceland. It is obvious that *B. lucorum* has already replaced the original species *B. jonellus* in some places. As a reason a strong competition of both species is given primarily (Kratochwil & Schwabe 2016). Factors effecting this competition are: the distribution of the neophyte *Lupinus nootkatensis*, the change in management of land as well as ethological but also morphological differences (Prys-Jones et al. 2016). A too low genetic diversity and a resulting suffering from diseases carried by other introduced bumblebee species (Prys-Jones et al. 2016) only can be supposed. Probably the influence of climatic change effects on *B. jonellus* in a negative way too (Kratochwil 2016, Kratochwil & Schwabe 2016). *B. lucorum* is just going to take the north top of Iceland. Only two locations could be found there without any bumblebees. In the future an ongoing expansion of *B. lucorum* is expected. *B. jonellus* will further be repressed and may become extinct in some places. A continuing expansion of *B. terrestris* can be expected.

Keywords: *Bombus*, Iceland, introduced bumblebee species, competition.

Veränderungen in der Hummelfauna Islands: Wird *Bombus lucorum* die Art *Bombus jonellus* verdrängen? (Hymenoptera: Apoidea)

Zusammenfassung: Die Arbeit liefert neue Fundortangaben zu allen auf Island vorkommenden Hummelarten: *B. hortorum, B. hypnorum, B. jonellus, B. lucorum, B. pascuorum, B. pratorum* und *B. terrestris*. *B. terrestris* wurde erstmals außerhalb der Gewächshäuser nachgewiesen. An 23 Lokalitäten wurden insgesamt 217 Exemplare gesammelt. Von *B. pratorum* liegt nur eine Sichtbeobachtung vor. Die bereits bekannte starke Ausbreitung von *B. lucorum* (Kratochwil 2016) konnte bestätigt werden. Das Verhältnis von *B. jonellus* zu *B. lucorum* hat sich seit Erscheinen von *B. lucorum* kontinuierlich zu Lasten von *B. jonellus* verschlechtert. An manchen Orten scheint *B. lucorum* die ursprüngliche Art *B. jonellus* bereits ersetzt zu haben. Als Grund wird in erster Linie eine starke Konkurrenz beider Arten untereinander genannt (Kratochwil & Schwabe 2016). Faktoren, die diese Konkurrenz bewirken, sind: Die Ausbreitung des Neophyten *Lupinus nootkatensis,* die veränderte Landnutzung durch den Menschen sowie ethologische, aber auch morphologische Unterschiede (Prys-Jones et al. 2016). Eine zu geringe genetische Variabilität und daraus resultierende mögliche Krankheiten durch andere eingeschleppte Hummelarten kann nur vermutet werden (Prys-Jones et al. 2016). Der Einfluß des Klimawandels wirkt sich vermutlich auch negativ auf *B. jonellus* aus (Kratochwil 2016, Kratochwil & Schwabe 2016). *B. lucorum* ist gerade dabei, die Nordspitze Islands zu erobern. Dort konnten nur 2 Lokalitäten gefunden werden, an denen noch keine Hummeln vorkommen. Für die Zukunft ist mit einer weiteren Ausbreitung von *B. lucorum* zu rechnen. *B. jonellus* wird immer weiter zurückgedrängt werden und mancherorts vielleicht sogar verschwinden. Eine weitere Ausbreitung von *B. terrestris* ist zu erwarten.

Introduction

The history of immigration to Iceland of the actually 6 bumblebee species of the genus *Bombus* has been recently discussed and summarised by Kratochwil (2016), Kratochwil & Schwabe (2016) and Prys-Jones et al. (2016). There is good evidence that all of them were introduced by man. *B. jonellus* was the first and started colonisation in the 9th to 10th century in ships' fright of the Vikings. For many centuries it remains the only bee species of Iceland and was considered to be the only original *Bombus* species when more intensive research started with the work of Prys-Jones et al. (1981). The next was *B. hortorum* established in the 1950s, followed by *B. lucorum* not found before 1979 (Prys-Jones et al. 2016). In the last decade *B. hypnorum* was discovered in 2008 and *B. pascuorum* first occurred in 2010 together with *B. pratorum*, which was the temporary end of the chronicle of colonisation of Iceland by bumblebees so far.

The intention of this investigation is to give some actual data of the bumblebee fauna of Iceland and offer some additional observations to show the actual dynamics of the development of the bumblebees of Iceland.

