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SPECIES COMPOSITION AND SEASONAL DYNAMICS OF MOSQUITOES (DIPTERA: CULICIDAE) IN FLOODED AREAS OF VOJVODINA, SERBIA

A. VUJIĆ, A. STEFANOVIĆ, I. DRAGIČEVIĆ, T. MATIJEVIĆ, L. PEJČIĆ, M. KNEŽEVIĆ, D. KRAŠIĆ and S. VESELIĆ

Department for Biology and Ecology, Faculty of Sciences, 21000 Novi Sad, Serbia

Abstract - Three years of sampling (2007–2009) of adult mosquitoes in the area of Vojvodina (Serbia) by dry ice baited CDC traps has provided information on mosquito species composition, prevalence and seasonal activity. A total of 58,247 adult mosquitoes were collected comprising twenty species belonging to the following genera: *Anopheles* Meigen (Diptera: Culicidae), *Aedes* Meigen, *Culex* L, *Culiseta* Felt and *Mansonia* Blanchard. The seven most common species collected during this study were: *Culex pipiens* L. complex (35.6%), *Aedes vexans* (Meigen) (33.4%), *Aedes sticticus* (Meigen) (15.2%), *Anopheles maculipennis* Meigen complex (4%), *Mansonia richiardii* (Ficalbi) (3.8%), *Aedes cinereus* Meigen (3.6%), *Aedes pulchritarsis* (Rondani) (3%) which made up 98% of all specimens. Seasonal population dynamics differed between years and between mosquito species in relation to wetland, urban and forest habitats, and was primarily influenced by the water level of the Danube, Sava and Tisa rivers, precipitation and temperature.

Key words: Mosquitoes; species composition; seasonal distribution; *Culex pipiens* complex, *Aedes vexans,* Serbia

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INTRODUCTION

Mosquitoes are the most important vectors of pathogenic organisms. Understanding the spatio-temporal distribution of risk for mosquito-borne infections is an important step in planning and implementing effective control measures. A well-organized program of mosquito control must be comprised of mosquito research, abundant monitoring, larval and adult control, as well as evaluation of these treatments. Spatial and temporal changes of mosquito populations can be evaluated in three ways: by sampling larvae and adults and by reports of citizens (Bogojevic et al. 2009). Two methods for sampling adult host-seeking mosquitoes are used in almost 90% of programs in the world. One of the methods is to aspirate mosquitoes landing on a person acting as bait: the other uses CDC traps (Centre for Disease Control, 1978), which replaced the New Jersey Light Trap (Reinert 1989). According to the World Health Organization (1996), 30 new diseases have emerged in the past 20 years. In addition, there has been a resurgence and redistribution of old diseases on a global scale, including malaria, dengue fever, West Nile fever, Rift Valley fever and Chikungunya (Gubler 1998, Vazeille et al. 2008, Paupy et al. 2009, Talbalghi et al. 2010).

A growing number of investigators propose that vector-borne diseases (VBDs), (e.g., involving insects and snails as carriers), could shift their range in response to climate change (Leaf 1989, Shope 1991, Carcavallo and Casas 1996, Patz et al. 1996, McMichael et al. 2006). For example, *Aedes (Stegomyia) albopictus* (Skuse), originally indigenous to South-East Asia, the islands of the Western Pacific and Indian Ocean, has spread during recent decades to Africa, the mid-east, Europe and the Americas (north and south) after extending its range eastwards across the Pacific islands during the early 20th century (Gratz 2004). Among public health authorities in the newly infested countries and those threatened with the introduction, there has been much concern that *Ae. albopictus* could lead to serious outbreaks of arbovirus diseases since *Ae. albopictus* is a competent vector of at least 22 arboviruses. Although tropical forests are considered to be its original habitat, the species has developed the capacity to exploit man-made environments. The capability to colonize used tires is the basis of the recent rapid establishment in new geographical areas (Reiter, 1998). The species *Ae. albopictus* has not been detected in Serbia but it is in its neighboring countries – Montenegro (Petrić et al. 2001), Croatia (Klobučar et al. 2006), Albania (Adhami and Reiter, 1998), Bosnia and Herzegovina (Petric et al. 2006).

The province of Vojvodina represents a region of large breeding sites due to natural wetlands along the rivers Danube, Tisa and Sava, mostly eradicated and converted to arable land. The first investigations of the mosquito fauna in Vojvodina, which is the area in Serbia most threatened by the invasion of vectors and spread of pathogens, were directed particularly toward species in the genus *Anopheles* (Kaman 1928, Dojmi 1938, Vukasović et al. 1953). This is understandable given the importance of these species in the epidemiology of malaria. After the eradication of malaria in the former Yugoslavia, there was a gradual decline of interest in those types of studies (Božičić 1980). More recent studies included the distribution and abundance of individual species in the area of Vojvodina, and more attention was given to species in other genera (Adamović 1975, Božičić 1980, Morović 1980, Božičić 1981, 1982, 1985, Petrić et al. 1986, Božičić 1988, Petrić 1989).

By 1983, there were 29 species of Culicidae recorded in Vojvodina. In her dissertation, Božičić (Božičić 1983) listed 15 species recorded solely in the area of the Fruška Gora mountain, which represents an island mountain habitat on the Vojvodina plain. The survey of Culicidae fauna in Vojvodina, conducted by Petrić in the period 1982 – 1989, documented 23 species and one subspecies of the 32 species and two subspecies documented in Vojvodina (Srdić et al. 1986), using two methods for adult sampling – landing rate count and dry ice-baited CDC traps (Petrić 1989).

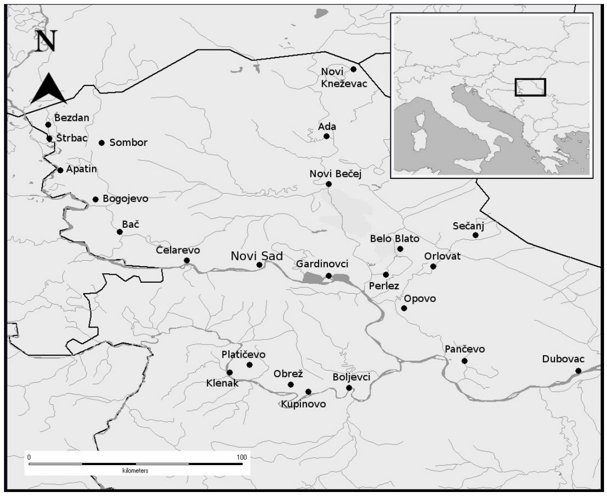

Fig. 1. Studied localities in Region Vojvodina (Serbia)

In the context of vectors, a number of native species in Vojvodina have significant importance. Sindbis virus vectors are largely ornithophilic mosquitoes: *Culex pipiens* L. complex, *Mansonia richiardii* (Ficalbi), *Ae. cinereus* Meigen, and *Anopheles hyrcanus* (Pallas) (Berezin et al. 1971, L'vov et al. 1985, Francy et al. 1989, Turell et al. 1990, Lundström 1999). *Cx pipiens* (Anderson and Main 2006), *Cx modestus* Ficalbi and *M. richiardii* are vectors WNV (Zdenek 2008). Occasional vectors are *Ae. cantans* Meigen and *An. maculipennis* Meigen group (Hannoun et al. 1964, Berezin et al. 1971, Filipe 1972, Labuda et al. 1974, Murgue et al. 2002). Tahyna virus arthropod vectors are the culicine mosquitoes *Ae. vexans* (Meigen), *Ae. cinereus*, *Ae. caspius* Pallas, *Ae. cantans*, *Ae. flavescens* Muller, *Culiseta annulata* Schrank, *Cx modestus*, and *Cx pipiens*, and *An. hyrcanus* in southern Europe (Kolman et al. 1964, Aspöck and Kunz 1966, Danielová et al. 1966, Hannoun et al. 1966, Arcan et al. 1974, Gligić and Adamović 1976, Traavik et al. 1985).

