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CHECKLIST, DISTRIBUTION MAPS, BIBLIOGRAPHY OF THE HUNGARIAN PHLEBOTOMUS (DIPTERA: PSYCHODIDAE) FAUNA COMPLEMENTING WITH THE CLIMATE PROFILE OF THE RECENT SANDFLY DISTRIBUTION AREAS IN HUNGARY

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KEY WORDS

Phlebotomus
sandfly species
Hungary
Pannonian ecoregion
climate

ABSTRACT

A checklist of sandflies containing 4 species from Hungary is given. The history of the scientific investigations of *Phlebotomus* species in Hungary was briefly reported. For each species the following data were provided: important synonyms, localities from Hungary with the reference of the publication. Distribution was mapped using the UTM system. Since climate conditions determine the distribution of sandfly species, the averages of monthly mean, maximum, minimum temperatures and the monthly precipitation values also were involved into the study. Most of the collecting sites can be found in 3 locations: in Budapest and its agglomeration, in the south-east part of Transdanubia and in the south-east part of the Great Hungarian Plain. It was found that *Phlebotomus papatasi* and *Phlebotomus perfiliewi* inhabit the coldest areas of sandfly distribution. *Phlebotomus mascittii* and *Phlebotomus major neglectus* occur in the warmer Transdanubian part of the country. The result of the cluster analysis for Hungarian occurrences of sandfly species based on the average values of monthly climatic variables showed the clear dichotomization of the north and south distribution areas. Data of monthly climatic factors of the four major distribution areas including temperature variables and monthly precipitation values is given.

INTRODUCTION

There are more than 700 sandfly species worldwide and 17 species of sandflies and 3 subspecies of the *Phlebotomus* (*Larroussius*) *major* complex in Europe. *Phlebotomus* species are the vectors of several *Leishmania* pathogens and Phleboviruses in the Mediterranean parts of Europe where five species can transmit visceral leishmaniasis to humans, namely *Phlebotomus (Larroussius) ariasi* Tonnoir, 1921, *Phlebotomus major neglectus* Tonnoir, 1921, *Phlebotomus (Larroussius) perfiliewi* Parrot, 1930, *Phlebotomus (Larroussius) tobbi* Adler, Theodor et Lourie, 1930, and *Phlebotomus (Larroussius) perniciosus* Newstead, 1911 (Minter 1989; Léger et al. 2000). Most of the sandfly species are typical tropical and subtropical fauna elements, but some species are native to the temperate areas of Europe. In contrast to the members of Culicidae, sandflies and several other species of Psychoda breeds in wet, decaying organic materials and microbial mats. Some of them are synanthropic species which can breed in water-wells of bathrooms and showers and along the rifts of old buildings or in the cracks of the walls. The anthropogenic climate change is predicted to trigger the northward spread of sandfly species and *Leishmania infantum* in Europe including the whole Carpathian basin (Trájer et al.

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Table 1. The delimiter coordinates and the correspondent grids of the collecting sites according to the used 0.25° resolution. For the visualization of the grids see Figure 5.

Locality (correspondent grid)	Longitude (N)	Latitude (E)
Kapolcs (A)	46.75 – 47.00	17.50 – 17.75
Törökbálint (B)	47.25 – 47.50	18.75 – 19.00
Villánykövesd (C)	45.75 – 46.00	18.25 – 18.50
Nagyharsány (C)	45.75 – 46.00	18.25 – 18.50
Hódmezővásárhely (D)	46.25 – 46.50	20.25 – 20.50
Földeák (D)	46.25 – 46.50	20.25 – 20.50
Maroslele (D)	46.25 – 46.50	20.25 – 20.50

Table 2. The monthly averages of mean, minimum, maximum temperature values and daily averages of precipitation. For the visualization of the grids see Figure 5.