Material and methods

The observations in Iceland were carried out from 19. vii. to 4. viii. 2016. They took place along the Ring Road No. 1 but also included the northeast part of the island. 217 specimens at 23 locations (Loc1–Loc23) were collected. 2 locations were visited twice on different days and therefore noted separately. For the determination of bumblebees the keys of Mauss (1986), Prys-Jones & Corbet (1987), Amiet (1996), Edwards & Jenner (2012) and Gokcezade et al. (2017) were used. Queens and workers were distinguished by the standard of von Hagen (1988). For botanical identification Wisniewski (1992) and Kristinsson (2010) were used.

The base Map follows Kratochwil (2016). It shows an UTM grid of 50 × 50 km squares. One square is quartered so that one grit point covers an area of 25 × 25 km. Each grit point gives four data references (see Maps 2–8): Black are all bumblebee reports before 1960 (Prys-Jones et al. 1981) digitalised and supplemented with the data of other data sources cited by Kratochwil (2016), green

are the data given by Prys-Jones et al. (2016), blue are the reports of Kratochwil (2016) found in 2014 and red are the newest data of the present work of 2016. The data of Prys-Jones et al. (1981) and especially those of Prys-Jones et al. (2016) lack precise dates and GPS data of the locations where the bumblebees shown on the maps were observed or caught. So they could only be estimated as precisely as possible, but their digitisation may contain mistakes.

The data of the observed and collected specimens are arranged as follows: number of location, name of location, date, GPS data, elevation, temperature (if measured), possible feeding plants (if registered).

The locations of *Bombus* catches in 2016 are found in Map 1.

List of the localities

Loc1: Þorlákshöfn, 20. vii. 2016, 63°51′5″ N, 21°22′38″ E, 11 m, –, *Leontodon autumnalis*, *Trifolium repens*, *Vicia cracca*.

Loc2: Þingvellir, 20. vii. 2016, 64°16′7″ N, 21°6′40″ E, 113 m, –, –.

Loc3: Reykir, 21. vii. 2016, 64°2′36″ N, 20°25′20″ E, 69 m, –, *Leontodon autumnalis*, *Trifolium repens*, *Comarum palustre*.

Loc4: Heimaey, 22. vii. 2016, 63°26′58″ N, 20°15′20″ E, 106 m, –, *Trifolium repens*.

Loc5: Heimaey, 23. vii. 2016, 63°26′58″ N, 20°15′20″ E, 106 m, –, *Trifolium repens*.

Loc6: Bakki (harbour to Heimaey), 24. vii. 2016, 63°31′50″ N, 20°7′14″ E, 9 m, –, *Leontodon autumnalis*.

Loc7: Stóraborg (visitor centre), 24. vii. 2016, 63°32′34″ N, 19°39′57″E, 31 m, –, *Vicia cracca*.

Loc8: Skaftafell, 25. vii. 2016, 64°0′55″ N, 16°58′30″ E, 97 m, –, *Leontodon autumnalis*, *Trifolium repens*, *Campanula rotundifolia*, *Chamerion latifolium*.

Loc9: Höfn, 26. vii. 2016, 64°15′54″ N, 15°12′7″ E, 1 m, –, *Angelica sylvestris*.

Loc10: Seyðisfjörður, 27. vii. 2016, 65°15′40″ N, 14°0′40″ E, 9 m, 10°C, *Leontodon autumnalis*.

Loc11: Reykjahlið, 28. vii. 2016, 65°38′30″ N, 16°54′14″ E, 300 m, 10°C, *Leontodon autumnalis*.

Loc12: Húsavik, 29. vii. 2016, 66°2′50″ N, 17°20′18″ E, 22 m, 9°C, *Vicia cracca*.

Loc13: Pórseyri, 30. vii. 2016, 66°4′48″ N, 16°40′50″ E, 11 m, 10°C, *Leontodon autumnalis*.

Loc14: Raufarhöfn, 31. vii. 2016, 66°26′53″ N, 15°56′30″ E, 7 m, 12°C, *Leontodon autumnalis*, *Trifolium repens*.

Loc15: Prestholar, 31. vii. 2016, 66°15′27″ N, 16°24′58″ E, 18 m, 11°C, *Leontodon autumnalis*, *Trifolium repens*.

