# The firebug *Pyrrhocoris apterus* (Linnaeus, 1758) (Hemiptera, Heteroptera) new to the Norwegian fauna – with an explosive expansion in Northern Europe

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The Firebug *Pyrrhocoris apterus* (Linnaeus, 1758) (Hemiptera, Heteroptera) is presented new to the Norwegian fauna. Several hundred individuals were observed in a residential area in southeast Norway, centred around two *Tilia* trees. *P. apterus* has had an explosive expansion in Northern Europe the recent years, and its range expansion and means of expansion is discussed.

Key words: Hemiptera, Heteroptera, Pyrrhocoridae, *Pyrrhocoris apterus*, Norway, Northern Europe, range expansion.

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## Introduction

There are about 470 species of Heteroptera registered in Norway (Ødegaard & Endrestøl 2015). Some of these have become established or introduced in Norway the recent years, either as a result of natural range expansion or human activity (e.g. Ødegaard & Endrestøl 2007, Staverløkk *et al.* 2009, Mjøs *et al.* 2010, Ødegaard 2014, Olsen *et al.* 2017). Many of the human induced introductions of alien insects into Norway and other countries in Europe are a result of trade with ornamental plants (e.g. Smith *et al.* 2007, Westergaard *et al.* 2020, Sandvik *et al.* 2020). Many species of true bugs have also been reported to change their distribution range in general, presumably due to a warmer climate (see review in Musolin & Fujisaki 2006).

*Pyrrhocoris apterus* (Linnaeus, 1758) (Pyrrhocoridae) is an example of a true bug that has expanded its range northwards the last decades (Voigt 2004, Tolsgaard 2005). Pyrrhocoridae Amyot & Serville, 1843 contains about 30 genera and 300 species worldwide, with 13 genera and 43 species present in the Palearctic Region (Kerzhner 2001). The genus *Pyrrhocoris* Fallén, 1814 is represented with six species in the Palearctic (Kerzhner 2001). Since *P. apterus* is easily bred in laboratory condition, its use as an experimental tool for biological research is extensive (review in Soucha 1993), even research on personality (Gyuris *et al.* 2010).

We here present *P. apterus* new to the Norwegian fauna. This represents not only a new species to Norway, but also a new family of true bug to Norway; Pyrrhocoridae. We also present data on, and discuss, its range expansion in Northern Europe.

## The records

The species was first observed by M. Grandahl in a garden in a residential area in Sarpsborg, Viken 18. April 2020. Photos where sent to the second author who identified them as *P. apterus*. Later, the first author went to the locality and confirmed the presence of the species.

**Ø** (Viken), Sarpsborg: Klokkerskogen (11. 18188, 59.25274), 18.IV.2020, 2 ex., leg. M. Grandahl, det. S. Roth; 23.IV.2020, 11♀♀ (brac.) 12♂♂ (brac.) 2♂♂ (macr.), leg./det. A. Endrestøl, coll. Norwegian institute for nature reseach (NINA) / University Museum of Bergen (UMB); 25.IV.2020, 5 ex. leg./coll. T.J. Olsen; 27.IV.2020, 1♀ (brac.) 1♂ (brac.), leg. M. Grandahl, coll. NINA; 30.IV.2020, 3♀♀ (brac.) 2♂♂ (brac.) 2♂♂ (macr.), leg. A. Endrestøl, coll. NINA.

From the 34 individuals investigated by the first author, 30 of the individuals were brachypter (brac. – short-winged) and four of the male specimens were macropter (macr. – long-winged). The body size of a pair in copula with an apparent size difference were measured to 7,5 mm (♂) and 10,3 mm (♀) (Figure 1c).

The species had never been observed in the area before, and there were several hundred individuals aggregated there at the time of the first observation. The species was observed several times the following days, and the number of individuals seemed to decrease (M. Grandahl pers. com). On the 23. April 2020 there were still probably several hundred individuals present, more scattered and in smaller aggregates (Figure 1a,b). The main population seemed to be distributed in an area of about 50 $m^2$, extending to 120 $m^2$ when counting single individuals. After some cold days at the end of April, most individuals seemed to have vanished at the 30. April (A. Endrestøl pers. obs.), and some where later seen burrowing themselves down into the sand (M. Grandahl pers. com.).