Tmean – mean monthly temperature, Tmax – maximum monthly temperature, Tmin – minimum monthly temperature [°C], Prec/day – mean monthly precipitations expressed in daily precipitation values

Grid	Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
A	**Tmean**	-0.87	0.95	5.33	10.55	15.39	18.77	20.61	20.07	15.91	10.72	5.19	0.78
	Tmax	2.47	5.12	10.54	16.27	21.27	24.62	26.74	26.37	21.88	16.18	8.98	3.80
	Tmin	-3.52	-2.33	1.24	5.74	10.19	13.65	15.24	14.70	11.05	6.40	2.33	-1.55
	Prec/day	1.05	1.12	1.06	1.56	1.99	2.37	2.03	1.96	1.94	1.53	1.95	1.45
B	**Tmean**	-0.27	1.58	6.09	11.59	16.45	19.76	21.66	21.08	16.66	11.26	5.67	1.31
	Tmax	2.29	4.81	10.41	16.65	21.72	25.01	27.18	26.77	22.08	16.02	8.55	3.62
	Tmin	-2.59	-1.27	2.32	6.96	11.47	14.80	16.51	16.01	12.15	7.38	3.16	-0.78
	Prec/day	1.13	1.10	0.95	1.23	1.74	2.03	1.54	1.57	1.34	1.27	1.75	1.40
C	**Tmean**	-0.39	1.54	6.14	11.51	16.49	19.83	21.59	21.05	16.77	11.48	5.79	1.29
	Tmax	2.85	5.66	11.47	17.25	22.26	25.61	27.74	27.54	23.17	17.44	9.82	4.29
	Tmin	-3.47	-2.12	1.41	5.98	10.64	13.93	15.38	14.87	11.18	6.54	2.40	-1.44
	Prec/day	1.09	1.17	1.03	1.53	1.91	2.35	1.84	1.65	1.59	1.44	1.72	1.50
D	**Tmean**	-1.01	0.81	5.63	11.27	16.46	19.84	21.65	21.03	16.57	11.03	5.51	0.93
	Tmax	2.30	5.00	11.21	17.33	22.51	25.88	28.11	27.86	23.39	17.41	9.75	3.97
	Tmin	-3.98	-2.78	0.90	5.63	10.38	13.65	15.05	14.55	10.77	5.95	2.08	-1.77
	Prec/day	0.86	0.91	0.86	1.23	1.59	2.07	1.56	1.40	1.26	1.04	1.32	1.28

2013). It seems that in the Pannonian ecoregion the observed and projected regional warming trends exceed the warming trends of Europe (Bartholy et al. 2007). The minimum temperature limit of the survival of larvae is about -4°C to 5 °C depending on the species and countries (Killick-Kendrick & Killick-Kendrick 1999; Naucke & Schmitt 2004; Rioux et al. 1984; Singh 1999). The January mean and mean minimum temperatures are important distribution liming factors of sandfly vectors in east and central Europe (Trájer et al. 2013). Urban heat island effect can help the survival of the extrazonal populations of sandfly species far north from their continuous distribution area in the Carpathian basin (Trájer et al. 2014; Bede-Fazekas & Trájer 2015). The purpose of this paper was to provide a checklist on *Phlebotomus* species and the comparable climate data of the distribution areas of sandfly species in Hungary.

History

Studies on Hungarian sandfly fauna started in the 1930's and only sparse data were published until the end of the 2000's. The first paper on the observation of *Phlebotomus* species in Hungary was published in 1933 by Lörincz & Szentkirályi. They investigated the regional outbreak of an unfamiliar type of dermatitis which was affected about 30 patients in Hódmezővásárhely, south-east Hungary during the August of 1931. The etiologic connection between the papular or vesicular eruptions and the bites of *Phlebotomus* species was proved.

