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Range of Occurrence of Bisexual and Parthenogenetic Populations of *Labidostomma luteum* (Acari: Prostigmata) in Europe

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Abstract: The current article describes an interesting case of geographic parthenogenesis among European mites from the Labidostommidae family (Acari: Prostigmata). In earlier publications on *Labidostomma luteum* Kramer, 1879, the authors pointed out that most of the populations of this species in Europe consisted of parthenogenetic females. Until now, populations of both sexes were known only in southwestern France. In the north–west areas, the number of males in the populations has gradually decreased, and in the populations found west of Paris there are no males at all. During the research project carried out in 2018, Błoszyk found the presence of populations which consisted of both sexes of the species in question near the town of Bény (60 km NE of Lion). This is the easternmost site of *L. luteum* in France where males have been found. All other known sites located east and north of the Bény–Paris line have only parthenogenetic females. Thus, this line can be considered as the boundary of *L. luteum* populations reproducing sexually. However, establishing the exact course of this range requires further research.

Keywords: distributional limits; glaciers; migration; Labidostommidae; parthenogenesis; sexual dimorphism; zoogeographic

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1. Introduction

Described over 140 years ago by Kramer, the species *Labidostomma luteum* is the most common representative of the Labidostommidae (Acari: Prostigmata) family in Europe. It owes its name to the unique colour scheme among the mites—the specimens of this species are bright yellow or orange. This predatory mite species has three simple eyes, which is unique among soil mites, and two large gland-like organs located on the sides of the body. The body is covered with a strong chitinous shell (divided into the dorsal and ventral part), ornamented in a very characteristic way. The species has two pairs of branched sensory setae embedded in the trichobothria in the front and central part of the body, and quite distinctive, i.e., massive, vertically positioned chelicerae. The sex of individuals can be easily distinguished—the female has one large anal–genital apparatus, while males have two smaller, separated shields—genital and anal [1].

Even in earlier publications on *L. luteum* Kramer, 1879, many authors pointed out that most of the populations of this species in Europe consist of parthenogenetic females [1–4]. Later studies and reports on this species have also always referred to populations exclusively comprising females [5–7]. Specimens of both sexes have only been reported in southwestern France. It has also been observed that, in the north–east areas, the number of males has gradually become lower, and they are absent in the areas near Paris [3,8–10].

The major aim of this study is to ascertain the geographic range of occurrence of parthenogenetic and sexual populations of *L. luteum* in Europe. Moreover, for the first time, scanning photos of males of this species are presented in this study to show the sexual dimorphism of *L. luteum*.

2. Materials and Methods

On the basis of the data from the available literature and the authors' observations, an analysis of the distribution of already known *L. luteum* sites in Europe was carried out, considering populations consisting only of females and populations containing males. The information obtained from the data was used to generate a map of the distribution of both types of population. The map was generated using CorelDRAW 2020 (18) ((64Bit)—licence No. 382586, Poland, Poznań) (legal version). The line of the easternmost populations where males have been reported was the present western boundary of populations where only females of *L. luteum* are found.

The analysed samples of female and male specimens have been deposited at the Natural History Collection at the AMU, and they were collected from the following sites.

Plot I. France. Areas around Bény (60 km NE from Lion), 27.09.2019. Riparian forest near a car park at a motorway, 46.32050 N 5.26917 E, 210 m MSL. Leg. J. Błoszyk. Eight samples collected.

1. Rotten oak stump of 1m diameter. The wood was considerably rotten and damp; 6 females, 2 males, 3 juveniles (F-2019/01);
2. Moss from tree stump. Not sieved; 7 females, 8 males, 2 juvenile (F-2019/02);
3. Moss from tree stump. Not sieved; 6 females, 1 male (F-2019/05);
4. Moss from tree stump. Not sieved; 3 females, 4 males 1 juvenile (F-2019/08);
5. Moss from tree stump. Not sieved; 7 females, 3 males (F-2019/17);
6. Riparian forest. Sieved litter; 24 females, 15 males, 2 juveniles (F-2019/18);
7. Riparian forest. Sieved litter; 21 females, 21 males, 1 juvenile (F-2019/21);
8. Rotten oak stump of 1m diameter. The wood was considerably rotten and damp; 6 females, 1 male, 4 juveniles (F-2019/26).

