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DISTRIBUTION AND HABITAT REQUIREMENTS OF THE HUNGARIAN MOSQUITO FAUNA (DIPTERA: CULICIDAE)

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1. SCIENTIFIC BACKGROUND AND AIMS OF THE STUDY

Due to the epidemiological significance of mosquito species, faunistic researches of them closely linked to researches on public health importance and on effectiveness of control strategies. There are many previous publications and monographs which investigated biology of the mosquito species in detail or researched mosquito fauna of the Hungarian Regions, but there are only a few papers, which involve the evaluation of the distribution of mosquito species at country level.

Considering the above mentioned facts, there are several relevant uncovered research subjects, which fact explains my study's aims:

1. To process the distribution data of the mosquito species from Hungary at UTM quadrat (10 × 10 km) scale, to carry out additional data collection in the unstudied areas supplementing the database and to determine the frequency of each species at national level.
2. To investigate the habitat preferences of the different species at the level of UTM quadrats (10 × 10 km), CORINE maps (habitat preference at landscape scale) and breeding site types (habitat preference at breeding site scale).
3. Targeted data collections on rare species (e.g. *Aedes geminus*, *Aedes hungaricus)*, and based on that revision of their frequency values.
4. Targeted data collections on invasive species (e.g. *Aedes j. japonicus*, *Aedes koreicus*), particularly on their overwintering strategies and dispersion.

2. MATERIALS AND METHODS

2.1. Distribution data processing of the Hungarian mosquito species at UTM quadrat scale and additional data collection in the unstudied areas

I created, using QGIS software, a database including all previous data from the publications. That helped to determine the unstudied areas of Hungary (Fig1).

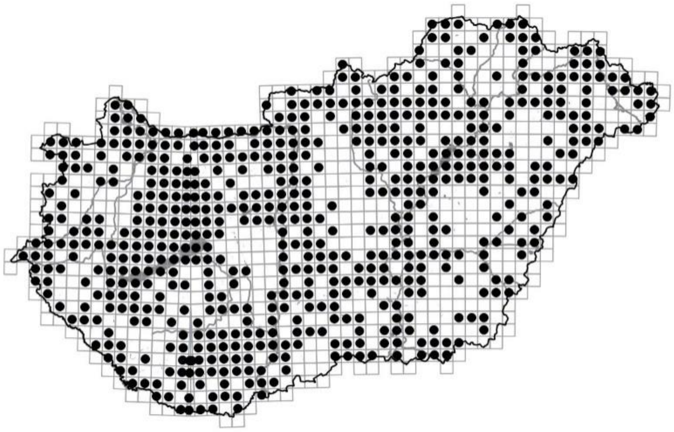

Figure 1. Locations of collected mosquitoes on UTM 10 × 10 km map of Hungary before my data collections.

During the three years having for additional data collections, I divided the fieldworks as follows: 2017: Transdanubia, 2018: Duna-Tisza köze Region and 2019: Tiszántúl Region. During the field works of the 2017-2019 period, I collected 1.083 presence-absence data of 34 taxa of mosquitoes from 355 previously not studied and 40 previously studied quadrates. I completed the database with these new detections. The created GIS database was appropriate to make uniform distribution maps for each species. In this way, I defined the mean of species numbers for the UTM quadrates belonging to each zoogeographical regions and macro- and mesoregions of the landscape. I also defined the numbers of presences of the mosquito species in the different zoogeographical regions.

2.2. Studies on habitat requirements of mosquito species

I investigated the habitat preferences of mosquitoes on two levels (at landscape scale and at breeding site scale).

For determination of the landscape scale habitat structure, I used CORINE Landcover map with a scale of 1:100.000. Relative surface cover in the 10 × 10 km UTM quadrates of certain habitat types were calculated.

Based on the mean values of the relative surface cover in UTM quadrates, I calculated the relative surface cover in the macro- and mesoregions of certain habitat types as well.

In case of the habitat preference at breeding site scale, I made a database, which includes data from 9,100 samplings (based mainly on former publications). To investigate the habitat preference at breeding site scale, I determined (1) the number of species detected in certain waterbody types, (2) proportion of different species in each waterbody types, (3) the number and the frequency of waterbody types preferred by the certain species.

2.3. Research on rare mosquito species

To identify the rare species, I used my own method (SÁRINGER-KENYERES 2017): I categorized the mosquito species into 5 groups based on in how many UTM quadrates were they found by former researches. I calculated proportions from these values and the total number of UTM quadrates of Hungary, which determined the five groups. Based on the result of my calculations, I could prove that there are 31 rare species in the Hungarian mosquito fauna, which is a considerable number.