Different authors have followed the seasonal dynamics of mosquitoes. Ponçon et al. followed the population dynamics of pest mosquitoes and potential malaria and West Nile virus vectors in relation to climatic factors and human activities in the Camargue, France (Ponçon et al. 2007). Gündüz et al (2009) studied the population dynamics of adult mosquitoes in Turkey. Sudarić Bogojević et al (2009) reported a study of the population dynamics of mosquitoes in the area of Osijek, in the wetland area of the Danube in Croatia, close to our investigated localities. Investigations presented in this paper were conducted to provide information on mosquito species composition and prevalence influenced by seasonal changes of environmental conditions in the region of Vojvodina.

MATERIALS AND METHODS

Study area and location

Our investigation was carried out in the wetland areas of the four great rivers of Vojvodina: Danube, Tisa, Sava and Tamis, during a period of three years. These areas are natural flood regions of the Danube, which have been largely drained and converted into arable land and urban settlements, but with remnant areas of wetlands. This study discusses the data obtained from 2007 to 2009. Traps were set in 24 locations among the four rivers (Fig. 1). Sites fell into 6 categories according to the CORINE Land Cover classification (European Environment Agency, 2009): 3.1.1 Broad-leaved forest (Bezdan, Štrbac, Apatin, Bogojevo, Čelarevo, Gardinovci, Dubovac, Orlovat); 1.1.2 Discontinuous urban fabric (Sombor, Novi Sad, Boljevci, Klenak, Novi Bečej, Ada, Novi Kneževac); 2.1.1 Non-irrigated arable land (Bač, Opovo); 5.1.2 Water bodies (Sečanj); 4.1.1 Inland marshes (Kupinovo, Obrež, Belo Blato); 2.4.2 Complex cultivation patterns (Perlez).

Along the Danube, there were 11 sites, downstream Bezdan in the following order: Bezdan (45°51'24.06“N, 18°53'14.45“E), Štrbac (45°48'39.15“N, 18°55'52.46“E), Sombor (45°45'23.29“N, 19°5'42.95“E), Apatin (45°41'3.35“N, 18°57'17.88“E), Bogojevo (45°32'21.05“N, 19° 4'11.87“E), Bač (45°23'33.01“N, 19°13'11.75“E), Čelarevo (45°15'14.67“N, 19°29'13.30“E), Novi Sad (45°15'16.76“N, 19°47'24.86“E), Gardinovci (45°11'57.77“N, 20° 7'57.62“E), Pančevo (44°53'5.96“N, 20°38'55.13“E) and Dubovac (44°47'48.03“N, 21°13'11.83“E). Along the river Tamiš there were three locations: Opovo (45° 3'0.27“N, 20°25'22.96“E), Orlovat (45°14'48.33“N, 20°35'13.90“E) and Sečanj (45°21'2.11“N, 20°46'28.13“E). Along the river Sava, we selected five sites: Boljevci (44°43'6.06“N, 20°13'25.12“E), Platičevo (44°49'32.39“N, 19°47'56.99“E), Klenak (44°47'23.57“N, 19°42'8.89“E), Kupinovo (44°42'21.02“N, 20° 2'56.24“E) and Obrež (44°44'7.73“N, 19°59'12.95“E). Along the river Tisa, there were five sites: Belo Blato (45°17'2.32“N, 20°25'45.69“E), Perlez (45°13'26.77“N, 20°24'26.16“E), Novi Bečej (45°35'57.21“N, 20°08'29.09“E), Ada (45°48'33.38“N, 20°8'33.02“E), and Novi Kneževac (46° 3'4.05“N, 20° 4'46.33“E).

Mosquito sampling

Battery powered, dry ice-baited CDC traps were set on posts, 1 m from the ground. Sampling was done for 24 h (±4h) periods and operated every two weeks, from April to September. The investigation ended in late July 2009. The determination of species was performed according to the keys in Gutshevich et al., 1976, Becker et al., 2003 and Božičić, 1985 (Gutsevich et al. 1976, Božičić 1985, Becker et al. 2003).

Environmental data

Climatic data, including the daily temperature at 12 am, mean temperature, rainfall and wind speed were provided by the Republički Hidrometeorološki Zavod, the Serbian national meteorological center, as recorded at three stations: Novi Sad, Palić and Sremska Mitrovica.

The data of the water levels of the Danube, Tisa and Sava were also obtained from the Republički Hidrometeorološki Zavod and were recorded at three stations: Novi Sad for the Danube, Sremska Mitrovica for the Sava and Senta for the Tisa (http://www.hidmet.gov.rs/eng/osmotreni/stanje_voda.php).

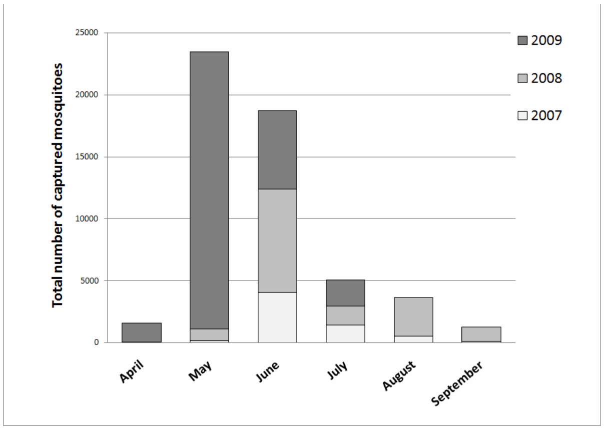

Fig. 2. The total number of specimens captured by month

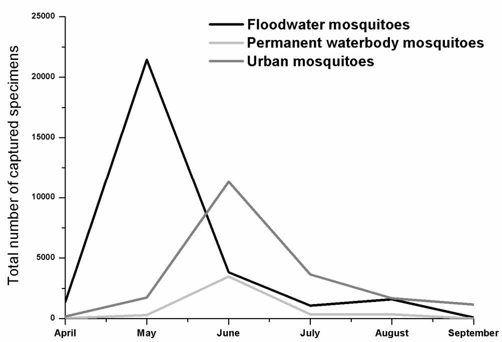

Fig. 3. Total number of captured group of mosquitoes by month for three years of research

RESULTS AND DISCUSSION

During the 3-year investigation presented in this paper a total of 58 247 mosquitoes belonging to 5 genera and 20 species were collected in Vojvodina. The highest number was captured in May, a total 23 492 specimens, followed by 18 726 specimens in June, then by 5061 in July and in other months less than 5000 (Fig. 2). The seven predominant species were the following: *Culex pipiens* complex, *Aedes vexans*, *Aedes sticticus* (Meigen), *Aedes cinereus*, *Mansonia richiardii*, *Anopheles maculipennis* complex and *Aedes pulchritarsis* (Rondani), and together made up 98.3%of the captured specimens.

The water level and the mean catch size of *Aedes* spp. were significantly correlated in the region of the rivers Danube and Sava ($P < 0.01$). The mean temperature and the mean catch size of *Culex* sp. were significantly correlated in the region of the Danube and Tisa ($P < 0.02$; $P < 0.05$) and the whole researched region ($P < 0.01$).

The catch size of *Culex* sp. and cumulative rainfall were significantly correlated in the region of the Danube and Tisa rivers ($P < 0.05$; $P < 0.02$) and the whole researched region ($P < 0.01$). The catch size of the group of permanent and semi-permanent water body mosquitoes (genus *Anopheles*, *Mansonia*, *Culiseta* and species *Culex modestus*) and cumulative rainfall were significantly correlated in the region of the Danube ($P < 0.02$) and in correlation significant at 0.1 for the whole researched region.