Plot II. France. A car park at a motorway near Mercurol-Veaunes, 27.09.2019. Riparian forest, 45.0774 N 4.8888 E, 172 m MSL. Leg. J. Błoszyk.

1. Litter, not sieved; 7 females, 3 males, 2 juveniles (F-2019/14).

3. Results and Discussion

3.1. Morphology of Males and Sexual Dimorphism of L. luteum on the Basis of SEM Scans

Although SEM images of *L. luteum* have been published previously, they only showed females [6]. In this study, the first images of males of this species are presented below. The size of the body is: length 700 µm, width 560 µm. The shape and chaetotaxy of the dorsal side of the male does not differ from that in the female (Figure 1). One of the characteristics of this species is the distinct sculpture of the back. The front and sides of the idiosoma are covered with a grid of fairly regular polygons, which are absent in the central part (Figure 1A,B and Figure 2A,B). On the dorsal side, there are six pairs of long smooth needle-like setae, which form two rows going through the centre of the back to the posterior edge of the idiosoma. There are also two pairs of feathery sensory setae, embedded in the anterior part of the body in characteristic bothridia (Figure 1B,C). The first pair is located slightly above the central eye near the anterior edge of the idiosoma, while the second pair is located backwards near the characteristic triangle with a different type of striation (Figure 1C).