The population was centred around two trees (*Tilia cordata*) (Figure 1d), to a large part on the ground. The ground around the trees was slightly sloped towards southeast, consisting of a lawn with grasses, moss and non-vegetated spots of sand, and some debris of leaves and *Tilia* seeds. Several other garden plants and bushes were present around the locality, and a linden hedge (*Tilia*) (with hawthorn (*Crataegus*) in between) was surrounding the garden. The hedge was more than 100 m long, but no individuals of *P. apterus* seemed to be dwelling on or under this hedge. The hedge was presumably planted there in the mid 1970-ies (M. Grandahl pers. com). Several clusters of individuals were found under a bush of *Philadelphus coronaries*, a few meters from the two *Tilia* trees.

One record of *P. apterus* is published on Gbif.org (2020) from Norway (via naturgucker.de) from Innlandet county, Sør-Fron municipality, Gålå 12. July 2018. We expect that to be erroneous (probably *Corizus hyoscyami* (Linnaeus, 1758)), as this is more than 900 m a.s.l., and no *Tilia* can be found in the area. This record is thus not considered. The closest known record from the new Norwegian population is in Munkedal, Sweden, some 85 km southeast of Klokkerskogen.

## The species

*Pyrrhocoris apterus* is a very conspicuous species, strikingly colored in black and red (aposematism) (Figure 1). The coloration is somewhat variable (Soucha 1993), and several forms are described (Kerzhner 2001). The species is given as 9,0 –11,5 mm by Wachmann *et al.* (2007), and 6,5 –12 mm by Soucha (1993). In Norway it can only be confused with the widely distributed *Corizus hyoscyami* (Rhopalidae), but the markings are different and ocelli are lacking in Pyrrhocoridae (*P. apterus*). In southern Europe *P. apterus* could easily be confused with a very similar species, *Scantius aegyptius* (Linnaeus, 1758) (Pyrrhocoridae), most easily separated by the color of the abdominal sternites (Mata *et al.* 2013). Other members of the genus *Pyrrhocoris* are in general colored in black or brown (Voigt 2004), except *P. sibiricus* Kuschakewitsch, 1866, which is also colored in black and red, but much duller compared to *P. apterus*. Finally, several species of Lygaeidae from Central Europe are also conspicuously coloured in red and black, but they also have ocelli as opposed to Pyrrhocoridae.