The investigations on the distribution of rare species were carried out in two parts: (1) during the fieldwork in unstudied quadrates, I aimed to collect rare species as well and (2) I dedicated special field works between 2017 and 2019 for searching species with narrow habitat tolerance (e.g. *Aedes hungaricus*, which species had been collected only along the Danube so far).

2.4. Research on invasive mosquito species

My presence-absence investigations on invasive mosquito species cover the whole Transdanubian region. Because of the importance of the subject, I collected data in locations close to my hometown: (1) carbon dioxide trapping and human landing collections (Badacsonytördemic, Balatongyörök, Keszthely); (2) after the first detection of *Aedes j. japonicus*, larvae collections twice a month between 2017 and 2018 in its breeding site at Balatongyörök (Bece-hegy).

3. RESULTS AND DISCUSSION

3.1. Results on the Hungarian mosquito fauna

3.1.1. Updated checklist of the mosquito fauna of Hungary

As a result of this dissertation, I published an updated checklist of the Hungarian mosquito fauna includes 54 taxa (53 species + 1 biotype) belonging to 7 genera, as follows: *Aedes* (27 species), *Anopheles* (7), *Coquillettidia* (1), *Culex* (8), *Culiseta* (8), *Orthopodomyia* (1), *Uranotaenia* (1).

3.1.2. Investigations on the Hungarian mosquito fauna according the zoogeographical and geographical regions

Regarding the zoogeographical regions and geographical mesoregions, results showed that the detected differences among certain subregions can be caused by the effects of the landscape habitat structures.

3.1.3. New data on the overwintering strategies of mosquito species

The related investigations confirmed that four taxa (*Anopheles maculipennis* complex, *Culex pipiens pipiens, Culex hortensis, Culiseta annulata)* overwinter in larval stage in Hungary. Additionally, I proved that *Aedes geniculatus* overwinters in larval stage and the invasive *Aedes j. japonicus* overwinters in the egg stage at the Hungarian climate.

3.1.4. Results on the distribution of the Hungarian mosquito species

I detected 34 species from the total Hungarian mosquito fauna. I detected presence of 32 species from previously unexamined UTM quadrates. In case of 22 taxa I confirmed the presence of them from the UTM quadrates, which had previous positive data.

3.1.5. GIS database of the Hungarian mosquito fauna at UTM scale

In the recent period, using the same methodology during the collection and data processing, allowed to create the first GIS database including all mosquito presence/absence data throughout Hungary.

3.2. Results on habitat preferences of mosquito species

3.2.1. Research on the habitat preferences at landscape scale

The analyses showed results mainly in cases of species common in Hungary, which turned up in larger number in human landing collection. The occurrence of majority of the species showed significant negative correlation with the cover of non-irrigated arable lands. Furthermore, it was shown significant positive correlation between several species and the surface cover of (1) deciduous forests, (2) inland marshes, (3) water courses, and (4) water bodies. At mesoregion scale significant correlation was detected between the landscape-scale habitat-heterogeneity and the mosquito species diversity. It could be concluded, that the larger landscape-scale habitat heterogeneity leads significant increase in the mosquito species diversity in areas dominated by natural habitats.

3.2.2. Study on the habitat preferences at breeding site-scale

The analysed database includes data of 200,434 larvae belonging to 48 species from 9,100 samplings. I classified the sampling locations into 33 main waterbody types. The largest number of mosquito larvae were collected in the types of marshy type natural ponds (30,63%), "tömpöly" type natural small water bodies (18,74%) and pits of rainwater (10,95 %). Analysing the number of the detected waterbody types and the number of the species collected in them, the presence of *Culex pipiens* complex was significant, and also, species of *Anopheles maculipenis* complex, *Culiseta annulata* and *Aedes vexans* were detected in large numbers.

The results on habitat preferences at breeding site-scale confirmed that habitat preference of different mosquito species depends mainly on the structural and flooding parameters of the environment. In this respect, permanent or temporary character of water cover, dynamic of drying out and the level of shading play important roles.

3.3. Results of researches on rare species

Notable result that the presences of the invasive and rare species *Aedes j. japonicus* and one of the rarest Hungarian native mosquito species *Aedes geminus* have been proved in the area of Lake Balaton.