From the 32 species and 2 subspecies registered in Vojvodina (Petrić, 1989), 20 species were found during this investigation. This number fluctuated from year to year; in 2009 - 19 species, 2008 - 15 species, and 2007 - 11 species (Table 1). Since the sampling was conducted on a limited habitat type (particularly flooded forests and wetlands) and using only one sampling method it was also expected that not all species recorded in Vojvodina would be detected.

The number of wetland species varied greatly from season to season, depending primarily on hydrological conditions. The highest number of wetland species individuals were captured in May (Fig. 3), and the same situation was observed in the Osijek region (Bogojevic et al. 2009). As can be seen in Figs. 4-6, spring 2007 was characterized by the low water-level values of the three largest Vojvodina rivers, in comparison to the next two years of research (Fig. 12). Minor fluctuations during this research period led to small populations of floodwater species, and the total number of captured individuals did not exceed 50, relatively low numbers compared to the following two years (Figs. 4a, 5a and 6a).

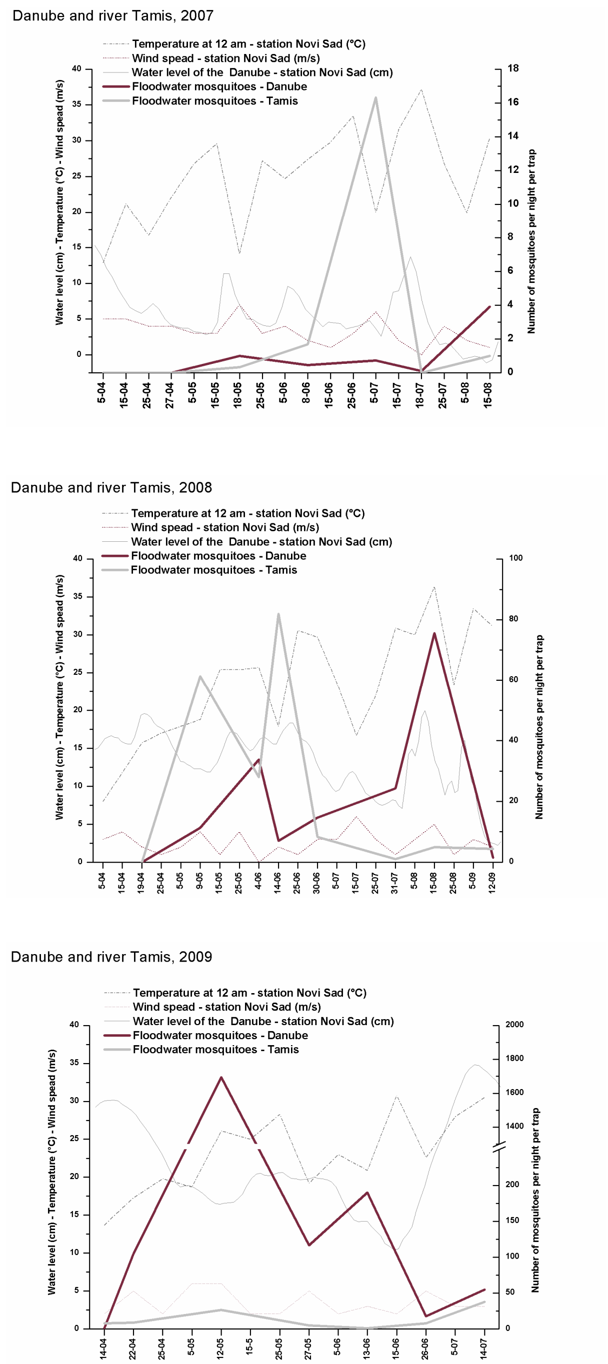

Fig. 4. Seasonal changes in trap catches of floodwater (genus *Aedes*) mosquitoes during three years in the floodplain of the Danube river: 4a) 2007; 4b) 2008; 4c) 2009. Number of captured mosquitoes per night per trap is shown. Climate data represents temperature at 12 am and wind speed in 10-day periods in station Novi Sad and daily water level of Danube river.

It can be concluded that, from a hydrological aspect, 2007 was an unfavorable year for flood water species development, which explains why they were absent in large areas of Vojvodina.

In 2008 there were a few water level peaks during the research season on the Danube river, which resulted in the development of floodwater species populations, primarily *Aedes vexans* and *Ae. sticticus* (Fig. 4b).

In the Danube area, two population peaks of the species *Ae. vexans* were recorded during 2008; one that appeared at the beginning of May and reached a maximum number at the end of June due to new Danube flooding at the end of May, and another that appeared at the end of June as a consequence of the high water level in June and it coincided with a water level peak in mid-August, when the temperature also reached its highest values (Fig. 4b).

In 2009 very favorable hydrological conditions led to the development of flood water species, particularly evident in the Danube floodplains (Fig. 4c). Extremely high water levels in April, unlike the two previous research years, led to a large population of *Ae. vexans* and *Ae. sticticus* species in mid-April and on some localities the *Ae. pulchritarsis* species (tree hole breeders) apparently originating from floodplain forests, as well. The *Ae. pulchritarsis* species appeared, as expected, on localities near the protected area of "Gornje Podunavlje" (The Upper Danube Basin), which indicates the presence of an appropriate habitat for this species, primarily in native forests of the genus *Salix*. The presence of this species was not recorded in this area during the previous two years. High water levels in the Danube during the next period extended populations of *Ae. vexans* and *Ae. sticticus*, whose numbers reached a maximum in mid-May, when the total number at localities along the Danube reached 18 000 (Fig. 4c). At several locations on the Upper Danube region (Bogojevo, Apatin) in mid-May, there was a large emergence of *Ae. cinereus*, which is most frequently found in permanent and semi-permanent bogs but can also be found in a variety of floodwater habitats. At the

