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Possible expansion of the range of *Xylocopa violacea* L. (Hymenoptera, Apiformes, Apidae) in Europe

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Abstract: The violet carpenter bee is a species which can chiefly be found around the Mediterranean Sea and the Black Sea. This bee species has rarely been found in Poland, which is the northernmost area of its occurrence. Between 1868 and 1935, the *Xylocopa violacea* (Linnaeus, 1758) was observed at only 8 locations in Poland. There were then no reports of the occurrence of this bee species in Poland for 70 years. The species was noted again in 2005; between 2005 and 2017, it was noted at 20 locations. This study provides detailed data on the history of the distribution of violet carpenter bees in Poland. The current data show that the population of violet carpenter bees is regenerating in Poland and that it is expanding northwards. The work contains information about the spread of this species northwards in other European countries. These changes in the species distribution may have been caused by climatic changes in Europe.

Key words: Bydgoszcz, climatic changes, Poland, range of occurrence, southern species, violet carpenter bee

The violet carpenter bee *Xylocopa violacea* (Linnaeus, 1758) is a Mediterranean species (Figure 1). It can commonly be found around the Mediterranean Sea and the Black Sea. This bee species is very rarely found in Poland. In addition to the *Xylocopa violacea*, there is one other species of the genus *Xylocopa* in Poland, *Xylocopa valga* Gerstaecker, 1872. Both species mostly inhabit the southern regions. They are rarely found in Poland because it is the northernmost area of their occurrence. In eastern and southern Europe, *X. valga* is more common than *X. violacea*; its range also reaches further north (Guershon and Ionescu-Hirsch, 2012; Huflejt and Gutowski, 2016).

The violet carpenter bee is a xerophilous species, which can be found in dry habitats. It can also be found on the edges of forests, in clearings, and in steppelike habitats. Adult specimens appear in May and fly during the entire summer season. The violet carpenter bee is a polylectic, solitary species which makes nests in the trunks and thick branches of dry, dead trees (Banaszak, 2004).

Due to climate change, there are numerous reports on changes in the distribution and phenology of numerous animal and plant species in both water and land ecosystems (Parmesan et al., 1999; Hickling et al., 2005; Luoto et al., 2006; Parmesan, 2006; Sparks et al., 2010; Tryjanowski et al., 2010). Changes in the range of species occur surprisingly rapidly (Krehenwinkel and Tautz, 2013). For example, the ranges of the European mantis (*Mantis religiosa*) (Linnaeus, 1758) and wasp spider (*Argiope bruennichi*) (Scopoli 1772) have changed considerably (Cannings, 2007; Liana, 2007; Krehenwinkel and Tautz, 2013).

As new northern areas of the occurrence of the *Xylocopa violacea* have recently been discovered in Poland and Europe, this article provides data on the history of the distribution of this species in Poland and discusses its northernmost range in Europe.

Bydgoszcz (53°07′N, 18°00′E) is a city of 355,600 inhabitants with an area of 176 km^2. It is situated in northern Poland. Since 2016, bee monitoring has been carried out in Bydgoszcz. Bees were sampled on 18 plots, with a radius of 250 m, located within an urban matrix representing a wide spectrum of urban environments. Direct searching along transects was conducted at each plot from May to September. Pollinators were netted by hand in 4 transects (each 200 m long and 1 m wide) on each plot once a month. Species that could not be identified in the field were kept for identification later.

Data of changes in the occurrence of *Xylocopa violacea* in Poland and Europe were collected and systematized. Historical and current localities of the violet carpenter bee in Poland and Europe were compiled from the literature. A map showing the estimated distribution of *Xylocopa*

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Figure 1. Estimated range map of *Xylocopa violacea* in Europe (data from Roberts and Peat, 2011; Guershon and Ionescu-Hirsch, 2012; Terzo and Rasmont, 2012; BWARS, Madsen et al., 2015; Pawlikowski et al., 2018; Cederberg, 2018). Locations noted from before 1900 until 2017.

violacea in Europe (Figure 1) is a compilation of data from various publications containing locations found from before 1900 until 2017 (Roberts and Peat, 2011; Guershon and Ionescu-Hirsch, 2012; Terzo and Rasmont, 2012; BWARS, Madsen et al., 2015; Pawlikowski et al., 2018; Cederberg, 2018). The map on Figure 2 was created using the open-source Geographic Information System QGIS Desktop 2.18.21 (QGIS Development Team, 2018).