The individuals of *Phlebotomus macedonicus* Adler et Theodor, 1931 (= *Phlebotomus* (*Larroussius*) *perfiliewi*) were found in the trapped materials. The insects were observed first in the August of 1931, but in the same month of 1932 the sandflies were observed again. Ivánovics (1953) mentioned the presence of *Phlebotomus* species in Hungary as the potential vector of Pappataci-fever. Szabó & Draskovits (1983) proposed the possible occurrence of *Phlebotomus papatasi* in the southern part of Hungary. They also mentioned the occurrence of *Phlebotomus perfiliewi* from Esztergom and the Gellért Hill cave, Budapest, based on the trappings of the National Public Health Service of Hungary which were performed sometimes in the 1960's (Tánczos 2012). These observations can be handled as 'uncertain occurrences'. The later surveys showed that the historical observations were not unfounded since two *Phlebotomus* species were observed in the agglomeration of the Capital and also two species in south-east Hungary. In 2007 – 2010 a countrywide survey was performed to investigate the presence of *Phlebotomus* species and canine leishmaniasis in Hungary. Tánczos (2012) summarized the results of the collection surveys in his doctoral dissertation and presented the detailed history of sandfly research in Hungary. Altogether the presence of 4 sandfly species was proved (Farkas et al., 2011; Tánczos 2012; Tánczos et al. 2012). In 2014, a minor survey was conducted for the investigation of the physical requirements of *Phlebotomus major* subsp. *neglectus* in Nagyharsány, Hungary (unpublished data) and another for the investigation of the proposed presence of sandfly species and *Aedes albopictus* Skuse, 1894 in the border region of south-west Hungary and Croatia (Trájer et al. 2016).

MATERIAL AND METHODS

Taxonomy

Both of the nomenclature and taxonomy were based on the Fauna Europea zoological taxonomic index database (Wagner 2013).

Climate data

The January mean minimum temperatures, the monthly averages of mean, minimum, maximum temperatures and daily average precipitation values were derived from the European Climate Assessment Dataset (Haylock et al. 2008). The values were averaged for the period of January 1950 to December 2014 (the year of the last collecting survey

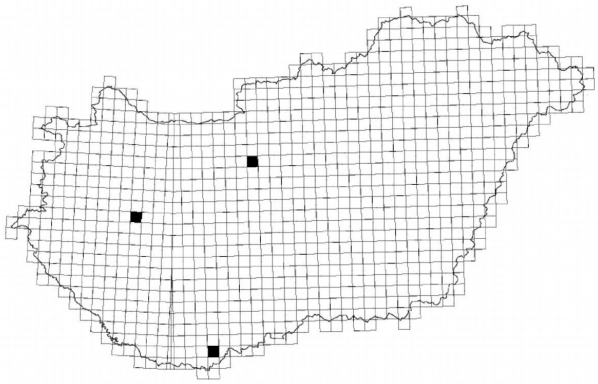

Figure 1. The distribution of *Ph. mascittii* in Hungary (black rectangles: confirmed observations).

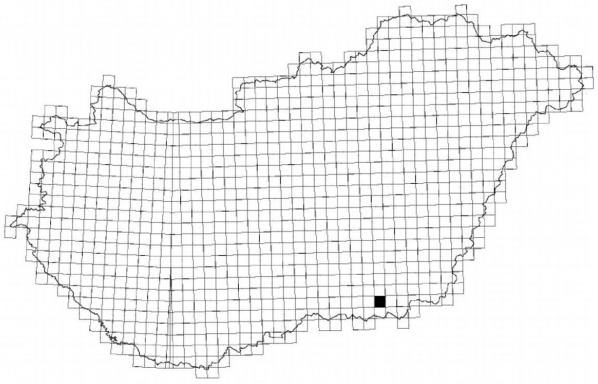

Figure 3. The distribution of *Ph. papatasi* in Hungary (black rectangles: confirmed observation).

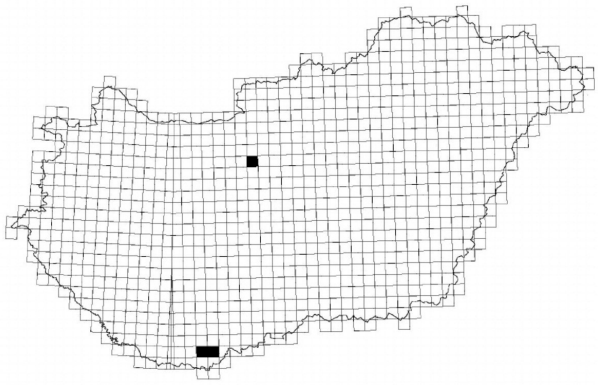

Figure 2. The distribution of *Ph. major* subsp. *neglectus* in Hungary (black rectangles: confirmed observations).