3.4. Results of researches on invasive species

The studies on the invasive species have provided new data on the distribution of *Aedes koreicus* and on the behaviour and ecology of *Aedes j. japonicus* in Hungary. *Aedes koreicus* was detected from four new, formerly unknown localities (at Pécs and Bóly). *Aedes j. japonicus* was detected from nine localities in the western half of Hungary.

The investigations on distribution of *Aedes j. japonicus* have proven, that (1) a few years after the first detection, it is widespread in at least two-thirds of the western half of Hungary; it spreads along ecological corridors formed by mosaics of rural areas with detached houses and gardens bordered by small forest areas; (2) large artificial containers can be named as main breeding sites of *Aedes j. japonicus* (which were previously known as the main habitat type of *Culex p. pipiens*).

4. NEW SCIENTIFIC RESULTS

1. As a result of my investigations, I detected 34 species from the known Hungarian mosquito fauna. I detected 32 taxa in UTM quadrates (10×10 km) unstudied previously. In the case of 22 taxa, I confirmed the presence of these species in previously studied UTM quadrates. I detected a total of 34 taxa during the field works. In the case of 20 taxa, I could not find them in new quadrates. Based on publications and the author's targeted data collection during the 2017-2019 period, the first UTM 10×10 km scale GIS database including all mosquito presence/absence data throughout Hungary was compiled.

2. I published an updated checklist of the mosquito fauna of Hungary including 54 mosquito taxa (53 species + 1 biotype) belonging to 7 genera, as follows: *Aedes* (27 species), *Anopheles* (7), *Coquillettidia* (1), *Culex* (8), *Culiseta* (8), *Orthopodomyia* (1), *Uranotaenia* (1).

3. I analysed the Hungarian mosquito fauna according to the zoogeographical and geographical perspectives. It could be concluded, that (a) the detected differences among the Culicidae fauna of the various zoogeographical regions and landscape mesoregions can be caused mainly by the cover of the different elements of the landscape-scale habitat structures and the diversity of that; (b) the higher landscape-scale habitat heterogeneity leads to significant increase in the mosquito species diversity in areas dominated by natural habitats; (c) the breeding site preference of the different mosquito species depends mainly on the structural and flooding parameters of the habitats.

4. My investigations on overwintering of mosquitos showed that *Aedes geniculatus* overwinters in larval stage and the invasive *Aedes j. japonicus* overwinters in egg stage in Hungary.

5. The research on extremely rare species proved the presence of the invasive *Aedes j. japonicus* and *Aedes geminus* (which is one of the rarest native mosquito species in Hungary) in the area of Lake Balaton.

6. The investigations on the invasive species have proven that *Aedes j. japonicus* (a) a few years after the first detection, it is widespread in at least two-thirds of the western half of Hungary; (b) it spreads along ecological corridors formed by mosaics of rural areas with detached houses and gardens bordered by small forest areas; (c) large artificial containers can be named as its main breeding sites.

5. THE AUTHOR'S PUBLICATION IN THE TOPIC OF THE DISSERTATION

Articles in English in international journal with IF

SÁRINGER-KENYERES M., BAUER N., KENYERES Z. (2020): Active dispersion, habitat requirements and human biting behaviour of the invasive mosquito *Aedes japonicus japonicus* (Theobald, 1901) in Hungary. *Parasitology Research*, 119 403–410. p.

Articles in Hungarian in international journal with IF

SÁRINGER-KENYERES M. (2018): Magyarországi csípőszúnyogfajok (Diptera: Culicidae) által terjeszthető fontosabb állati kórokozók, valamint ezek hatása a haszonállatokra [Important animal pathogens transmitted by mosquito species (Diptera: Culicidae) and their effects on livestock in Hungary]. *Magyar Állatorvosok Lapja*, 140 25-35. p.

Articles in English in refereed journals

SÁRINGER-KENYERES M., TÓTH S., KENYERES Z. (2018): Updated checklist of the mosquitoes (Diptera: Culicidae) of Hungary. *Journal of the European Mosquito Control Association*, 36 14-16. p.

SÁRINGER-KENYERES M., KENYERES Z. (2019): A case study on phenology and colonisation of *Aedes japonicus japonicus* (Theobald, 1901) (Diptera: Culicidae). *Natura Somogyiensis*, 32 81–86. p.

SÁRINGER-KENYERES M., KENYERES Z., BAKONYI T. (2019): Biting mosquito data from the Lake Balaton region for the surveillance of West Nile Virus infection. *Journal of the European Mosquito Control Association*, 37 34–40. p.