The Polish sites where the occurrence of violet carpenter bees was recently confirmed are some of the northernmost areas of the range of the species. Further to the east, the range of occurrence of the related species *Xylocopa valga* stretches from Lithuania. This species, in a way, replaces the *Xylocopa violacea*, which is common in southeastern Europe (Noskiewicz, 1953).

Between 1868 and 1935, the *Xylocopa violacea* was observed at only 8 locations in Poland in the southern part of the country (Table). Despite regular research carried out in various regions of Poland (Pawlikowski and Celary, 2006; Banaszak, 2010), there were no reports on the occurrence of this bee species in Poland for nearly 70 years. Therefore, *Xylocopa violacea* was added to the Red List of Threatened Species in 2002 and marked EX (extinct) (Banaszak, 2002). In 2004, it was also listed as a presumably extinct species in the Polish Red Book (Banaszak, 2004).

The species was then found in Poland again. Between 1998 and 2016, it was noted at 19 locations (Table, Figure 2).

During monitoring research on 16 September 2017, a male *Xylocopa violacea* was also found in Bydgoszcz. It was identified based on its morphological characters (det. J. Banaszak). The insect was observed on nasturtium flowers (*Tropaeolum* sp.) growing in a garden located in an estate of single-family houses on the outskirts of the city.

The distribution of *Xylocopa violacea* ranges from the Iberian Peninsula through Turkmenistan, Tajikistan, and