Loc16: Laufás (outdoor museum), 1. viii. 2016, 65°53′38″ N, 18°4′19″ E, 17 m, 13°C, *Vicia cracca*.

Loc17: Akureyri (botanical garden), 1. viii. 2016, 65°40′32″ N, 18°5′45″ E, 55 m, 14°C, (lots of different flowers).

Loc18: Blönduós, 1. viii. 2016, 65°39′36″ N, 20°16′45″ E, 31 m, 14°C, *Leontodon autumnalis*, *Trifolium repens*, *Achillea millefolium*.

Loc19: Höfði, 2. viii. 2016, 64°46′8″ N, 21°31′24″ E, 82 m, 16°C, *Chamerion latifolium*.

Loc20: Borgarnes, 2. viii. 2016, 64°33′14″ N, 21°54′12″ E, 17 m, 16°C, *Leontodon autumnalis*, *Trifolium repens*, *Chamerion angustifolium* (not on *Trifolium hybridum*).

Loc21: Reykjavik (botanical garden), 2. viii. 2016, 64°8′22″ N, 21°52′1″ E, 15 m, 17°C, (lots of different flowers).

Loc22: Þorlákshöfn, 3. viii. 2016, 63°51′5″ N, 21°22′38″ E, 11 m, 13°C, *Vicia cracca*.

Loc23: Grindavík, 3. viii. 2016, 63°50′21″ N, 22°26′17″ E, 13 m, 12°C, *Trifolium repens*.

Results

Specimens of the following 6 species of the genus *Bombus* could be collected: *B. hortorum*, *B. hypnorum*, *B. jonellus*, *B. lucorum*, *B. pascuorum* and *B. terrestris*. All specimens are located in the private collection Hallmen. Tab. 1 shows the distribution in all 23 locations. Several more sightings were made. In these places local conditions like bad wind, rain, cold temperatures or rocky areas prevented catching the very rare flying animals. These locations were: Skógarfoss (63°31′36″ N, 19°30′40″ E, 33 m, 24. vii. 2016) and Hallbjarnarstaðir (66°8′55″ N, 17°14′44″ E, 71 m, 29. vii. 2016). But field identification without catching the animals was too imprecise for an exact determination. So it can only be stated that there were bumblebees.

Species records

The distribution of all 7 bumblebee species found can be seen on Maps 2–8. – "W" means worker.

Bombus (Megabombus) hortorum (Linnaeus, 1761)

Loc17 4 ♀♀/7 W/3 ♂♂, **Loc21** 2 ♀♀/7 ♂♂, **Loc23** 1 ♀.

B. hortorum was rare to find. It was found in only 13% of all locations with bumblebees (Map 2). The reports for Loc17 and Loc23 are new for their grids.

Bombus (Pyrobombus) hypnorum (Linnaeus, 1758)

Loc2 2 ♂♂, **Loc17** 3 W/2 ♂♂, **Loc20** 1 W/5 ♂♂, **Loc21** 1 ♀/6 W/5 ♂♂.

B. hypnorum was also not very common. 17% of the locations showed this species (Map 3). New reports are Loc17 and Loc20.

Bombus (Pyrobombus) jonellus subborealis Richards, 1933

Loc2 1 W/5 ♂♂, **Loc3** 1 ♀/2 W, **Loc8** 2 W, **Loc14** 1 W, **Loc16** 2 W, **Loc17** 3 ♂♂, **Loc18** 1 ♂, **Loc19** 1 ♂.

With 35% of all locations *B. jonellus* was the second common bumblebee found (Map 4). There are no new locations for this species. Remarkable were Loc11 and Loc17 where *B. jonellus* was missing. At Loc 17 only 3 drones could be found amongst hundreds of other bumblebees.

Bombus (Bombus) lucorum (Linnaeus, 1761)

Loc1 5 W, **Loc2** 2 ♂♂, **Loc3** 5 W/1 ♂, **Loc4** 3 W/1 ♂, **Loc5** 2 W/1 ♂, **Loc6** 2 W, **Loc7** 7 W, **Loc8** 6 W, **Loc9** 1 ♀/3 W/1 ♂, **Loc10** 3 W/1 ♂, **Loc11** 6 W/1 ♂, **Loc12** 5 W, **Loc13** 4 W/1 ♂, **Loc14** 3 W, **Loc15** 6 W, **Loc16** 3 W, **Loc17** 2 ♀♀/3 W/19 ♂♂, **Loc18** 5 W/6 ♂♂, **Loc19** 2 ♂♂, **Loc20** 3 W/6 ♂♂, **Loc21** 8 ♂♂, **Loc22** 5 W, **Loc23** 4 W.