Articles in Hungarian in refereed journals

KENYERES Z., TÓTH S., SÁRINGER-KENYERES T., **SÁRINGER-KENYERES M.** (2016): A Tisza-tó térségében előforduló csípőszúnyog fajok és lokális elterjedésük [Mosquito species and their distributions around shallow lake Tisza-tó]. 30 40–69. p. In: KENYERES Z. (Szerk.): A Tisza-tó térségének csípőszúnyog-faunája, tenyészőhely-térképe és a fajok élőhelyválasztása. *Acta Biologica Debrecina. Supplementum Oecologica Hungarica*, 74. p.

SÁRINGER-KENYERES M., TÓTH S., KENYERES Z. (2018): Csípőszúnyog fajok (Diptera: Culicidae) magyarországi áttelelésére vonatkozó adatok [Data to the knowledge on overwintering of mosquitoes (Diptera: Culicidae) in Hungary]. *Folia Historico-Naturalia Musei Matraensis*, 42 197–203. p.

SÁRINGER-KENYERES M., TÓTH S., KENYERES Z. (2019): Inváziós csípőszúnyogfajok (Diptera: Culicidae) újabban feltárt dunántúli előfordulásai [New occurrences of invasive mosquito species (Diptera: Culicidae) in Transdanubia, Hungary]. *Folia Historico-Naturalia Musei Matraensis*, 43 145–148. p.

TÓTH S., KENYERES Z., BAUER N., **SÁRINGER-KENYERES M.**, SÁRINGER-KENYERES T. (2019): A Balaton fauna- és tenyészőhely-képének értékelése [Discussion about fauna and map of the breeding-sites of Lake Balaton]. 80–81. p. In: KENYERES Z. (Szerk.): A Balaton térségének csípőszúnyog-faunája és tenyészőhely térképe. *Acta Biologica Debrecina. Supplementum Oecologica Hungarica*, 34 83 p.

TÓTH S., KENYERES Z., **SÁRINGER-KENYERES M.** (2019): A Balaton térségében előforduló csípőszúnyog fajok és lokális elterjedésük [Mosquito species and their distribution around Lake Balaton]. 31–79. p. In: KENYERES Z. (Szerk.): A Balaton térségének csípőszúnyog-faunája és tenyészőhely

térképe. *Acta Biologica Debrecina. Supplementum Oecologica Hungarica*, 34 83 p.

Full-length conference paper

SÁRINGER-KENYERES M., TÓTH S., KENYERES Z. (2017): Magyarország csípőszúnyog faunájának UTM alapú térinformatikai adatbázisa. [1–6. p.] In: XXIII. Ifjúsági Tudományos Fórum, Pannon Egyetem Georgikon Kar, Keszthely, Május 26, 2017.

SÁRINGER-KENYERES M., KENYERES Z. (2018): Invazív csípőszúnyog fajok (Diptera: Culicidae) Magyarországon. [1–6. p.] In: XXIV. Ifjúsági Tudományos Fórum, Pannon Egyetem Georgikon Kar, Keszthely, Május 24, 2018.

SÁRINGER-KENYERES M. (2019): A csípőszúnyogok (Diptera: Culicidae) által terjesztett fontosabb férgekre (Spirurida) vonatkozó hazai kutatási eredmények. [1–6. p.] In: XXV. Ifjúsági Tudományos Fórum, Keszthely, Május 23, 2019.

Abstracts in Hungarian in conference proceedings

SÁRINGER-KENYERES M. (2017): Magyarországi csípőszúnyog fajok elterjedésének állatföldrajzi és földrajzi tájak szerinti vizsgálata (Abstr.). [17 p.] In: XIII. Makroszkópikus Vízi Gerinctelenek (MaViGe) Kutatási Konferencia, Pécs, Április 20-21, 2017.

SÁRINGER-KENYERES M., KENYERES Z. (2019): Az invazív csípőszúnyog fajok terjedésével és biológiájával kapcsolatos legújabb hazai eredmények (Abstr.) In: Magyar Szúnyogírtók Országos Szövetsége Konferencia, Budapest, Máricus 28, 2019.

SÁRINGER-KENYERES M., SÁRINGER-KENYERES T., KENYERES Z. (2019): Az *Aedes japonicus japonicus* helyzete és gyérítési lehetőségei Magyarországon (Abstr.). [8 p.] In: Magyar Egészségügyi Gázmesterek

Egyesülete XVII. Országos Szakmai Konferenciája, Balatonalmádi, Április 03-05, 2019.