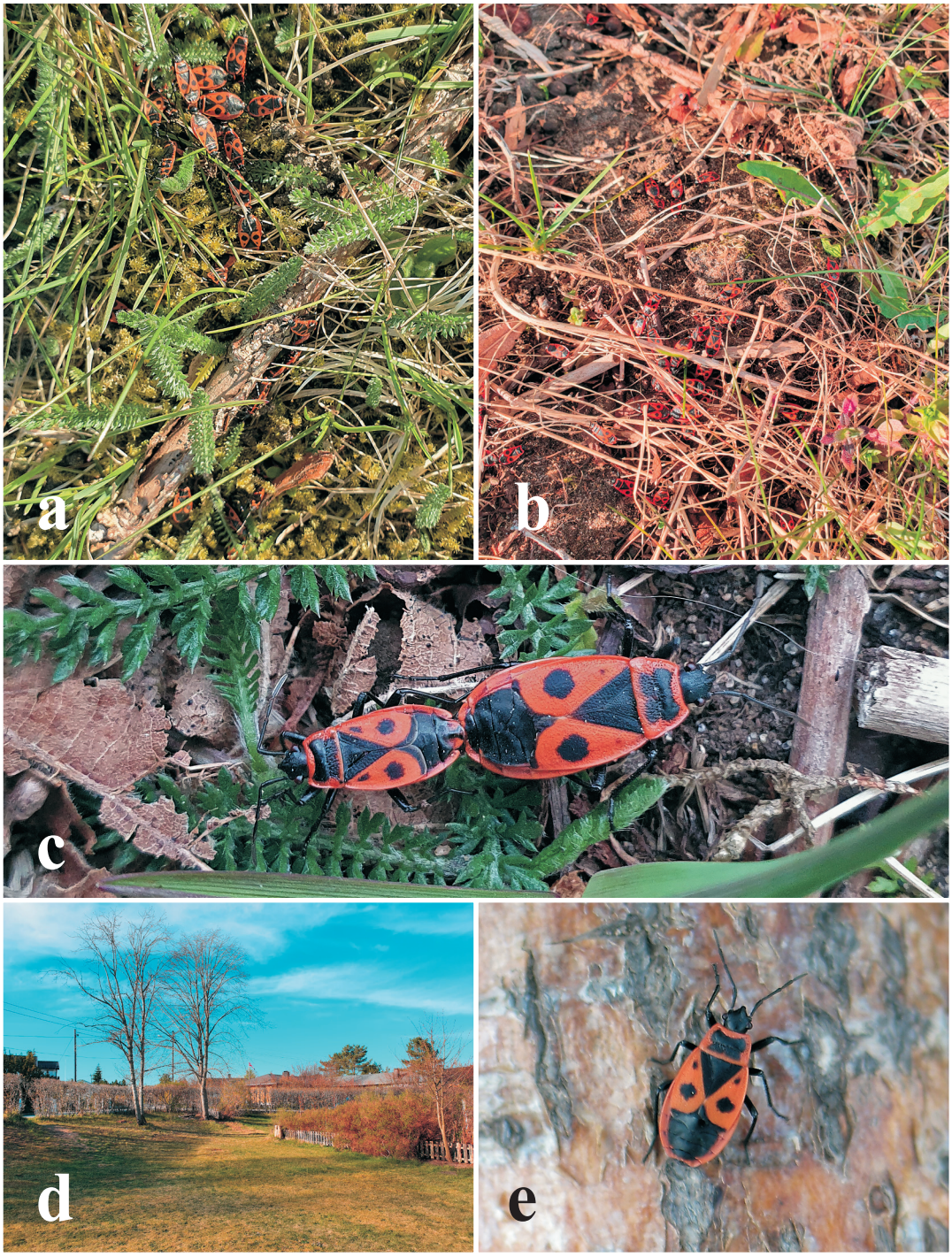


**FIGURE 1. a,b.** Aggregations of *Pyrrhocoris apterus* from Sarpsborg, Norway 23. April 2020. **c.** A pair of *P. apterus* in copula (♂:7,5 mm, ♀: 10,3 mm). **d.** The locality of *P. apterus* from Klokkerskogen, Sarpsborg, where the majority of individuals were observed under the two *Tilia* trees. **e.** *P. apterus* on the trunk of a *Tilia* tree. Photos: Anders Endrestøl, NINA.

Another strikingly feature with this species is that it aggregates in large groups as a result of aggregation pheromones and contact pheromones (Wachmann *et al.* 2007). They also have alert pheromones that results in an alarm response that quickly can dissolve aggregations (Soucha 1993, Wachmann *et al.* 2007).

The species lives on various Malvaceae such as *Tilia*, *Hibiscus*, *Malva*, *Alcea*, *Althaea* and *Lavatera* (Voigt 2004). They can also be found on and around other trees, eg. *Robinia pseudacacia* (Fabaceae) (Wachmann et al. 2007) and even on spruces *Picea* (Spuris 1995). In Europe, *Tilia* is the most common food source and *P. apterus* therefore tends to cluster under linden trees, which coincides with observations on the Norwegian locality reported here. They are adapted to an extremely dry diet of ripe seeds (Soucha 1993). To some extent they might also be zoophagous, necrophagous and cannibalistic (Soucha 1993, Wachmann *et al.* 2007). This form of polyphagy is according to Soucha (1993) one of the reasons