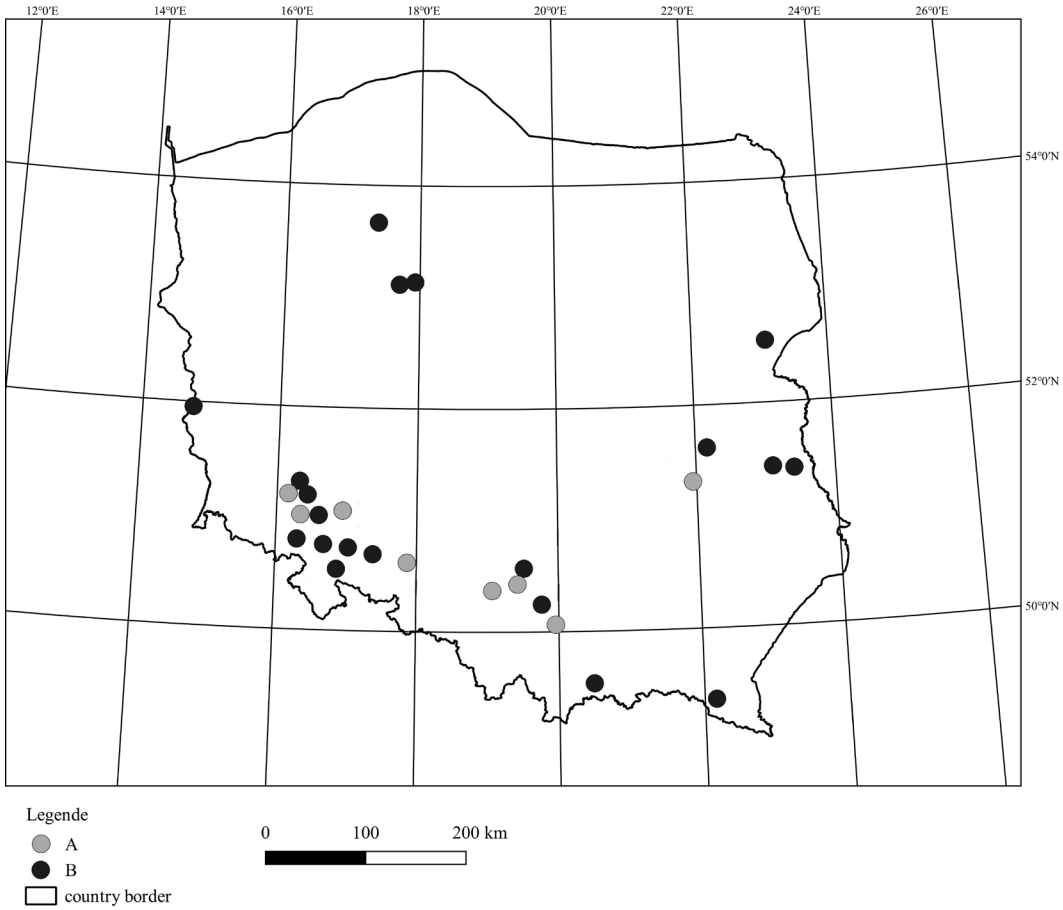

Figure 2. A map showing the history of distribution of *Xylocopa violacea* in Poland. A. locations noted until 1935; B. locations noted between 1998 and 2017.

Iran to India (Warncke, 1976; Guershon and Ionescu-Hirsch, 2012). In the Mediterranean region, violet carpenter bees can be found as far south as Morocco, Algeria, Tunisia, and Israel (Guershon and Ionescu-Hirsch, 2012). The bee has also been found in France, Switzerland (Rasmont et al., 1995), the Czech Republic, and Slovakia (Kocourek, 1989).

In northern Europe, it has been found in the United Kingdom, Belgium, Luxemburg, Germany (Kocourek, 1989; Rasmont et al., 1995; Schwarz et al., 1996; Baldock, 2009, 2010; Roberts and Peat, 2011), Poland (Banaszak and Piotrowski, 2008; Regner et al., 2016), and Ukraine (Popov, 1947). Guershon and Ionescu-Hirsch (2012) reported the occurrence of the species in Sweden and Finland, but only one female was observed in Finland in 1923 by W. Wichmann (Elfving, 1968; Vikberg, 1986). What is interesting is that in Poland and other European countries, there are more reports regarding the occurrence of *Xylocopa violacea* further north. New records of violet carpenter bee in northern Germany has been presented. The species bred there successfully in 2003 and 2004 (Thomas and Witt, 2005). Furthermore, this bee has occasionally been observed over the last decade in Sweden, with one case in which a female of *X. violacea* was found to have successfully reproduced in 2005 in Uppsala (Cederberg, 2018). In recent years, this species has also been added as new to Denmark (Madsen et al., 2015).

It is noteworthy that the 6 sites in which *Xylocopa violacea* has been found in Poland in 2016 and 2017 are located outside the area of earlier occurrences of *Xylocopa violacea* in Poland, i.e. the south of Poland—Upper and Lower Silesia, areas around Cracow and Kazimierz Dolny (Banaszak and Piotrowski, 2008). Although we do not have data for the successful reproduction and overwintering of violet carpenter bee in Bydgoszcz yet, the occurrence of representatives of this species in nearby areas a year earlier may indicate that this bee is overwintering in this region. According to Warncke (1976), the range of the species in

Table. Occurence of *Xylocopa violacea* in Poland (1868–2017).

Place of finding	Year of finding	References
1868–1935		
Wrocław, Opole, Strzegom, Legnica (Lower Silesia)	1895 (Opole)	Dittrich 1903
Bytom, Zawiercie (Upper Silesia)	-	Scholz 1912
Cracow (Cracow-Wieluń Lowland)	-	Wierzejski 1868, Łoziński 1920, Śnieżek 1910
Lublin Upland – Kazimierz Dolny	1933	Minkiewicz 1935
1998–2017		
West Bieszczady Mountains	1998	Banaszak and Ziemba 2009
Polesie National Park	2000	Banaszak and Piotrowski 2005
Miechów, Włoszczowa	2007	Banaszak et al. 2008
Bielsko-Biała	2011	Pawlikowski et al. 2018
Wrocław	2015	Micholap et al. 2015
Oława	2015	Regner et al. 2016
Steppe reserve Góra Gipsowa near Kietrz	2016, 2017	Biwo and Olszanowska-Kuńka 2018
Mechnica, Kozienice, Jabłonna, Hańsk Pierwszy, Wola Uhruska, Mielnik, Gubin, Kłodzko, Nysa, Damasławek, Człuchów	2016	Pawlikowski et al. 2018
Bydgoszcz	2017	Banaszak 2017 (unpublished data)

(-) no information about exact date of finding.