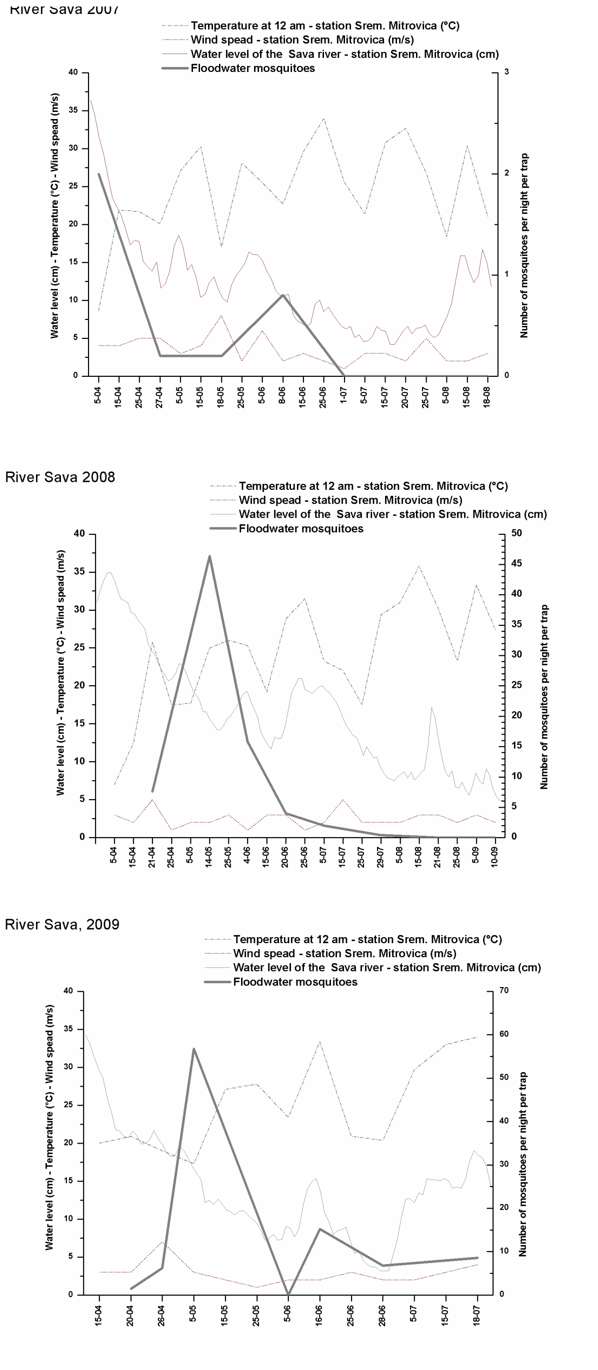

Fig. 5. Seasonal changes in trap catches of floodwater (genus *Aedes*) mosquitoes during three years in the floodplain of the Sava river: 5a) 2007; 5b) 2008; 5c) 2009. Number of captured mosquitoes per night per trap is shown. Climate data represents temperature at 12 am and wind speed in 10 dav periods at station Sremska Mitrovica and daily water level of the Sava river.

end of May, the abundance of floodwater species decreased; however in comparison to the previous two years it was still at high level (Fig. 4c).

In the Tamiš area, flood water species did not show a major number increase during 2009, the number is even less than in 2008. There is a link between the Danube water level and the appearance of generations of *Ae. vexans* and *Ae. sticticus* in the Tamiš area, most likely because of the Danube influence on the Tamiš water level in the lower part of the flow. However, this influence is not crucial to the appearance of large populations (Fig. 4c).

On the flood plains of the Sava river, flood water species were largely absent in 2007 (Fig. 5a). It is probable that this was a consequence of the insufficiently high water level of the Sava during the whole season (Fig. 12b). In the following 2 years *Ae. vexans* i *Ae. sticticus* were recorded at the beginning of May as a consequence of high water levels in April (Figs. 5b,c). A second emergence of *Ae. vexans* was not recorded in 2008, but in 2009 one occurred in mid-June (Fig. 5c). On the Tisa river, in 2007, a mass appearance of flood water species also was not recorded (Fig. 6a). Low water levels did not lead to population production of this species until mid-May and the beginning of June; however a small water level increase from mid-May until the beginning of June didn't allow a massive appearance. In 2008 there are three peaks of water level on the Tisa river - at the end of April, at the end of May and in mid-August (Fig. 6b). The first two caused the appearance of a first generation of *Ae.vexans* species at the end of May, while the other generation in the beginning of August can be rather considered as a consequence of the small water level increase at the end of June (Fig. 6b). In 2009, a massive generation of the *Ae.vexans* species appeared in the beginning of May as a consequence of the high water levels of the Tisa in April (Fig. 6c). It can be concluded that the number of populations of floodwater species depends on the regime of flooding of the breeding sites along the big rivers of Vojvodina. This is of great practical importance, especially in the spring months when the elevated water levels allow prediction of appearance of the

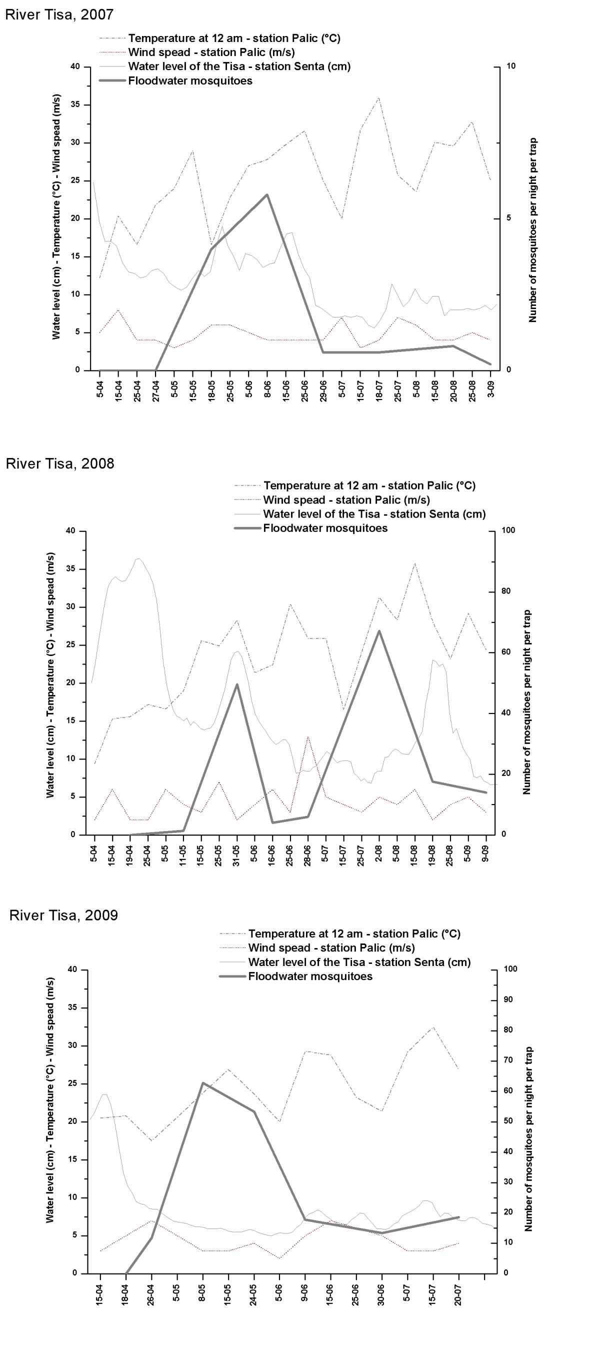

Fig. 6. Seasonal changes in trap catches of floodwater (genus *Aedes*) mosquitoes during three years research in the floodplain of the Tisa river: 6a) 2007; 6b) 2008; 6c) 2009. Number of captured mosquitoes per night per trap is shown. Climate data represents temperature at 12 am and wind speed in 10 day periods at station Palić and daily water level of the Tisa river at station Senta.

first spring generation of species that do not require high temperatures for development. The appearance of successive peaks of water level in spring leads to an extended spring generation that is often more massive after a second wave of increased water level. This was observed during the spring months of 2009 on the Danube (Fig. 4c) when continuously high water levels led to the most massive appearance of flood water species in the last three years.

If we look at the seasonal dynamic of appearance of urban species as well as the species that develop in permanent waters we find its dependence on environmental conditions very complex (Fig. 7-9). The main number of specimens of the *Cx pipiens* complex were captured in June (11 330) (Fig. 2), which is a similar pattern to that reported by Ponçon et al (2007) from the south of France, where the species was most abundant near the beginning of the summer. In contrast, in the region of Osijek the same species is most common in July (Bogojevic et al. 2009). The species *Culex pipiens* complex in 2007 reached a maximum number in mid-July on the Danube (Fig. 7a), in the beginning of June on the Tamiš and Tisa (Figs. 7a, 9a), and in mid-June on the Sava (Fig. 8a). Therefore, the maximum number, in a wider context, is recorded from the beginning of June until the end of July (Figs. 7a, 8a and 9a). The later appearance of urban species is correlated with a lack of precipitation during April 2007, what wasn't usual for this period of the year. Heavier precipitations occurred in May, which, in correlation with higher temperatures after a significant fall at the end of May, led to the appearance of urban mosquito species in the beginning of June (Figs. 7a, 8a and 9a). In 2008, frequent precipitations during April, as well as the temperature growth, led to an increase in the number of urban species in the beginning of May in all the studied areas (Figs. 7b, 8b and 9b). From the end of May until the end of June the number culminated, when it began to decrease rapidly on all rivers (Figs. 7b, 8b and 9b). the number decrease is in correlation with temperature fall on the areas of