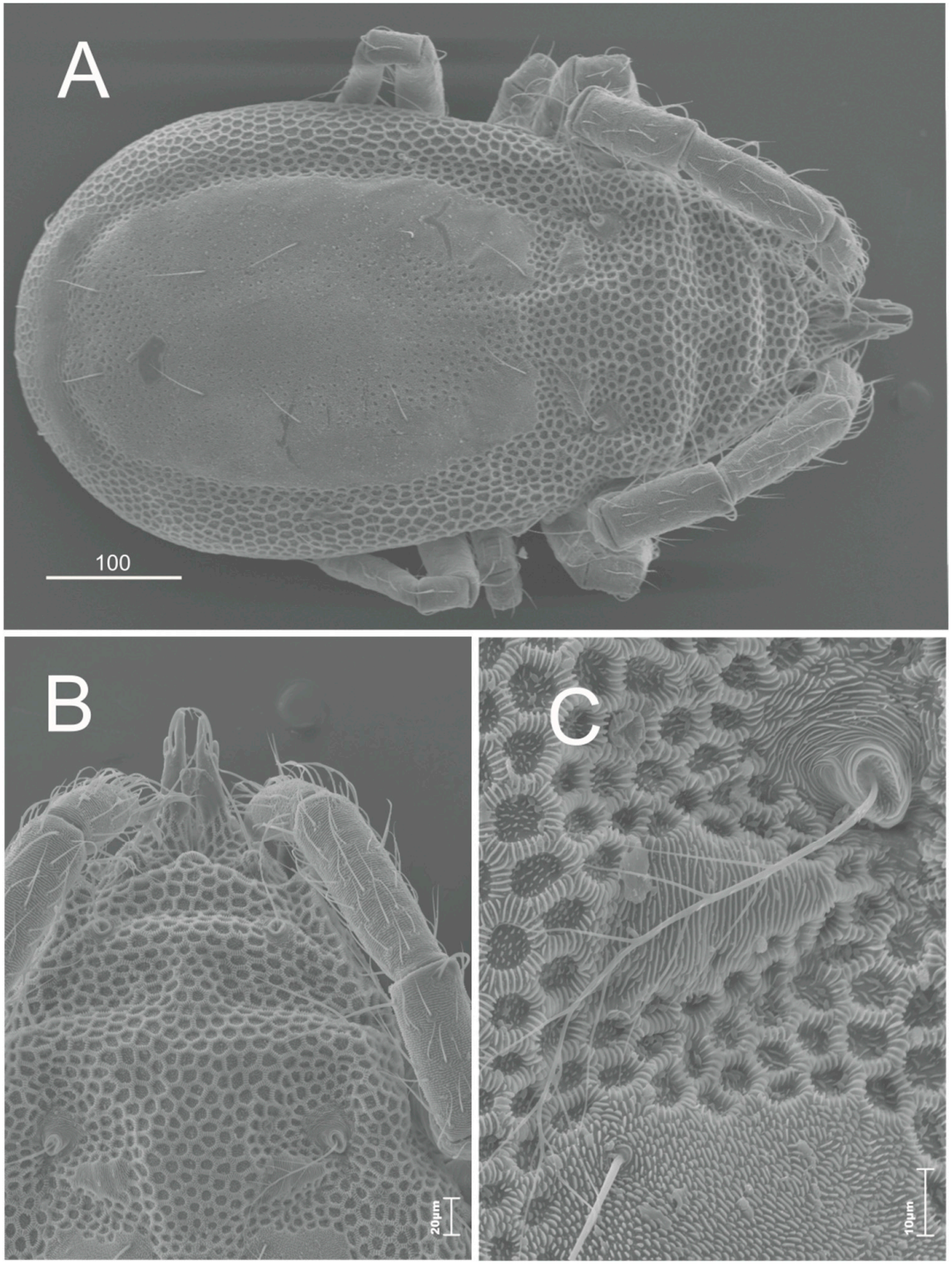

Figure 1. Male of *L. luteum*—dorsal side: (**A**)—overall view; (**B**)—anterior part of dorsal idiosoma with central eye and bothridia; (**C**)—body surface sculpture, bothridium and plumose sensory seta (ultra-high resolution). SEM observations.