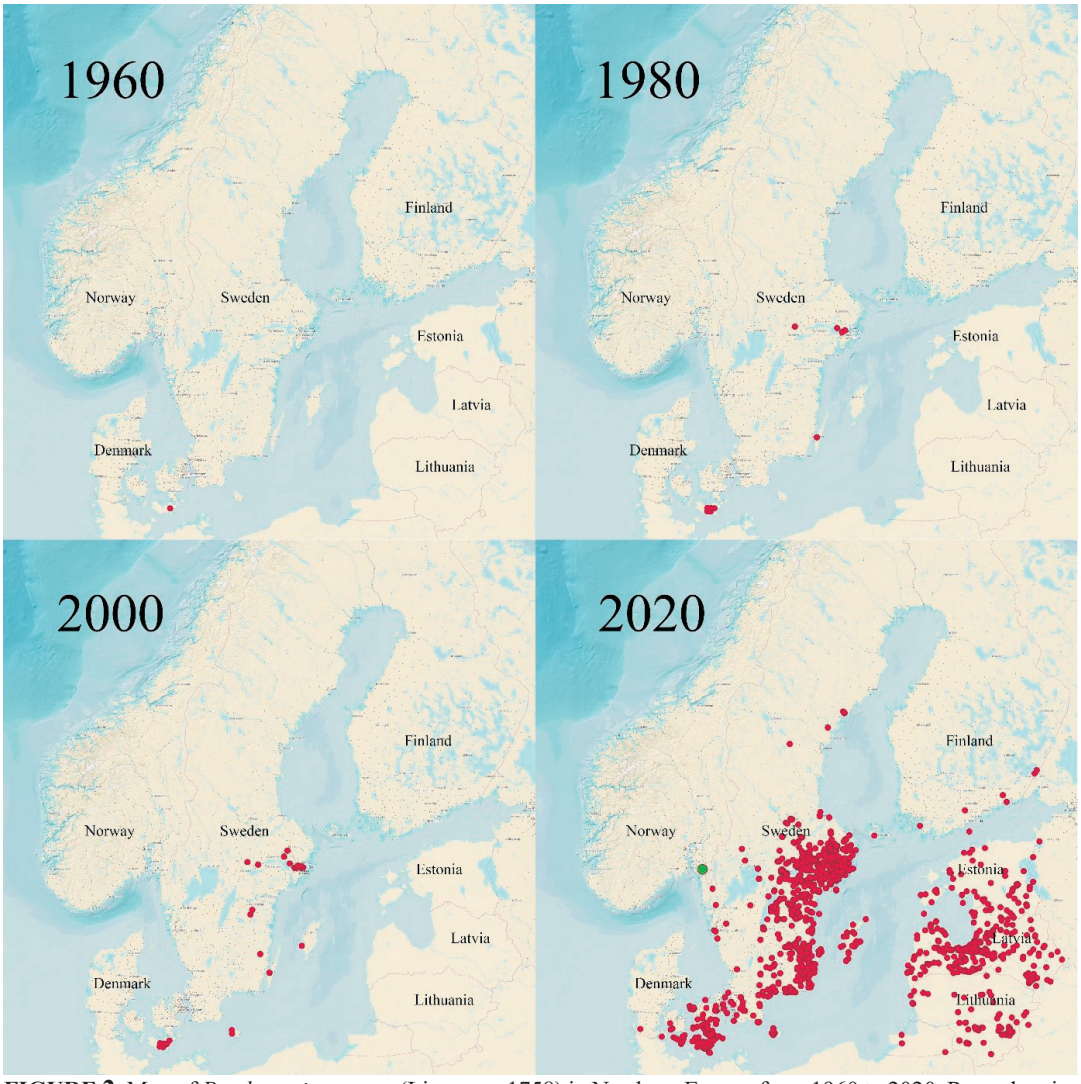


**FIGURE 2.** Map of *Pyrrhocoris apterus* (Linnaeus, 1758) in Northern Europe from 1960 to 2020. Records prior to 1960 are not considered. Green dot is the record presented here. Source: Gbif.org (2020), Fugleognatur (2020), ArtPortalen (2020), FinBif (2020), Dabas Dati (2020), eElurikkus (2020).

the species is widespread and expanding its range.

According to Wachmann *et al.* (2007) the species overwinters as adults under moss, loose bark or leaves. That is in accordance with the observation of adults in mid-April in Norway. The females start to lay eggs in May, and can continue to lay eggs for a longer period (Voigt 2004, Wachmann *et al.* 2007). One brachypterous female lays about 383 eggs, but with substantial variation (± 208 eggs) (Soucha 2013). The lifespans and total number of eggs laid by females of the two wing morphs do not differ significantly, even though such a difference is found in several other insect-species with wing dimorphism (Soucha 2013 and references therein). Eggs are laid in the ground (Voigt 2004), and females makes small pits in the ground where she lays the eggs before covering them (Soucha 1993). The embryonic development lasts 10–14 days at 18–20°C, and the nymphs pass through 5 instars (Soucha 1993). Nymphs can appear in June, with adults appearing in August (Wachmann *et al.* 2007). The life cycle in Central Europe takes about 2–3 months, and adults lifespan may vary from two months to a year depending on the conditions (Soucha 1993). In warm summers and mild winters, the species can have an uncompleted second generation with nymphal overwintering (Wachmann *et al.* 2007). The chill tolerance for 50 % survival ($LT_{50}$) have been estimated to be -15°C/1–2 weeks (Koštál & Šimek 2000).