Tab. 1: Overview of locations and *Bombus* species found in 2016; × = collected, (×) = observed only.

Location	*Bombus hortorum*	*Bombus hypnorum*	*Bombus jonellus*	*Bombus lucorum*	*Bombus pascuorum*	*Bombus pratorum*	*Bombus terrestris*
Loc1				×			
Loc2		×	×	×		(×)	
Loc3			×	×			
Loc4				×			
Loc5				×			
Loc6				×			
Loc7				×			
Loc8			×	×			
Loc9				×			
Loc10				×			
Loc11				×			
Loc12				×			
Loc13				×			
Loc14			×	×			
Loc15				×			
Loc16			×	×			
Loc17	×	×	×	×	×		
Loc18			×	×			
Loc19			×	×			
Loc20		×		×			
Loc21	×	×		×			×
Loc22				×			
Loc23	×			×			

Fig. 1: At the historic open air museum at Laufás (Loc16) 5 bumblebee colonies (of *B. jonellus* and *B. lucorum*) could be found in the peat the buildings are made of. **Fig. 2:** The expansion of the neophyte *Lupinus nootkatensis* is one factor of the increase of *Bombus lucorum* and the reduction of *Bombus jonellus*. **Fig. 3:** Drone of *Bombus lucorum* at the botanical garden of Akureyri, one of the famous bumblebee highlights of Iceland. **Fig. 4:** The first specimen of *Bombus terrestris* in Iceland found in the Botanical Garden of Reykjavik.

B. lucorum was the most frequently bumblebee found nearly all over suitable parts of Iceland (Map 5). In 100% of all locations with bumblebees *B. lucorum* was present. It also provided the very most individuals in each of the 23 locations. There are new reports for the grids of Loc2, Loc3, Loc8, Loc11, Loc12, Loc13, Loc14, Loc15 and Loc16.

At Loc11 behind the houses of the small village of Reykjahlið there were large meadows flowering totally yellowish by *Leontodon autumnalis*. Masses of *B. lucorum* were found there. They might not be hundreds but thousands of individuals. Large parts of the area showed an average of 3 animals per m^2. Only a few drones occurred in between the huge number of workers. It was also obvious that in face of the large amount of flowers and good weather conditions no other *Bombus* species could be found at this location.

Bombus (Thoracobombus) pascuorum sparreanus (Løken, 1973)

Loc17 2 ♀♀/5 W/3 ♂♂.

Loc17 was the only one with *B. pascuorum* (4%) (Map 6). Therefore it was one of 3 bumblebee species seen only in one location.

Bombus (Pyrobombus) pratorum (Linnaeus, 1761)

Loc2 1 W (sighting only).

At Loc2 one smaller worker of *B. pratorum* could be observed while foraging on *Thymus praecox arcticus* (Map 7). The yellow collar and the red tip of the abdomen could clearly be recognised. But it was in a rocky area without any access. More intensive searches in the surroundings remained unsuccessful.

Bombus (Bombus) terrestris (Linnaeus, 1758)

Loc21 1 ♂.

One single specimen of *B. terrestris* at one single location could be found (4%) (Map 8; Fig. 4). It was the rarest bumblebee of Iceland. The species determination was confirmed by Prof. Dr. Rasmont (Mons, Belgium) by morphological pattern and RELP analysis on mtDNA.

Locations without bumblebees

In the northeast of Iceland 2 locations without any bumblebee could be found. At Blikalón (66°24′23″ N, 16°30′35″ E, 5 m, 30. vii. 2016) with good weather conditions (sunny, 10°C, no wind) and meadows with lots of *Leontodon autumnalis* not one single bumblebee was to be seen. The information of some residents was, that they never see any bumblebees around, only more to the south. The roadside at the most northern part of road No. 870 next to the north tongue of Iceland (66°29′13″ N, 16°18′17″ E, 7 m, 30. vii. 2016) showed the same setting with lots of possible feeding plants and good weather conditions. But *B. lucorum* and *B. jonellus* could be found at Loc14 at nearly the same geographical altitude.