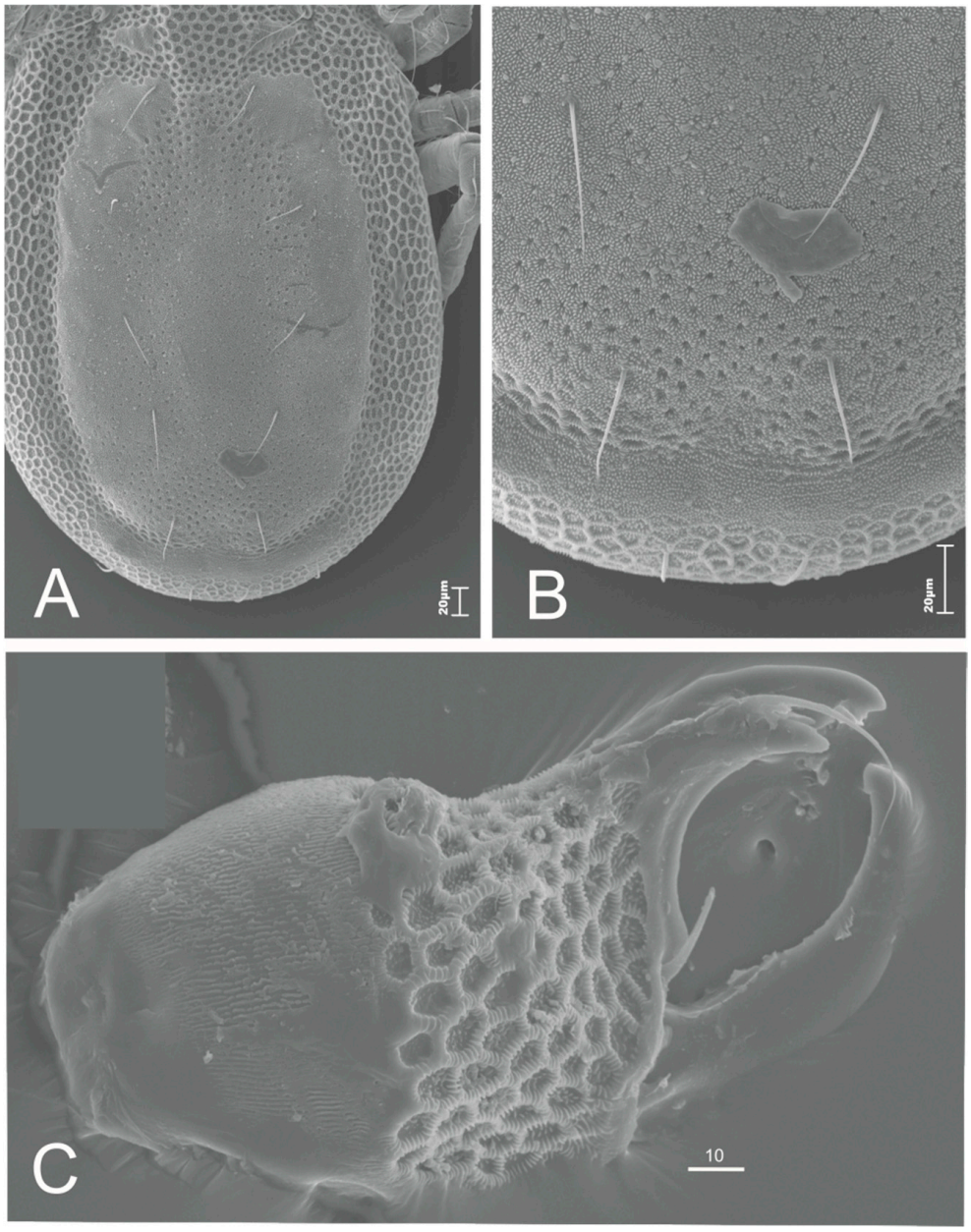

Figure 2. Male of *L. luteum*: (**A**)—central part and rear part of idiosoma with two different types of body surface sculpture; (**B**)—non-polygonal body surface sculpture (ultra-high resolution); (**C**)—chelicerae. SEM observations.

One of the characteristics of this species are the massive vertical chelicerae (Figure 2C).

The body surface sculpture and chaetotaxy of the ventral side in males and females are very similar (Figure 3). Both in males and females, anterior to the genital apparatus there is a characteristic area with specific striation. Sexual dimorphism is clearly visible. In females there is only one big genital–anal shield complex (Figure 4A), whereas in males the genital and anal shields are separate (Figure 4B).