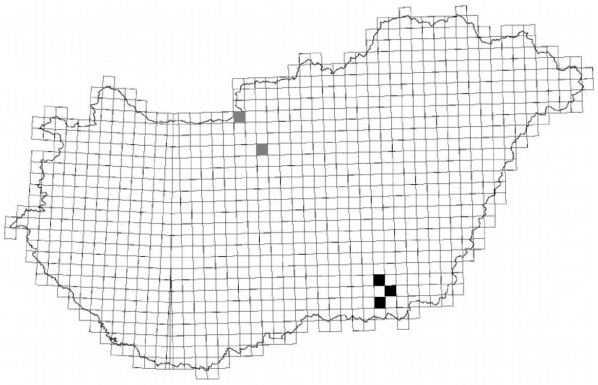

Figure 4. The distribution of *Ph. perfiliewi* in Hungary (black rectangles: confirmed observations, dark grey rectangles: unconfirmed observations).

in Hungary for sandfly species). Average values were calculated from the 0.25° grid within the domain including the certain collecting sites and almost the entire south Pannonian ecoregion. The latitudinal range of the whole frame was 45°00'N to 46°25'N, while the longitudinal was 16°45'°E to 21°00'E. The monthly average values of the used climate values were averaged according to the following grids (Table 1, 2).

RESULTS

Checklist of sandfly species

***Phlebotomus (Transphlebotomus) mascittii* (Grassi, 1908)**

Loc. Kapolcs – Bakony Mts, Veszprém County (Farkas et al. 2011; Tánczos 2012), Nagyharsány – Villány Hills, Baranya County (Farkas et al. 2011; Tánczos 2012), Törökbálint – Buda Mts, Pest County (Farkas et al. 2011; Tánczos 2012; Figure 1).

***Phlebotomus* (*Larroussius*) *major neglectus* (Tonnoir, 1921)**

Loc. Nagyharsány – Villány Hills, Baranya County (Farkas et al. 2011; Tánczos 2012, Trájer et al. 2016) Törökbálint-Buda Mts, Pest County (Farkas et al. 2011; Tánczos 2012), Villánykövesd-Villány Hills, Baranya County (Farkas et al. 2011; Tánczos 2012; Figure 2).

***Phlebotomus (Phlebotomus) papatasi* (Scopoli, 1786)**

Loc. Maroslele Maroslele – southern Hungary, Csongrád County (Farkas et al. 2011; Tánczos 2012; Figure 3).

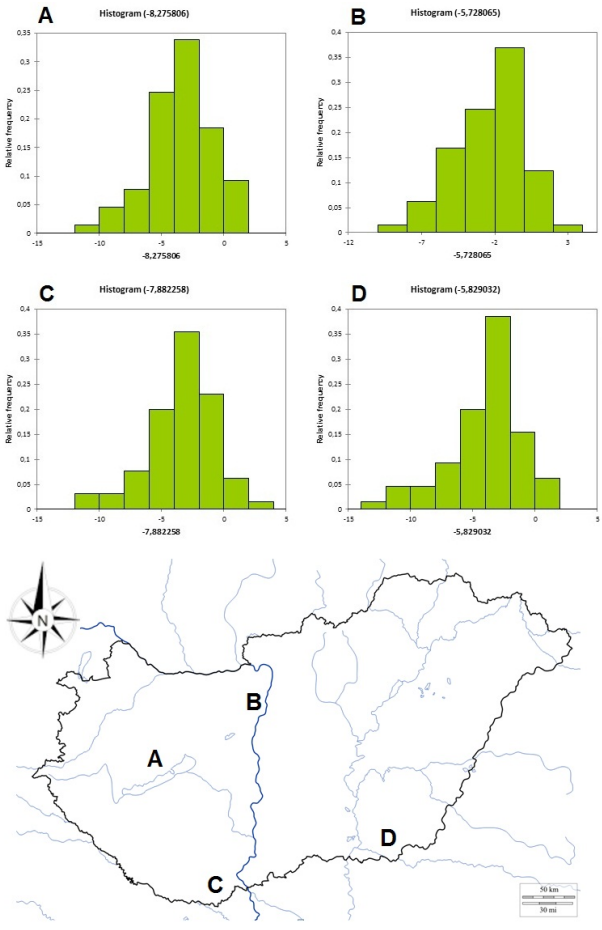

Figure 5. The mean January minimum daily temperature values in 1950-2014 according to the five grid of confirmed observations of *Phlebotomus* species.