*P. apterus* is a Holarctic species (Kerzhner 2001). The natural habitat includes Europe, the Near East to Pakistan, in Russia it reaches Central Siberia and the southern states to Kazakhstan and Uzbekistan, as well as SW Mongolia and NW China (Voigt 2004). In Central Europe it can be found up till 1000 m a.s.l. (Wachmann *et al.* 2007). It is reported from USA, Central America and India by Barber (1911) and Soucha (1993), but according to Kerzhner (2001) these records were based on occasional import or mislabelling. IThough it is published from Utah, USA (Hodgson 2008) and Canada (Oviedo Rojas & Jackson 2018) the last decade. Several observations from Melbourne, Australia (from 2018–2020) are found on Gbif.org (2020). It was published new to Malta in 2019 (Cassar 2019). In the recent few years, the species has expanded explosively in Northern Europe (Figure 2 and 3).

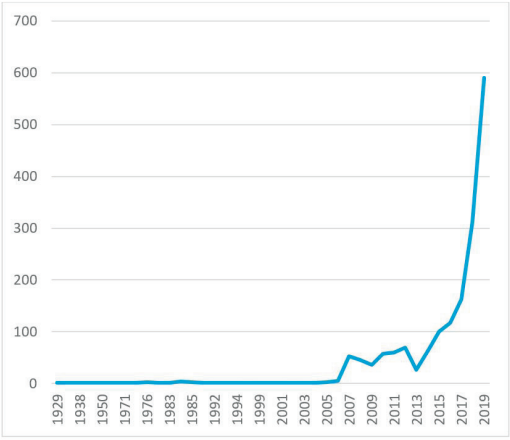


**FIGURE 3.** Number of records (one record per locality) per year of *Pyrrhocoris apterus* (Linnaeus, 1758) in total in Norway, Sweden, Finland, Estonia, Latvia, Lithuania and Kaliningrad.

The name refers to the fact that most individuals of *P. apterus* are "apter", wingless. According to Voith (2004), about 90 % of the individuals are apter, 5 % brachypter and 5 % macropter. There is a higher proportion of macropterous males than females (Wachmann *et al.* 2007). Tolsgaard (2005) refers to a material collected by Lindgren from Lolland, where < 4 % were macropterous. Jaus (1934) described different forms of wing polymorphism on *P. apterus* and found several different forms, including specimen with fully developed forewings and reduced hindwings, and specimens with asymmetrical wing development. The species thus has a high plasticity of wing morphism (Soucha 1993). In general, wing morphs are either macropterous (fully developed hind- and forewings) or brachypterous (reduced fore wing membrane and reduced hindwings). In macropters, the membrane tends to break off after the gonads have become active (Honěk 1976). Long photoperiod and high temperature encourage production of macropters (Honěk 1976). This might explain the recent expansion given that macropterous species really can fly (see discussion below)?

## Range expansion

We have combined records from different databases (Gbif.org 2020, Fugleognatur 2020, ArtPortalen 2020, FinBif 2020, Dabas Dati 2020, eElurikkus 2020) to evaluate the increase in records of *P. apterus* and to do calculations of its expansion rate. All the records of the different databases where combined into a single shapefile and analyzed further in QGIS (v. 3.4.2-Madeira) in the following manner: 1) the vector layer was split by year, 2) the expansions distance in year X was calculated using the function "distance to nearest hub" to year X-1 (or year of previous record), 3) the vector layers X and X-1 was combined to Y, 4) expansion distances for layer in year X+1 were calculated using the nearest hub to layer Y, 5) this was done for the years with records in the period 1829–2020, a total of 50 layers. These layers were later combined again, and expansion distances per year were calculated based on the year of the nearest hub. Since the dataset was combined with several databases, the risk of duplicate records is high. We therefore only allowed for one record on each locality defined to records closer than 1,5 meters. So, if a locality was registered with the exact same coordinate several times through a season or during several years, we reduced this to one record. Records with zero hub distance were thus omitted, including records with hub distances differing less than 1,5 m compared to the next record. A few extreme distances within one year were removed: 1) the first Latvian record in the dataset, with nearest record in Estonia, 2) the first Kaliningrad record, with nearest record in Lithuania, and 3) the first Finnish record, with nearest record in Sweden. Based on the remaining 1929 records we calculated an average expansion rate for *P. apterus* to be 8397 m per year (±2994 95%CI).