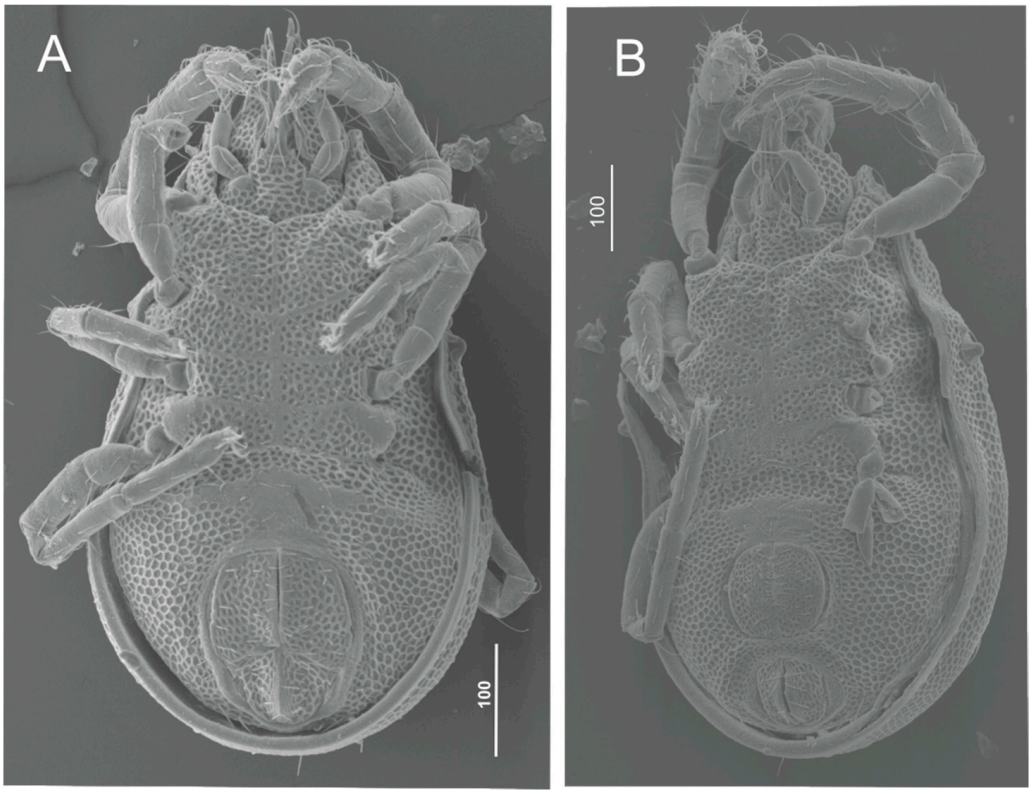

Figure 3. Ventral side of the female (**A**) and male (**B**).

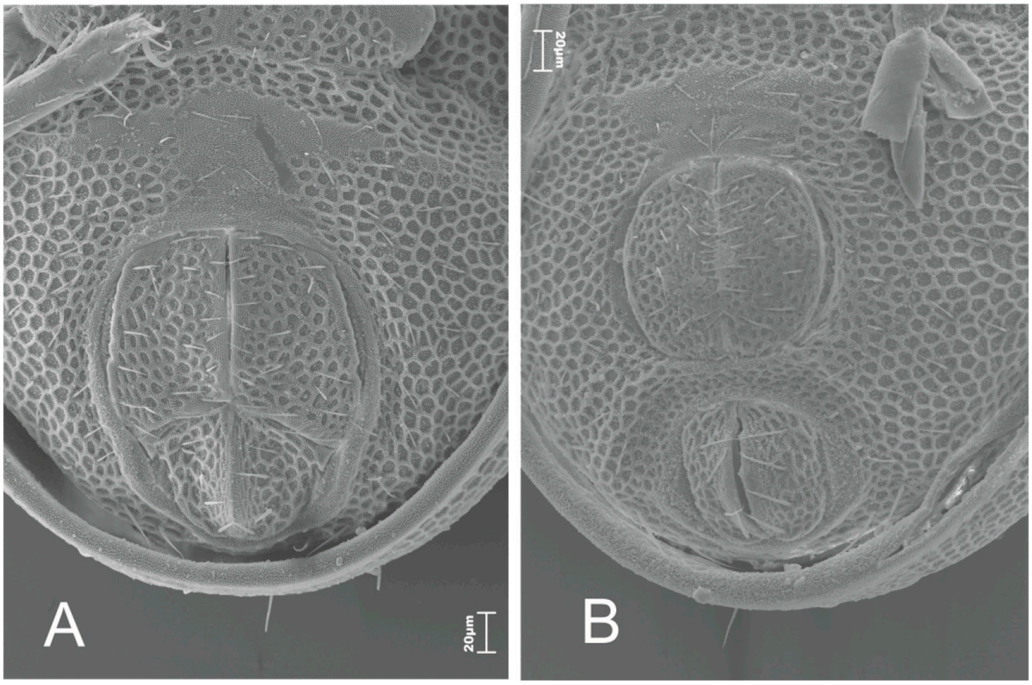

Figure 4. Sexual dimorphism of *L. luteum*: (**A**)—female; (**B**)—male. SEM observations.

On each side of the body there are gland-like organs and simple eyes, which are characteristic of many mite species from this group (Figure 5A).