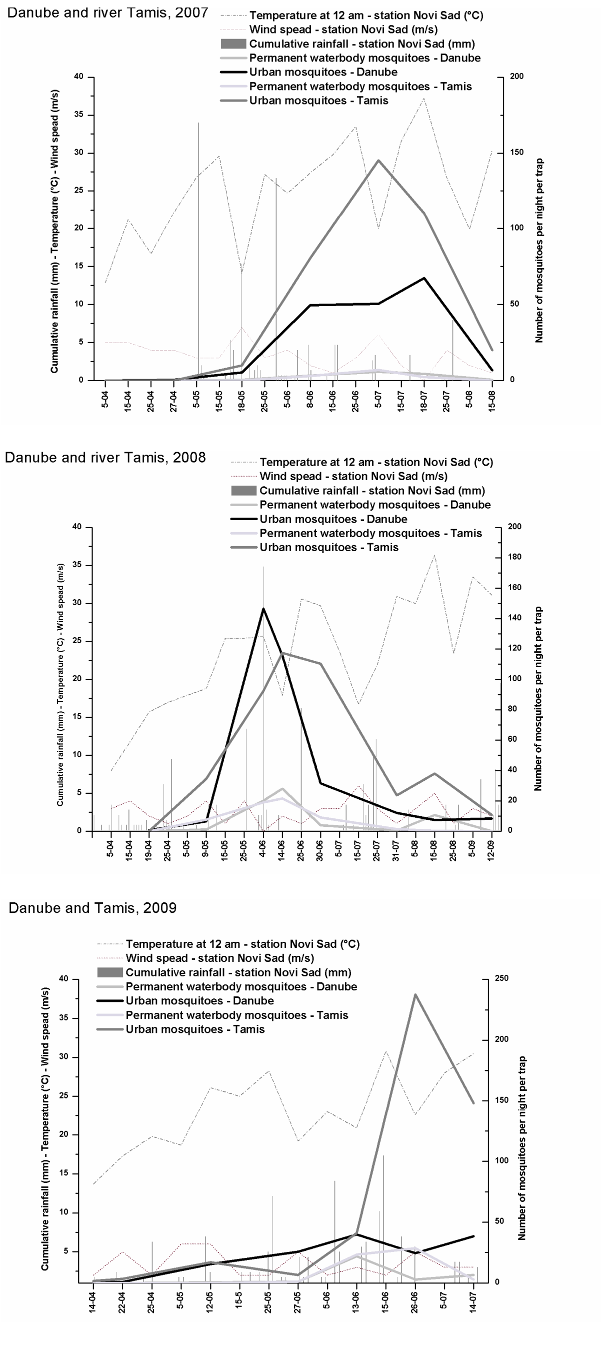

Fig. 7. Seasonal changes in trap catches of urban (*Culex pipiens* complex) and permanent water body mosquitoes (Genus *Anopheles*, *Culiseta*, *Mansonia*, species *Culex modestus*) in the Danube floodplain during three years' research: 7a) 2007; 7b) 2008; 7c) 2009. Number of captured mosquitoes per night per trap is shown. Climate data in columns represents cumulative rainfall during each sampling period of the year, temperature at 12 am, wind speed in 10-day periods at station Novi sad.

Danube, Tamiš and Tisa at the end of May until mid-June, while in the region of Sava the number decrease is in correlation with temperature fall at the end of June. The maximum number of urban species in all areas from the end of May until the end of June is followed by heavier precipitations whose maximum values overlap with peaks in numbers of urban mosquito species (Figs. 7b, 8b and 9b). High temperatures in mid-August led once again to an increase in the number of urban mosquito species that had a more massive appearance in the region of the Tisa than in June (Fig. 9b). In 2009 a certain regularity in the appearance of urban mosquito species in the different areas but with different mass is recorded (Figs. 7c, 8c and 9c). Accordingly, an increase in the number of urban mosquitoes in all areas occurred already at the beginning of May. This was the first observed peak in 2009, while has come to the next increase occurred in mid-June. On the Danube, Tamis and Tisa this first peak is negligible in comparison to the culmination observed in June (Fig. 7c, 9c), while in the region of the Sava the most massive appearance of urban mosquito species is recorded already at the beginning of May (Fig. 8c). This peak on the Sava is in correlation with heavier precipitations at the end of April while daily temperatures were around 20°C (Fig. 8c).

Mosquitoes whose larvae develop in natural permanent water surfaces did not show mass appearance throughout the research (Figs. 7, 8 and 9). Their number culminated in early June in all three years studied and in all areas, except on the Sava River, where it was greatest at the beginning of May in 2008 and 2009 (Figs. 8b, 8c). In the Osijek region, the *An. maculipennis* complex is most abundant in July (Sudarić et al. 2009). This ecological group of mosquitoes occurs in the period after heavy precipitations, while the temperature after a certain degree does not play a key role. Thus, the observation that in all three years, the highest number recorded on the Danube was accompanied by a temperature decrease supports the above hypothesis. As can be seen in Figs. 7-9, there is some overlap between the appearance of urban and permanent water body mosquitoes.

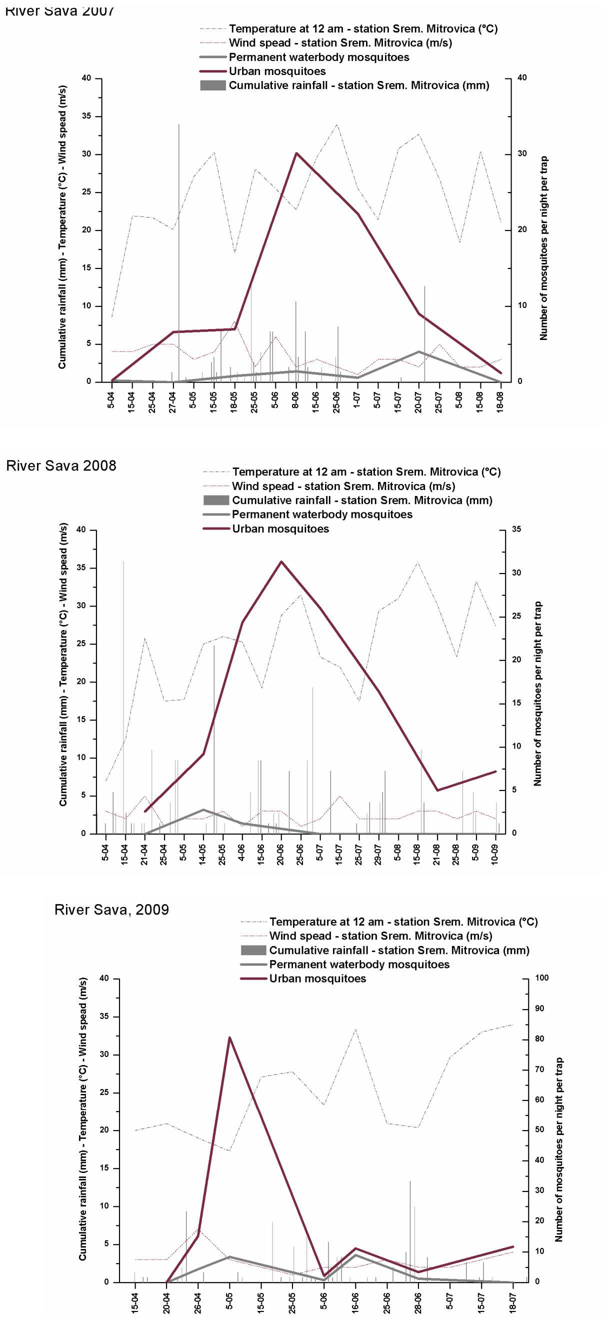

Fig. 8. Seasonal changes in trap catches of urban (*Culex pipiens* complex) and permanent water body mosquitoes (Genus *Anopheles*, *Culiseta*, *Mansonia*, species *Culex modestus*) in the river Sava floodplain during three years: 8a) 2007; 8b) 2008; 8c) 2009. Number of captured mosquitoes per night per trap is shown. Climate data in columns represents cumulative rainfall during each sampling period of the year, temperature at 12 am, wind speed in 10-day periods at station Sremska Mitrovica.