We also compared this method to another method used to calculate expansion rates of alien species in Norway (see e.g. Sæther *et al.* 2010, Sandvik *et al.* 2013). In this method, the expansion rate is estimated as the assumed invasion front starting from the position of the first observation. In the dataset presented here, that would be Denmark for Northern Europe. We used the same dataset as described above, with unique localities, in the program EXPANSION 1.4 (http://www.evol.no/hanno/12/expans.htm). The speed of the invasion front was obtained using linear regression under the assumption of sampling error and no process variance. With this method we calculated the expansion rate to be 8242 m per year (±1451 95%CI).

## Discussion

### *Northward expansion*

According to Tolsgaard (2005), *P. apterus* has since the 1930-ies been found several times on Lolland and Falster, but with a decrease in populations at the end of the 20th century. In an unpublished manuscript referred by Tolsgaard (2005), Lindgren points out that *P. apterus* was collected in southern Sweden several times in the 19th century (e.g. by Fallén 1829, Wallengren 1851, see Tolsgaard 2005). Lindgren suspected *P. apterus* to hold on some Swedish localities during the 18th and 19th century even though cold summers in this period largely reduced its populations (Tolsgaard 2005). The same seems to be true for Denmark, where several of the previously known population are gone (Nielsen & Skipper 2015). The species was registered from Finland also, but according to Kerzhner (2001) this was based on occasional import to Helsinki. Several new records are found in Finland the recent years (FinBif 2020).

*P. apterus* was not found in northern Germany until the 1940-ies, and Wachmann *et al.* (2007) described the distribution to be Europe except the northern parts of the British Islands and Scandinavia. According to Hawkins (2003) the only permanent colony of *P. apterus* in the British Islands was on a small island off the coast of Devon, but he also reported an established population in Surrey (Hawkins 2003). Today, *P. apterus* is well established in Scandinavia and found as far north as Portglenone in Northern Ireland (NBC atlas 2020, Artportalen 2020). The northernmost record globally is probably from Höglandssjön in Västernorrland, Sweden (Lat

63°N). For some reason, no record exists from northern Jutland in Denmark.

In the recent years, the number of records has increased exponentially in Northern Europe, especially in Sweden, but the data must be interpreted with some caution. Databases for citizen science have only been operational for about 15 years, and national applications still are missing in several countries (even though international applications exist, e.g. iNaturalist 2020a that can be used globally). Also, several institutions have still not digitalized their collection. Older records and some countries could therefore be underrepresented. One example is Latvia, were the oldest record in the national database Dabas Dati (2020) is from 2005 and the oldest record on Gbif.org (2020) is from 2016 (through iNaturalist 2020b). *P. apterus* is in fact mentioned from Latvia already by Flor (1860): "von Gimmerthal bei Riga gefunden". The first verifiable specimen in collections (The Latvian Museum of Natural History) can be dated back to 1938 (U. Piterans pers. com.). It is further mentioned in several publications by Zandis Spuris in the 1950-ies (U. Piterans pers. com.), and again found several times during the 1990-ies (Spuris 1995). The same would also apply for several other countries, making distribution maps and expansion rates less accurate.

We have calculated the expansion rate of *P. apterus* using two different methods, both resulting in an expansion rate of about 8,4 km per year. This would probably be an over-estimate as older records are underrepresented and the species distribution is not completely known. Large "leaps" could indicate that there are populations in-between or that human activity has been involved in the expansion into new territories.
Still, the northern expansion of this species and the massive increase in records the last five years (almost 500 % increase) is undisputable, and the question would be why and how this species is expanding.