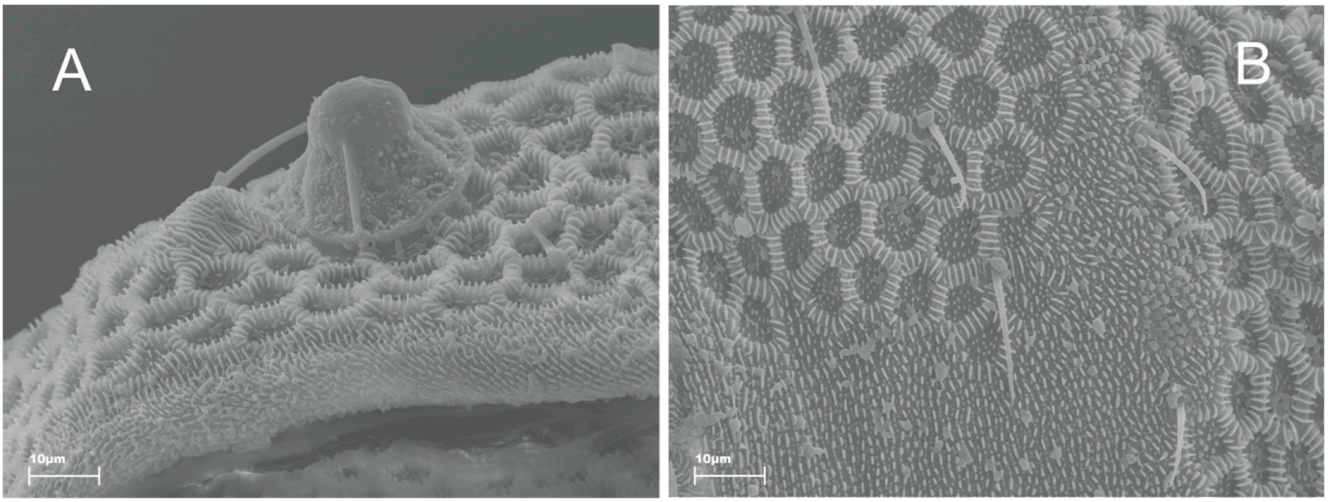

Figure 5. Male of *L. luteum*: (**A**)—gland-like organs and side eye; (**B**)—different body surface sculpture (polygonal and striate surface sculpture). SEM observations.

3.2. Geographic Distribution of Known Populations of Labidostomma luteum

The information on the geographic distribution of *L. luteum* in European countries can be found in many studies [1,2,5–7,9,11–16]. The ascertained range of this species extends from the western border of France to the south of Finland. However, there is no reliable data on the occurrence of this species in the Iberian Peninsula. In the southwest of France, populations consisting of both sexes have been reported, but in other countries (Belgium, Netherlands, Austria, Germany, Czech Republic, Slovakia, Denmark, Sweden, Norway, Finland and the United Kingdom) only populations consisting of females have been found so far. The distribution of *L. luteum* in Poland is quite well documented [5,14–17]. This species does not occur only in the southeastern part of the country, i.e., the region that has never been glaciated.

The population found near Bény in France is the westernmost site of this species with both males and females (Figure 6). In eight samples collected in this location, a total of 80 females, 55 males and 13 juveniles were found. The sex ratio was 1.5:1 (F:M). There was a clear decline in the number of males in the population, as in the case of the populations in northern France, whereas in southern France the sex ratio of *L. luteum* is 1:1. However, this decrease is not yet significant enough to speak of a transition towards parthenogenetic reproduction. The situation was similar at the second examined site: a car park near the town of Mercurol-Veaunes where 7 females, 3 males and 2 juveniles were found.

3.3. Places of Origin and Dispersion Trajectories of L. luteum

The contemporary distribution of bisexual and female-only populations allows us to determine the place of origin of this species (Figure 6). It is located in southwestern France, from where the species has spread to the east and north of Europe. The absence of *L. luteum* in the Iberian Peninsula could be caused by two significant natural barriers, preventing the species from expanding to the west. The barrier was primarily the Pyrenees. *L. luteum* is a lowland species, which usually does not occur in places located higher than 600 m MSL [5,14,16], and therefore the high mountains between France and Spain effectively prevent further dispersion to the west.