On the high plateau between Egilsstaðir and lake Mývatn nearly no vegetation could be found. One exception in this rocky desert was at 65°35′40″ N, 16°7′20″ E (393 m, 10°C, 28. vii. 2016) with one of the last flowering fields of the season of *Lupinus nootkatensis*. No bumblebee was found there.

Foraging plants

Studies on foraging plants are not the focus of this work. The plants listed at the different locations were those where bumblebees could be found in most cases. These are: *Leontodon autumnalis*, *Trifolium repens* and *Vicia cracca*. In areas with significant numbers also *Achillea millefolium*, *Angelica sylvestris*, *Campanula rotundifolia* and *Salix* spec. attracted bumblebees. *Trifolium hybridum* never showed any bumblebee visits. The partly huge fields with *Lupinus nootkatensis* (Fig. 2) were withered in most places. But in the few places with lupine flowers bumblebees often seem to prefer other flowers around.

Additional observations

The botanical gardens in Akureyri (Loc17, Fig. 3) and Reykjavík (Loc21) have been highlights for bumblebee observations. They both are real magnets for bumblebees and surely attract them from all the areas around. So they could be considered as a reliable detector for all bumblebee species living there. Loc 17 is one of the most northern botanical gardens in the world. All 5 established *Bombus* species could be seen there. In Reykjavík (Loc21) however *B. jonellus* and *B. pascuorum* remained missing after intensive search under perfect conditions.

At the historic open air museum at Laufás (Loc16) it was interesting to see how bumblebees profit from traditional house construction techniques (Fig. 1). In the northwest wall of the ancient farm house complex 5 bumblebee colonies of *B. jonellus* and *B. lucorum* could be found in the peat the buildings are made of.

Used to central European studies it was an interesting experience to see honey bees *Apis mellifera* very rarely while looking at flowers. Only at Loc20 and Loc21 honey bees could be seen.

Discussion

Bombus hortorum

B. hortorum is known for the southwest of Iceland (Prys-Jones et al. 1981) (Map 2). Because of its long tongue it depends on flowers mainly planted by man. So Reykjavik (Loc21) as the biggest city of Iceland and Þorlákshöfn (Loc23) as a little village fit into these requirements of *B. hortorum*. The new report in Akureyri (Loc17) confirms this too. Between the capital of Reykjavik and Akureyri there exists an active exchange of goods and therefore a lot of traffic. Most likely this is the way *B. hortorum* got there. But it also could be a second autonomous settlement by shipping into the harbour of Akureyri and spreading from there. Further observations between these two cities might clarify this question. Loc23 as a

new report for *B. hortorum* shows that colonization of the southwest of Iceland is still going on. The failure to spread throughout the country postulated by Prys-Jones et al. (2016) seems to have to be modified with the new report in Loc17.

Bombus hypnorum

The situation of *B. hypnorum* (Map 3) is in many aspects similar to *B. hortorum*. Even the new reports in the southwest (Loc20) and in Akureyri (Loc17) are comparable. Especially the new report from Loc17 confirms the prediction of Prys-Jones et al. (2016) that *B. hortorum* will probably continue to prosper in Iceland in urban environments. The reason for this migration has to be clarified.

Bombus jonellus and *Bombus lucorum*

B. jonellus (Map 4) and *B. lucorum* (Map 5) are the dominant bumblebee species of Iceland. Since 1979, when *B. lucorum* was first found in Reykjavik (Prys-Jones et al. 2016), the two species have a very special relationship. Living alone on the island for centuries *B. jonellus* was well adapted to the northern environmental conditions of Iceland (Kratochwil 2016). As a stenoecious-hylophilous species (small ecological amplitude and preferring humid regions) (Pittioni & Schmidt 1942) it is adapted to a high frequency of winter thaws typical for the climate of Iceland. In contrast to other species where winter thaws correlate with high mortality rates. Hot summers are of negative influence for *B. jonellus* (Bolotov et al. 2013). *B. lucorum* has a broader ecological amplitude by preferring humid regions also (euryoecious-hylophilous) (Kratochwil 2016).