*Means of expansion*

Does *P. apterus* migrate via flying? This easy question is not easy to answer. The macropterous individuals can move their wings (references in Soucha 1993, Soucha & Zemek 2000a), but to our knowledge, *P. apterus* has only been observed flying once (!) under very constrained conditions in an experimental set up in the laboratory (Seidenstücker 1953). Seidenstücker (1953) concluded: "die Feuerwanze fliegt!". Soucha & Zemek (2000a) also tested the hypothesis of flying macropters under laboratory conditions, using a population with a high proportion of macropterous individuals and breeding them under conditions that yield 36 % macropterous individuals. They studied the individuals for two weeks (video recording) without observing flight, though macropterous individuals flapped their wings. They hypothesize that the macropters of ancestral population of *P. apterus* were flying and that the wing flap capability could be considered a relic of flight capability (Soucha & Zemek 2000a). Soucha & Zemek (2000b) found macropterous individuals to walk more than brachypterous, and concluded that flightless macropters of *P. apterus* maintained their dispersal behaviour, even if flight is substituted with walking. Based on genetic and developmental studies, the maintenance of marcoptery can be explained by other factors than by selection for migration/ dispersal ability (Soucha 1993). Macroptery is affected by photoperiod, temperature, diet and density in particular of the fifth nymph stadium and increases development time, which might be just an adaptation to environmental conditions (Honěk 1976, Soucha 1993).

Thus, flight in this species has to our knowledge never been observed in nature. Still, some authors conclude from the dispersal to Baltic Islands and Southern Scandinavia (Tolsgaard 2005) or pattern of regional spread (Voigt 2004) that active migration by flying is very likely.

Introduction of this species into USA and Canada led to the conclusion that this species was spread with imported plants from Europe (Hodgson 2008, Oviedo Rojas & Jackson 2018). The question is if this also could explain the northward expansion in Europe. As adults overwinters, one might expect them to be hibernating under leaves and litter (or even in the soil) of plants traded between countries.

In Norway, soils of imported plants have been investigated yearly since 2012, and even though only about 1 % of the soil imported with plants into Norway has been investigated, no specimen of *P. apterus* have been found (e.g. Endrestøl *et al.* 2016, Bruteig *et al.* 2017, Westergaard *et al.* 2020). One could speculate if eggs could be transported with soils in horticulture trade, but the vast majority of the plant volume traded (at least to Norway), is done in April–May, which makes this a less likely hypothesis for a range expansion into Norway (even though it is possible as eggs are laid in May). Several alien Heteropteran species that overwinter as adults, have been found in Norway hitchhiking on other goods (or expected to do so, e.g. *Halyomorpha halys* Stål, 1855 (Kvamme 2019); *Leptoglossus occidentalis* Heidemann, 1910 (Endrestøl & Hveding 2017). One of the localities in Britain was suggested to be a result of *P. apterus* hitchhiking with imported *Eucalyptus* wood from Portugal (Brooke & Nau 2007), and a dead specimen found in Edinburgh, Scotland in 2019 was suspected to been in a bulk of straw and hay that was bought (iNaturalist 2020).

Assuming that this species is flightless, the expansion would have to be human assisted, even on short distances. The increase in trade and travel have been substantial in Northern Europe the last decades, e.g. with a fourfold increase in plant import into Norway from 1997–2016 (Bruteig *et al.* 2017), but no human vector has increased to the amount the last five years that could explain the increase in reports of *P. apterus* in that period. Moreover, the general impression is that species spread with such vectors tends to have a more random distribution, with no clear direction or continuous establishment, which is not the case in *P. apterus* (see Figure 2 with distribution map).

Even though some recent experiments have failed to show flying capabilities in this species (Soucha & Zemek 2000a), and based on the recent distribution data presented here, we tend to agree with Voigt (2004) and Tolsgaard (2005) who do not exclude flight as mean migration in this species. In addition, human assisted expansion is also probably an important factor for the range expansion of *P. apterus*. Finally, there has been a temperature increase in Europe this century, with the average city being 1 °C warmer in the 21th century than in the 20th century (Kayser-Bril 2018). This would facilitate establishment and a further northward expansion of a species limited by climatic factors, such as *P. apterus*.

### *Further expansion in Norway and northern Europe*

The species is so far only found on one locality in Norway, but in large numbers. We therefore consider the species established in Norway. Considering the cold hardiness of *P. apterus* we expect the species to keep expanding in Norway and colonizing at least coastal areas of south-eastern Norway. Both records from Sweden and Finland indicate that it can expand further north, but northern records are mainly coastal suggesting that the winter temperature might be the limiting factor for this species. As history of this species in Sweden and Denmark indicates (Tolsgaard 2005, Nielsen & Skipper 2015), some cold winters might eradicate several of its population, but considering future climate scenarios, the species will probably expand further in Northern Europe, and further northwards in the Nordic countries.

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