Fig. 10 shows that the largest number of species was detected in 2008 along the rivers Sava, Tisa and Tamiš, while in 2009 along the river Danube 17 species were collected from the total of 20 determined in this study (Fig. 10).

From the 38 155 specimens captured along the river Danube, 45.4% were *Ae. vexans*, 21.4% *Ae. sticticus*, 20% were in the *Cx pipens* complex, while the remaining 13.2% belonged to other species (Fig. 11a). At the sites near the Sava river, 61.1% of the 2 660 specimens were members of the *Cx pipiens* complex, 16.1% *Ae. vexans*, 13.8% *Ae. sticticus*, while the remaining 9% were members of other species (Fig. 11b). Along the Tamiš river, 5 742 adults were captured; 77.4% belonged to the *Cx pipiens* complex, 11.5% were *Ae. vexans*, 4.4% *M. richardii*, and the remaining 6.7% were members of other species (Fig. 11c). As in the case along the Sava river, 61.1% of the captured specimens on the Tisa belonged to the *Cx pipens* complex followed by *M. richiardii* (13.3%) and *An. maculipennis* complex (8.9%) while the remaining 16.7% were members of other species (Fig. 11d).

Because the sampling was carried out within an area dominated by the influence of the Danube wetlands, as well as in the special reserves of flooded forests and reed beds, *Ae. vexans* has proved to be dominant in this area (Fig. 11a). A similar situation was documented in Vojvodina in the period 1982 - 1989 (Petrić 1989). Specimens of the *Cx pipiens* complex, collected along the river Danube (20%), were the second most abundant species and matched with the Petrić, 1989 study. It is interesting that the third most common species captured was *Cx modestus*, which occurs at only 0.1% in this survey. From the results obtained, it can be seen that the species *Cx modestus* occurs in the third year of research when the hydrological conditions were favorable for species who develop in natural waterbodies, particularly in reed marshes (Fig. 12).

A ten-year monitoring of the area of Osijek showed that the species *Ae. vexans* was also dominant at 76 % of all species caught. The second

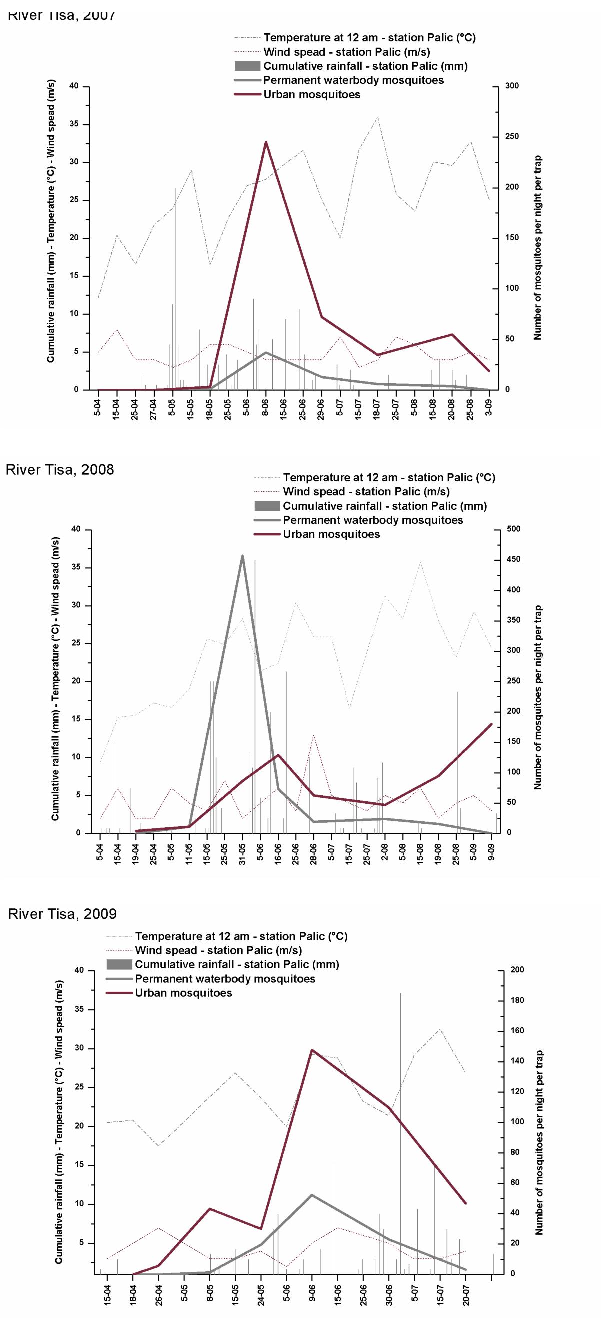

Fig. 9. Seasonal changes in trap catches of urban (*Culex pipiens* complex) and permanent water body mosquitoes (Genus *Anopheles*, *Culiseta*, *Mansonia*, species *Culex modestus*) in the Tisa river floodplain during three years: 9a) 2007; 9b) 2008; 9c) 2009. The number of captured mosquitoes per night per trap is shown. Climate data represents cumulative rainfall during each sampling period of the year, temperature at 12 am, wind speed in 10-day periods at station Palić.

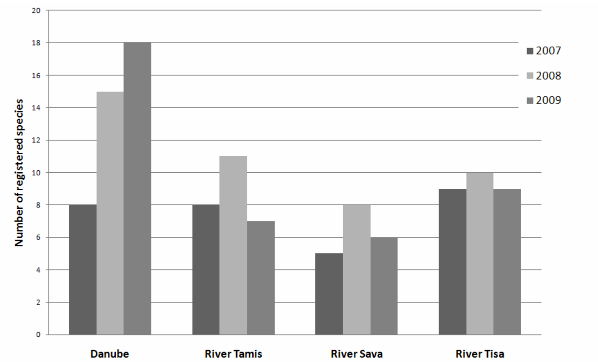

Fig. 10. Number of species collected during three years' study by area.

most frequent in the wider area of the city of Osijek was the "floodwater" species *Ae. sticticus* with 13%, while the *Cx pipiens* complex was third with only 6% and it was found predominantly in urban areas. This data is not surprising if we take into account the proximity of the protected Danube wetland of Kopački Rit, which supports the mass production of larvae of the dominant species (Sudarić et al. 2008). At the Bogojevo site, located on the opposite side of the Danube, the dominant species of mosquito fauna were *Ae. vexans*, with 64%, *Ae. sticticus* with 13.4%, and *Ae. cinereus* with 9.4%, *Ae. pulchritarsis* with 9.2% and the *Cx pipiens* complex represented with only 1.2%. It is interesting that *Ae. sticticus* in the year 2007 occurs only in localities on the Tamiš river and with only a few individuals.

The mass mosquito production established at the Danube sites was partly influenced by the conserved region of Danube wetland in the Special Nature Reserve Upper Danube Valley, which was the main breeding site for rural mosquito species in Vojvodina.