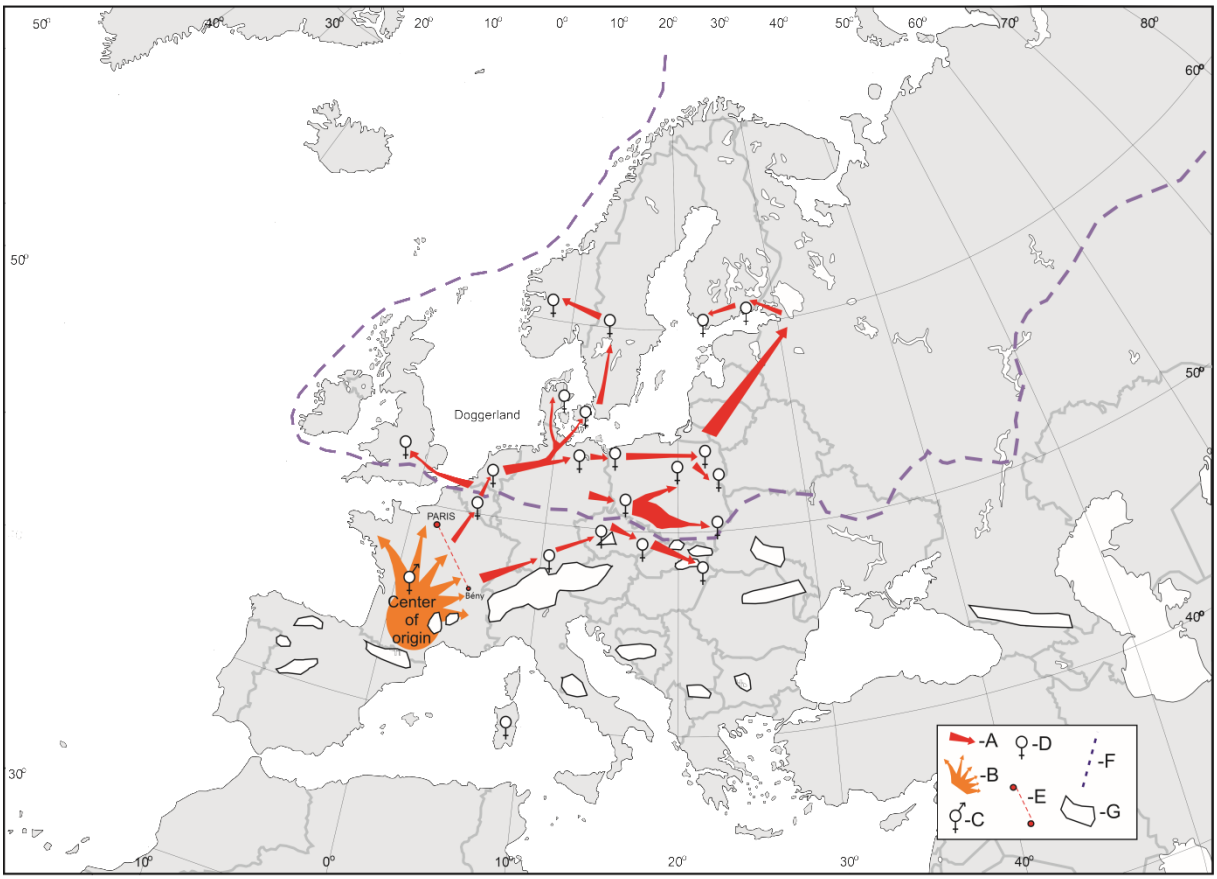

Figure 6. Hypothetical migration routes of *Labidostomma luteum* after glaciation: A—direction of dispersion of populations consisting only of females; B,C—populations consisting of males and females; D—populations consisting only of females; E—boundary of populations consisting of males and females; F—range of glaciation in Europe; G—local mountain glaciations.