The results show a decline of *B. jonellus* reports by a simultaneous increase of *B. lucorum* detections. Only 35% of the locations showed a *B. jonellus* population. The relation of collected *B. jonellus* (19) to *B. lucorum* specimens (138) is 1 : 7.3 witch demonstrates the actual massive presence of *B. lucorum*. The relation between locations with *B. jonellus* to those with *B. lucorum* is 1 : 2.6. A historic retrospection of all data form Prys-Jones et al. (1981, 2016), Kratochwil (2016) and the new ones of this work illustrate a clear trend (Tab. 2): First the relation was explicitly in favour of *B. jonellus*. Over the last 40 years this species has declined constantly and in the last few years the relationship has changed in favour of *B. lucorum*. This evidently documents the change going on in the bumblebee fauna of Iceland. But it would not be correct to restrict this change to the point of the recent recognisable changeover. The data place a change from the very beginning in 1979 with the first detections of *B. lucorum* on the island. So it was and is a process lasting over the total cohabitation. This confirms to Prys-Jones et al. (2016) who considered that *B. jonellus* has been less common over the past 35 years. The year of changeover cannot be told exactly. Seasonal fluctuations surely have had influence. But it may have taken place in the last years.

Tab. 2: Relation of reports of *B. jonellus* to *B. lucorum* since the first detection of *B. lucorum* (data of Prys-Jones et al. 2016 also include older reports).

Period	Relation *B. jonellus* : *B. lucorum*
before 1979 (Prys-Jones et al. 1981)	(only *B. jonellus*)
1979–1981 (Prys-Jones et al. 1981)	9.5 : 1
1979–2015 (Prys-Jones et al. 2016)	2.5 : 1
2014 (Kratochwil 2016)	1.4 : 1
2016	1 : 2.6

The decline of the *B. jonellus* population can also be documented by the situation at Loc11. It was formerly known as a suitable place for *B. jonellus*. In 2016 not one single specimen could be found under best flower and weather conditions neither by observations nor by catches. In contrast masses of *B. lucorum* occurred at Loc11. Has *B. jonellus* already been suppressed by *B. lucorum* at that place? The fact that there was not one single specimen of *B. jonellus* to be found in the botanical garden of Reykjavik (Loc21) is also surprising. And the second botanical garden of Iceland in Akureyri (Loc17) only showed a very few drones of *B. jonellus* even though lots of other bumblebees could be found there. Or is this fact just due to the presence of other bumblebee species, especially *B. lucorum*?

The northern top of the island seems to be significant for the rest of Iceland. It looks like *B. lucorum* is actually going to take this little rest suitable for bumblebees coming from the climatically more benefited east coast of northern Iceland.

There are several reasons stated for these dynamic changes in population sizes of *B. jonellus* and *B. lucorum*. A more speculative one because not yet studied in detail may be a certain genetic decline. In Iceland *B. jonellus* lived isolated for a long time. As a result this species may have developed a low genetic diversity (Prys-Jones et al. 2016). So it may be not well adapted to some of the recent changes for example diseases carried by recently colonising bumblebee species (Prys-Jones et al. 2016).

But for sure there is a competitive effect between the two bumblebee species. The massive advance of the neophyte *Lupinus nootkatensis* may play a major part. *B. lucorum* is known as very effective in nectar robbing by biting a hole in the tube of a flower (Pekkarinen 1979, Teräs 1985). This special resource strategy may lead to a correlation between the expansion of the lupine *Lupinus nootkatensis* and *B. lucorum*. Additionally this lupine shades out important forage plants of *B. jonellus* (Prys-Jones et al. 2016). *B. lucorum* also feeds on a very similar range of plant species. The longer colony cycle of *B. lucorum* seems to be a disadvantage in the short summer season of Iceland. But it has adapted to use longer days in summer better than *B. jonellus* does (Prys-Jones et al. 2016). Management of land in cultivated areas has become more intensive, causing a general deduction in the availability of forage plants for all bumblebee species (Prys-Jones et al. 2016). Therefore all

bumblebee species got into competition about the diminishing sources. *B. jonellus,* not used to this for centuries, may have suffered from this mostly. At last there may exist a morphological benefit for *B. lucorum*. All animals of this species found in Loc11 were bigger than the average size of *B. jonellus*. Goulson et al. (2002) found out that bigger bumblebees are more effective in foraging behaviour than smaller ones, because they do not lose temperature so fast. So the average size may be another positive factor for *B. lucorum*. All factors together cause a huge competition between both species leading to the reduction of *B. jonellus* and the increase of *B. lucorum* populations. Competition is estimated to be the most important factor in the relationship of the two bumblebee species in Iceland.