Given the predominantly urban and cultivated habitats in the flood area of the Sava river, the species of the *Cx pipiens* complex appear as expected with a dominant representation of 61% of the total number of captured specimens in this area, followed by two "wetland" species, *Ae. vexans* and *Ae. sticticus*. *Ae. sticticus* was not collected in the first year of research at the investigated sites on the Sava river (Fig. 11b). This was the result of hydro-

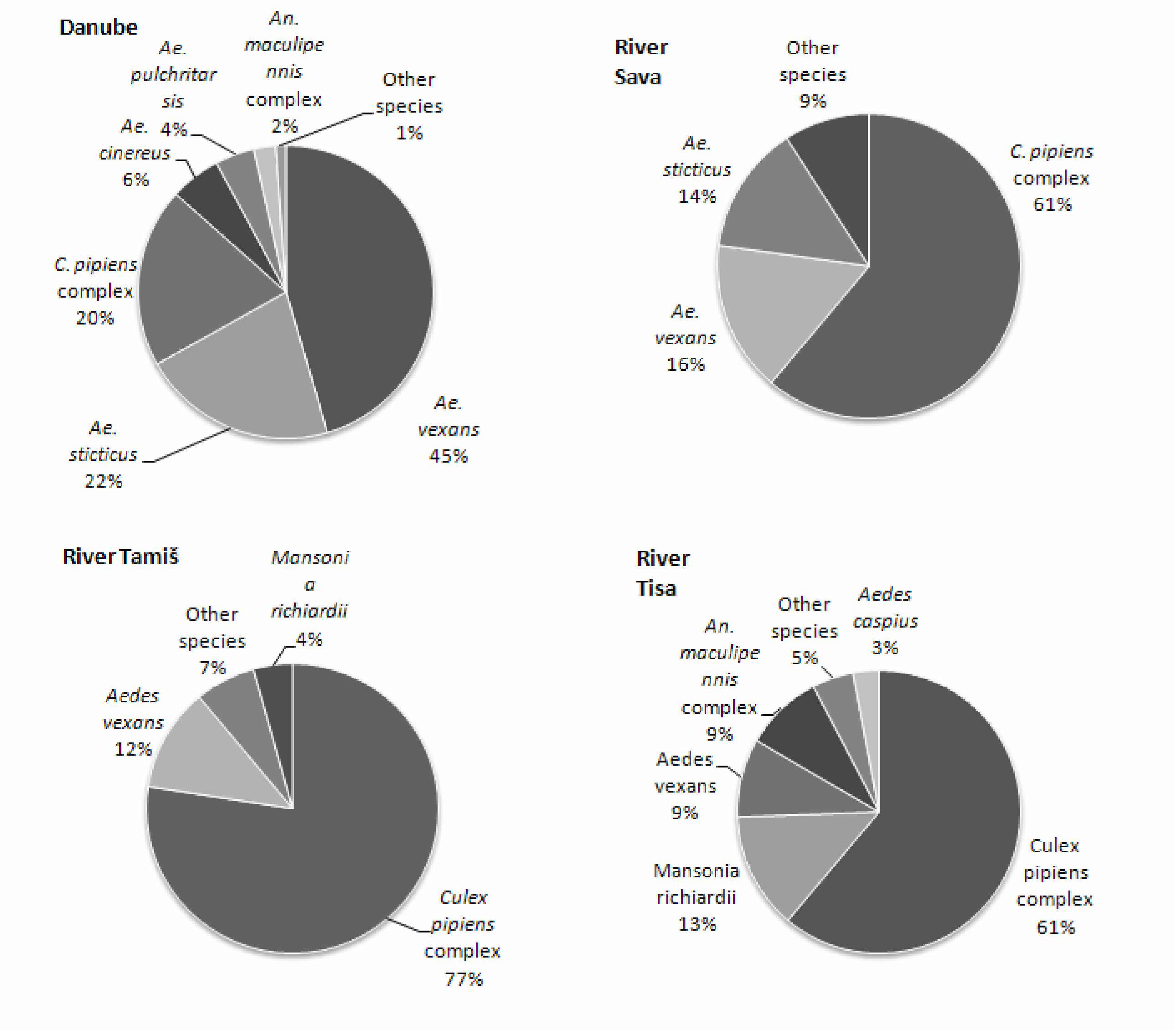

Fig. 11. Share of certain species of total number by region.

logical conditions in that year and the same applied to localities on the Danube and Tisa rivers. *Ae. vexans* occurred with extremely low abundance during 2007, which was also the result of unusually low water levels on all the major rivers of Vojvodina (Fig. 12). This was particularly reflected in the lack of a spring cohort of wetland species. Compared to the first two years, 2009 was characterized by the largest number of species of the genus *Aedes*, especially on the Danube (Fig. 4). On the Sava, during the three years studied, we observed a lower water level for a dry period in the year 2007, which lasted from April to September (Fig. 12b).

Species of the *Cx pipiens* complex also emerged as dominant on the Tisa and Tamiš, due to mainly

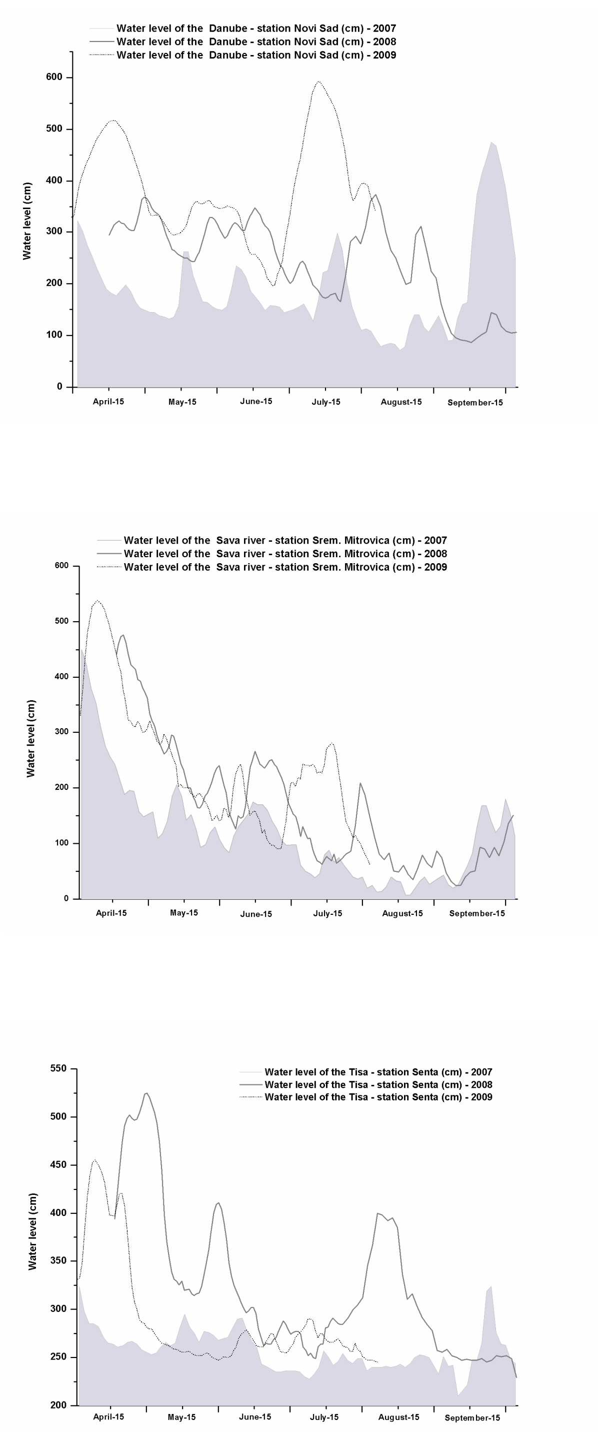

Fig. 12. a) Water level of the Danube at measuring station Novi Sad from April to September; b) water level of the river Sava at measuring station Sremska Mitrovica from April to September; c) water level of the river Tisa on measuring station Senta from April to September.

urban and cultivated habitats in these areas and a number of artificial water surfaces. A large number of this taxa were collected at the site Sečanj, where large water surfaces for aquaculture are its major breeding sites.