In addition, the local mountain glaciations occurring in the Pleistocene on the border of France and Spain further limit the possibility of the spread of the species to the west, similarly as the Alps limit spread to the Italian Peninsula. In this situation, the expansion of the species was directed to the east and north. In many parts of France, the examined populations consisted of males and females, with a clear reduction in the proportion of males in the east. Currently, populations with males and females can be found around Paris (northeast) and Bény (southeast). The boundary line connecting these places is so far the first demarcated line dividing the occurrence of local populations reproducing sexually and asexually. As the glaciers receded, local female-only populations began to expand north and east of Europe. All known sites of this species from countries other than France are inhabited by local populations consisting only of females. Changing the life strategy and the transition to parthenogenetic reproduction facilitated the colonization of new areas. The predatory lifestyle of this mite species was also helpful in this, as nematodes and springtails constituting the main food component of the species were abundant in the initial soil [16]. The potential migration of the species to the east and north of Europe is described in detail in the study published by Błoszyk et al. [14]. It is also noteworthy that the role of high mountain ranges in Central Europe (the Sudetes and Carpathians), which separated the populations of mites moving eastwards, is significant in this case. These mites are more often found north of these mountain ranges (on the territory of Poland) than on their southern side (Czech Republic, Slovakia).

The species reached the British Isles probably using short-term connections with the mainland, the so-called Doggerland, i.e., the land massif existing in the southern part of the North Sea during the North Polish Glaciation, connecting Great Britain with continental

Europe (the present coasts of Denmark, Germany and the Netherlands) [18]. This land connection was also successfully used by other organisms, as well as man, to colonize the British Isles. It is very likely that part of the *L. luteum* population turned its expansion north to the British Isles; the rest moved further east, again splitting into two routes. One of them was directed north, through the area of present-day Denmark, and reached the Scandinavian peninsula (Sweden, Norway). The second, through northern Poland, reached the southern borders of Finland.

The territory of central and northern France has never been affected by Scandinavian glaciation, even in its maximum phase. The southern part of Germany, the Czech Republic and Slovakia, as well as Hungary, were also beyond the reach of the glacier, but there are only populations of *L. luteum* composed exclusively of females [19]. This, in turn, suggests that they come from the populations migrating to the east, which arrived in these areas much later than the origin of the species in the place of its origin. The lack of data from the countries east of Poland obviously does not exclude the presence of *L. luteum* there. It is quite possible that this species also occurs in Belarus and western Ukraine, as well as in Lithuania, Latvia and Estonia. Establishing the exact current range of the species in question in Europe will require further research and obtaining more soil samples from countries where the occurrence of *L. luteum* is highly probable. Finally, also determining the exact boundary between the populations consisting of males and females and those consisting only of females will be essential for further research.

4. Conclusions

Based on the available data on the distribution of bisexual and female-only populations of *L. luteum*, the authors could analyze the dispersion routes of this species in Europe. Moreover, the observed decrease in the percentage of males in the populations from west to east allows to draw conclusions about the place of its origin. The phenomenon of male reduction in the populations of soil mite species is well known also from the research into Uropodina mites (Acari: Mesostigmata). The study shows that in many species there is a tendency to reduce males - the sex ratio is from 1:100 to 1:20,000. In general, the number of parthenogenetic species is higher in Central European and Scandinavian fauna of Uropodina [20]. When only female populations occur in a large area, and both sexes are present in one place, such a place should be considered the place of origin of the species because the populations with specimens of both sex are prior in relation to all female populations. In such cases, geographical parthenogenesis can be observed.

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Data Availability Statement: The data presented in this study stored in a computer database called AMUNATCOLL and openly available at: https://amunatcoll.pl/ (accessed on 25 April 2022).

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Conflicts of Interest: The authors declare no conflict of interest.

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