And last but not least Björnsson & Jónsson (2009) showed that Iceland is not separated from the world wide climatic change effects. They bring more winter thaws which is good for *B. jonellus*. But it also correlates with warmer summers which seem to damage the populations of *B. jonellus* more than the positive winter influence promotes them. Kratochwil (2016) and Kratochwil & Schwabe (2016) found this to be an important factor of the decline of *B. jonellus*.

In summary the statement of Kratochwil (2016) about *B. jonellus,* "it occurs as a dominant *Bombus* species in nearly all suitable habitat types in Iceland", must be seen as originated by history. The actual setting shows a completely different situation. Most likely each of the factors will play their part. Certainly it is the summation of the competition with *B. lucorum*, the change of land management and the expansion of the lupine *Lupinus nootkatensis*, the morphological differences, the change of climate in Iceland especially warmer summers and may be the suffering from several diseases introduced by new bumblebee species.

And in all considerations it should be mentioned what Prys-Jones et al. (2016) pointed out: *B. lucorum* is part of a complex of sibling species, including *B. cryptarum*, *B. magnus* and *B. terrestris*. These species are very difficult or impossible to distinguish reliably not even in the field but also in the collections of entomologists, because they all show very similar morphological patterns. May be studies by barcoding Icelandic specimens of this complex will emerge some surprises.

Bombus pascuorum

The report of *B. pascuorum* at Loc17 (Map 6) conforms to Kratochwil (2016) and Prys-Jones et al. (2016). Clear new data from the primary distribution area in the southwest of Iceland doesn't exist. That might mean that *B. pascuorum* is not expanding. At best it is holding its population size. But it also might decrease. Investigations especially in the southwest of Iceland would be helpful to find out the status of this bumblebee species.

Bombus pratorum

So far *B. pratorum* has only been reported from Eskifjördur in the very east of Iceland not far from the harbour of Seydisfjördur, where the ferries arrive from the Faroe Islands (Prys-Jones et al. 2016). There *B. pratorum* has been established since 2010 (Madsen & Jensen 2011). So it seems to be introduced to Iceland from Denmark via the Faroe Islands.

The sighting of *B. pratorum* in the rocks of Þingvellir (Loc2) (Map 7) doesn't seem to suit to any classical processes of expansion of bumblebees. There is a long distance between Loc2 and the first record at Loc10. And because Loc2 is not a human settlement trading is a too implausible explanation for travelling the distance by technical vehicles. More reports of *B. pratorum* are needed for a reasonable theory.