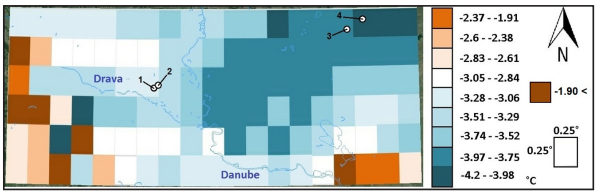

Figure 6. The averages of the January mean minimum temperature values in the South Pannonian Ecoregion (45°00'N to 46°25'N – 16°45'°E to 21°00'E) in 1950 – 2014.

1 – Nagyharsány, 2 – Villánykövesd, 3 – Maroslele, 4 – Földeák

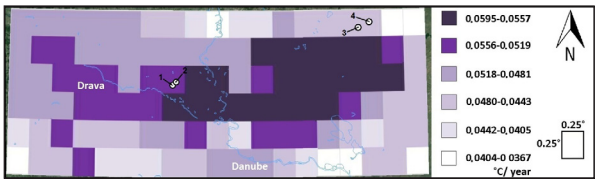

Figure 7. The trends of the January mean minimum temperature values in the South Pannonian ecoregion (45°00'N to 46°25'N – 16°45'°E to 21°00'E) according to the linear trend of the annual mean temperature values in 1950 – 2014.

1 – Nagyharsány, 2 – Villánykövesd, 3 – Maroslele, 4 – Földeák

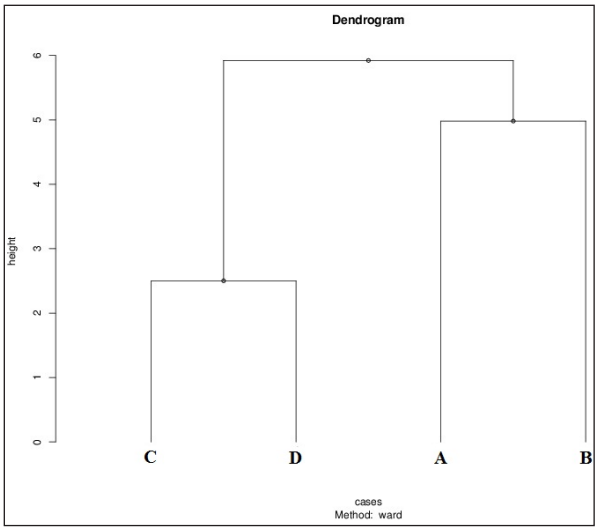

Figure 8. Cluster analysis for Hungarian occurrence sites of sandfly species based on the average values of four monthly climatic variables are listed in Table 2.

Phlebotomus (Larroussius) perfiliewi (Parrot, 1930)

Loc. Földeák – southern Hungary, Csongrád County (Farkas et al. 2011; Tánczos 2012), Maroslele-southern Hungary, Csongrád County (Farkas et al. 2011; Tánczos 2012), Hódmezővásárhely – southern Hungary, Csongrád County (Lőrincz & Szentkirály 1933), Budapest (?) – Buda Mts, Budapest (Szabó & Draskovits 1983), Esztergom (?) – Danube Bend, Komárom – Esztergom County (Szabó & Draskovits 1983; Figure 4).