Europe reaches 52°N. The new sites located further north (Człuchów, Bydgoszcz, Damasławek, Mielnik) show that in recent years the population of *Xylocopa violacea* has been restored in Poland and that the range of the species may have extended (Figure 2). Apidological research in the area of Bydgoszcz as well as in the entire Wielkopolska-Kujawy Lowland has been carried out regularly, but *Xylocopa violacea* was not found in this region until 2016 (Banaszak, 1982; Banaszak, 1987; Banaszak, 2010). The situation of this species in other European countries included in the northern limit of its range appears similar. There are more frequent reports on the occurrence of violet carpenter bees in the United Kingdom (Roberts and Peat, 2011), which may have been caused by climate change or transport of wood from continental Europe. The records are randomly distributed, "which suggests that accidental introduction is most likely to be the major cause of the increase" **(Roberts S**, personal communication). Other researchers have also reported the spread of this species toward the north. While twenty years ago *Xylocopa violacea* was extremely rare in Belgium, it is now quite common, and several nests have been discovered (Terzo and Rasmont, 2012). The species seems especially abundant along the corridors of traditional colonization areas that include rivers (Terzo et al., 2007). In Germany, northwest of Hamburg at about 53.7°N, the species bred successfully in 2003 and 2004 (Thomas and Witt, 2005). It has also been found to successfully reproduce in 2005 as far north as Uppsala (59.8°N) (Cederberg, 2018).

Data on the distribution of the *Xylocopa valga*, which is a related species, also strongly support that the range of its occurrence is extending northward in Poland (Huflejt and Gutowski, 2016). Because *Xylocopa valga* and *Xylocopa violacea* are the largest and relatively characteristic bee species which can be easily noticed and identified by a specialist, and also because of regular apidological research carried out in Poland, we can conclude that the new records of this species in Poland are not related to methodology. One of the possible reasons for changes in the distribution of the species may be climatic changes in Europe. It is difficult to disentangle human-mediated movements and natural migration processes. Large bees like *Xylocopa violacea* or *Megachile scupturalis*, originally native to East Asia and now expanding in Europe, seem to have a strong tendency to spread naturally in a short time (Westrich et al., 2015). Therefore, some of the occurrences may be the result of active migration. The present northward expansion of *Xylocopa violacea* probably results from a combination of natural expansion triggered by climate warming and of accidental transport by humans. Continuous finds are interpreted as an area extension or temporary establishment in connection with the warmer climate (Thomas and Witt, 2005). Higher temperatures increase the chance for survival among representatives

of species with higher thermal requirements, enabling colonization and reproduction. Warmer climate provides new opportunities for introductions to areas where, until recently, introduced species were not able to survive. In consequence of these changes, there are increasing numbers of reports on extensions of the areas of occurrence of various species of insects, including rare species which are native to southern regions. For example, in the last 100 years, 65% of European butterflies have extended the ranges of their occurrence northwards by 35–240 km (Parmesan et al., 1999), e.g., the following species of the Aculeata subclade: *Scolia hirta* Schrank (Banaszak et al., 2004; Banaszak and Twerd, 2009), *Formica glauca* Ruzsky (Czechowska et al., 2004), *Andrena fulva* (Műller) (Banaszak, 2006), and *Parnopes grandior* (Pallas) (Jaroszewicz, 2007; Twerd and Banaszak, 2018). Further monitoring and comprehensive analysis of various factors that may affect the occurrence of *Xylocopa violacea* are necessary to explain changes in its distribution.

The current study demonstrates that the population of *Xylocopa violacea* is regenerating in Poland; furthermore, its range is expanding northwards. One of the hypotheses for this is that these changes in the species' distribution in Europe may have been caused by climatic changes. It may be a combination of the natural migration of this species and human-mediated movements. Individuals may naturally expand their range due to global warming. In addition, some individuals can be transported with wood by humans, and thanks to the new, more convenient climatic conditions, can survive and multiply in the environment and, as a result, colonize new areas. This issue, however, requires further detailed research to explain other possible causes of this phenomenon.

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