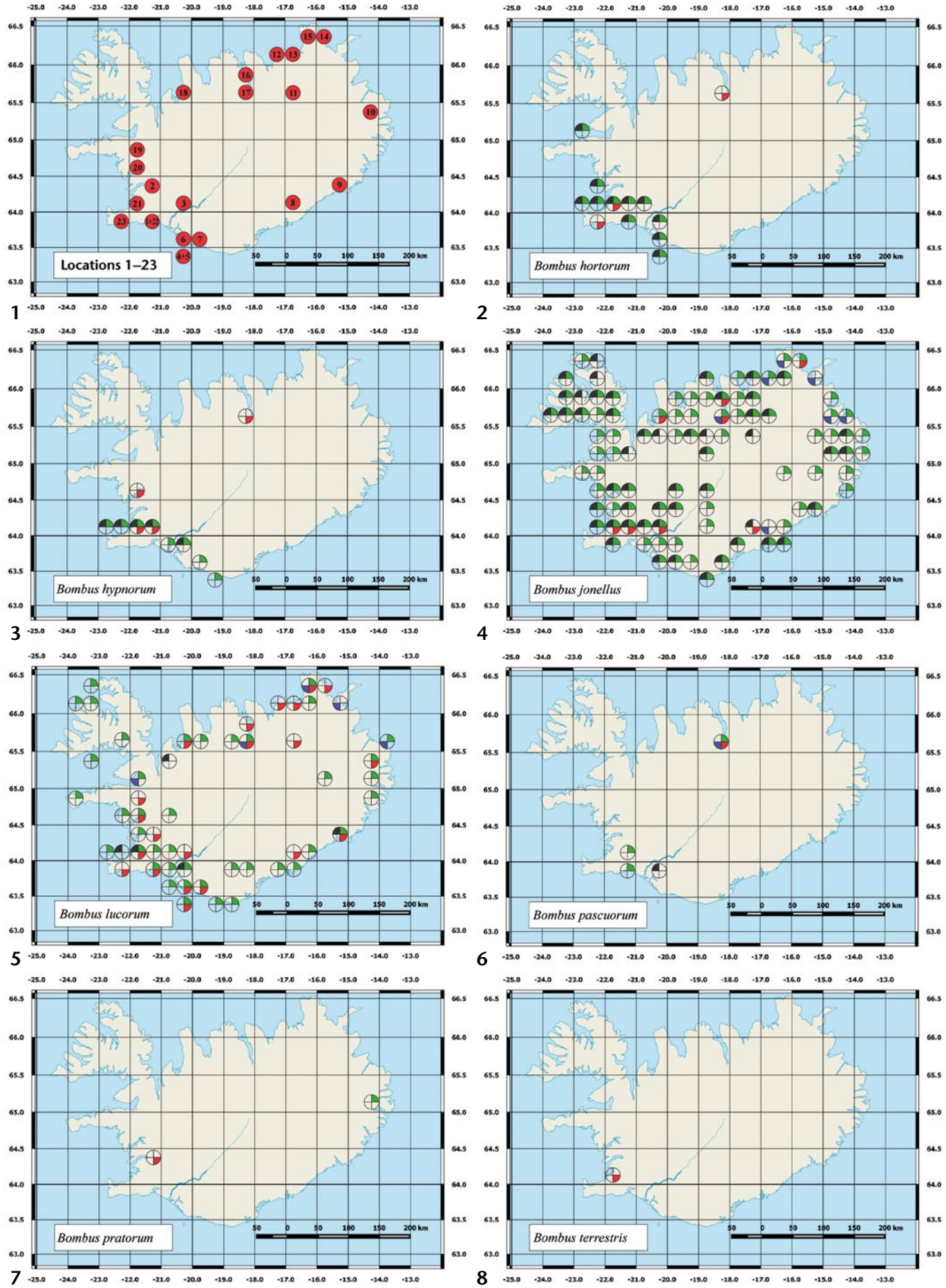
Bombus terrestris

Since 1994 *B. terrestris* has regularly been imported to Iceland for tomato pollination in greenhouses (Kratochwil 2016, Prys-Jones et al. 2016). Around 800–900 colonies are imported to Iceland each year (Kristjánsson 2013). Therefore it is most likely that some of them will or have already escaped. Prys-Jones et al. (2016) assume that it will become part of the Iceland fauna very soon. But even if this bumblebee species is expected no specimen of *B. terrestris* has been detected in the wild so far.

The drone of *B. terrestris* caught in the botanical garden in Reykjavik (Loc21; Fig. 4) is the first record for Iceland of this bumblebee species in the wild. It may be an accidental finding of a directly escaped specimen from a greenhouse. In this case it only proves that this happens. But it is more likely that it is a specimen from a small number of meanwhile established wild colonies of *B. terrestris* in the area of Reykjavik. That may indicate that this species has already left the greenhouses and is possibly going to spread over the climatically benefited and man influenced southwest of the island. It will be interesting to see the next detections and if this species can establish bigger populations in Iceland. Effects of global warming in Iceland (Björnsson & Jónsson 2009) will surely promote *B. terrestris* in the future.

Trends for the future

At the moment we find a very dynamic situation in the bumblebee species in Iceland. Predictions are not easy because of possible effects of newly introduced diseases, new bumblebee species and last but not least of the changing climate in Iceland. But some tendencies are emerging: *B. lucorum* will continue and may be intensify its expansion. That will be at the expense of *B. jonellus*. The negative influence of the strong competitor *B. lucorum* and global warming will cause further decreases in population size, losing some parts of the island or may be going extent all over the island. *B. terrestris* may benefit of the climatic changes and goodness knows if



Maps 1–8: Map 1: The locations of *Bombus* observations in 2016. — **Maps 2–8:** Records of bumblebee species in Iceland: grey = records before 1980 (Prys-Jones et al. 1981), green = records in Prys-Jones et al. 2016, blue = records from 2014 (Kratochwil 2016) and red = actual records of the present work.

it's sitting in the starting blocks for a new invasion of the island? What we can state for sure is that studying the bumblebees of Iceland will remain exciting.

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