Climatic zoogeography of the sandfly fauna

The January mean minimum temperature, which is an important climatic limiting factor of the distribution of sandflies, showed notable differences between the main distribution areas in 1950 – 2014. *Ph. papatasi* and *Ph. perfiliewi* inhabit the coldest areas where the January mean minimum daily temperatures were the lowest C in 1950 – 2014 (mean: -3.95, maximum: 0.48 °C and the minimum: -12.55 °C). The winters were relatively mild in Törökbálint (belongs to the agglomeration of Budapest), where both *Ph. major* subsp. *neglectus* and *Ph. mascittii* were found (mean: -2.54, maximum: 2.70 and the minimum: -8.83 °C). *Ph. mascittii* also was observed in Kapolcs, where the winters are somewhat milder than in the distribution area of *Ph. papatasi* and *Ph. perfiliewi*, but colder than the climate of the agglomeration of Budapest (mean: -3.45, maximum: 1.15 and the minimum: -10.21 °C). *Ph. major* subsp. *neglectus* was also collected in Nagyharsány and Villánykövesd (mean: -3.25 to -3.40, maximum: 2.39 to 2.25 and the minimum: -10.72 to -11.09 °C; Figure 5).

The warmer, submediterranean Croatian areas (January mean minimum temperature is more than -2.37 °C) are close to the Nagyharsány-Villánykövesd area. The south-east Hungarian occurrences of sandfly species are situated north to the warmer south-west areas of Romania and north-east Serbia (Figure 6).

Based on the linear trend of the January mean minimum temperature data of 1950 – 2014, the most notable winter warming trends (3.9 – 3.6 °C per 65 years) were observed in the south-east parts of the Great Hungarian Plain and Vojvodina, Serbia, that about cover the south Hungarian distribution area of sandfly species (Figure 7).

The result of the cluster analysis for Hungarian occurrence grids of sandfly species based on the average values of monthly climatic variables showed the clear dichotomization of the north (A and B) and south (C and D) main distribution areas. The climates of the C and D distribution areas are more similar to each other than the climates of the A and B distribution areas' (Figure 8).

DISCUSSION

Altogether the presences of four *Phlebotomus* species were confirmed in Hungary in the last one hundred years: *Ph. mascittii*, *Ph. major neglectus*, *Ph. papatasi* and *Ph. perfiliwei* (Farkas et al. 2011; Lőrincz & Szentkirály 1933; Tánczos 2012; Trájer et al. 2016). Four major distribution areas were found. Most of the positive collecting sites can be found in south-west Hungary, in the south-east part of the Great Hungarian Plain and in the agglomeration of Budapest. It is noticeable that -excluding the uncertain observations- the composition of the recent sandfly faunas of south-east and west Hungary are different: *Ph. perfiliewi* and *Ph. papatasi* recently only presents in the south-east, *Ph. neglectus* and *Ph. mascittii* only in the Transdanubian (west) part of Hungary. The Transdanubian distribution of *Ph. mascitti* can be explained by the wider zoogeography of the species since it is the fauna element of the west Balkan. The population of this species in Törökbálint forms the most eastern, but not the most northern occurrence of the species in the Pannonian ecoregion since Dvorak et al. (2016) found *Ph. mascitti* in Slovakia. In contrast, *Ph. papatasi* and *Ph. major* subsp. *neglectus* can be found both in the south-east and south-west of the Pannonian ecoregion. *Ph. perfiliewi* presents in Serbia (Depaquit et al. 2013) and Croatia (Bosnić et al. 2006). These zoogeographical observations indicate that the Hungarian *Phlebotomus* fauna is also related to the east and the west Balkan sandfly faunas.

The recent warming trend of the south Pannonian ecoregion raises the possibility of the increasing abundance of sandfly species in the region and a possible faunistic exchange between the south-west and south-east sandfly faunas. Due to the heat island effect of the Capital's agglomeration the winters are milder in Törökbálint, where both *Ph. major* subsp. *neglectus* and *Ph. mascittii* were found, than the winters of the south-western and south-eastern distribution areas of these species. The influence of heat island effect of Budapest on the overwintering potential of *Ph. major* subsp. *neglectus* and *Ph. mascittii* previously was studied by Bede-Fazekas & Trájer (2015) and Trájer et al. (2014).

Data of monthly climatic factors of the four major distribution areas including temperature variables and monthly precipitation values is given. This can be the basis of further climatic zoogeographical investigations of the Carpathian basin's sandfly fauna.

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