The difference in number of species collected can be caused by quite different hydrological conditions during the years of study as well as microclimatic conditions during the nights of collection (Fig. 4-9). The water level three weeks before sampling and the mean catch size of *Aedes* sp. were in significant correlation in the region of the Danube and Sava ($P < 0.01$). The mean temperature for two weeks before sampling and the mean catch size of *Culex* sp. significantly correlated in the region of the Danube and Tisa ($P < 0.02$; $P < 0.05$) and the whole researched region ($P < 0.01$). Similar results were obtained by Ponçon et al in their study (Ponçon et al. 2007) where the mean catch size of *Cx pipiens* were significantly correlated with the mean temperature ($P < 0.05$) at Marais du Vigueirat.

The catch size of *Culex* sp. and cumulative rainfall three weeks before sampling, significantly correlated in the region of the Danube and Tisa ($P < 0.05$; $P < 0.02$) and the whole researched region ($P < 0.01$). The catch size of the group of permanent and semi-permanent water body mosquitoes (genus *Anopheles*, *Mansonia*, *Culiseta* and species *Culex modestus*) and cumulative rainfall, three weeks before sampling, significantly correlated in the region of the Danube ($P < 0.02$) and at the 0.1 level.

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REFERENCES

Adamović, Ž. R. (1975). A preliminary survey of the mosquitoes (Diptera: Culicidae) of Obedska Bara, Serbia. *Bull. Mus. Hist. Nat. Belgrade* **30**, 75-80.

Adhami, J., and *P. Reiter* (1998). Introduction and establishment of Aedes (Stegomyia) albopictus skuse (Diptera: Culicidae) in Albania. *J. Am. Mosq. Control Assoc.* **14(3)**, 340-343.

Anderson, J. F. and *A. J. Main* (2006). Importance of Vertical and Horizontal Transmission of West Nile Virus by Culex pipiens in the Northeastern United States. *J. Infect. Dis.* **194**, 1577–1579.

Arcan, P., Topciu, V., Roşiu, N. and *N. Csaky* (1974). Isolation of Ťahyňa virus from *Culex pipiens* mosquitoes in Romania. *Acta Virol.* **18**, 175.

Aspöck, H. and *C. Kunz* (1966). Isolierung des Tahyna-Virus aus Stechmücken in Österreich. *Arch Gesamte Virusforsch* **18**, 8-15.

Becker, N., Petric, D., Zgomba, M., Boase, C., Dahl, C., Lane, J. and *A. Kaiser* (2003). *Mosquitoes and Their Control.* Kluwer, New York.

Berezin, V. V., Chumakov, M. P., Semenov, B. F., Reshetnikov, I. A., Hannoun, C., Corniu, B. and *J. Mouchet* (1971). [A study of the ecology of mosquito-borne arboviruses using sentinel animals in the Volga delta] [Article in Russian]. *Vopr. Virusol.* **16**, 739–745.

Bogojević, M. S., Hengl, T. and *E. Merdić* (2009). Spatiotemporal monitoring of floodwater mosquito dispersal in Osijek, Croatia. *J. Am. Mosq. Control Assoc.* **23**, 99-108.

Božičić, B. (1980). Prilog poznavanju faune Culicidae Vojvodine. *Acta Entomol. Jugosl.* **16**, 93-99.

Božičić, B. (1981). *Culex territans* Walker (nec apicalis Adams) (Culicidae). Nova vrsta za Jugoslaviju. *Acta Biol. Jugosl.* **7**, 63-66.

Božičić, B. (1982). Istraživanje faune Culicidae na području Srema. *Proc. Nat. Sci, Matica Srpska Novi Sad* **63**, 143-151.

Božičić, B. (1983). *Culicidae Fruške gore*. Doctoral dissertation., pp. 190, Faculty of Natural Sciences. University of Novi Sad, Novi Sad.

Božičić, B. (1985). Komarci Fruške Gore (Diptera, Culicidae), pp. 1-102, *Monographs of Fruška Gora*. Matica srpska, Novi Sad.

Božičić, B. (1988). Komarci Vršačkih planina (Diptera, Culicidae), pp. 1-50, *Monographs of Vršačke Planine (Vrshac Mountains)*. Matica srpska, Novi Sad.

Carcavallo, R. U., and *D. d. Casas* (1996). Some health impacts of global warming in South America: vector-borne diseases. *J. Epidemiol.* **6(4)**, S153-S157.

Danielová, V., Hájková, Z., Kolman, J. M., Minář, J. and *A. Smetana* (1966). [Results of virological examination of mosquitoes in southern Moravia, 1962-64] [Article in Czech]. *Ceskoslov. Epidemiol. Mikrobiol. Immunol.* **15**, 178-184.

Dojmi, L. (1938). Biološko suzbijanje malarije. *Priroda* **28 (9)**, 268-278.

Filipe, A. R. (1972). Isolation in Portugal of West Nile virus from *Anopheles maculipennis* mosquitoes. *Acta virol.* **16**, 361.

Francy, D. B., Jaenson, T. G. T., Lundström, J. O., Schildt, E. B., Espmark, Å., Bo, H. and *N. Bo* (1989). Ecologic studies of mosquitoes and birds as hosts of Ockelbo virus in Sweden and isolation of Inkoo and Batai viruses from mosquitoes. *Am. J. Trop. Med. Hyg.* **41**, 355-363.

Gligić, A., and *Z. R. Adamović* (1976). Isolation of Tahyna virus from *Aedes vexans* mosquitoes in Serbia. *Mikrobiologija* **12**, 119-129.

Gratz, N. G. (2004). Critical review of the vector status of *Aedes albopictus*. *Med. Vet. Entomol.* **18**, 215-227.

Gubler, D. J. (1998). Dengue and Dengue Hemorrhagic Fever. Clinical microbiology reviews **11**, 480-496.

Gündüz, Y. K., Aldemir, A. and *B. L. Alten* (2009). Seasonal dynamics and nocturnal activities of mosquitoes (Diptera: Culicidae) in the Aras Valley, Turkey. *Turk. Zool. Derg.* **33**, 269-276.

Gutsevich, A. V., Monchadskii, A. S. and *A. A. Shtakel 'berg* (1976). *Fauna of the U.S.S.R. Diptera:* Mosquitoes Family Culicidae. Israel Keter Publishing House, Jerusalem.

Hannoun, C., Panthier, R. and *B. Corniou* (1966). Isolation of Ťahyňa virus in the South of France. *Acta Virol* **10**,362–364.

Hannoun, C., Panthier, R., Mouchet, J. and *J. P. Eouzan* (1964). Isolement en France du virus West Nile à partir de malades et du vecteur *Culex modestus* Ficalbi. *C. R. Hebd. Seances Acad. Sci* .**259**, 4170–4172.

Kaman, M. (1928). Nešto o zoofiliji anofela. *Priroda* **18(6)**, 116-121.

Klobučar, A., Merdić, E., Benić, N., Baklaić, Ž. and *S. Krčmar* (2006). First record of *Aedes albopictus* in Croatia. *J. Am. Mosq. Control Assoc.* **22**, 147-148.

Kolman, J. M., Málková, D., Nemec, A., Smetana, A., Hájková, Z. and *J. Minár* (1964). The isolation of the Tahyna virus from the mosquito *Aedes vexans* in southern Moravia. *J Hyg Epidemiol Microbiol Immunol.* **8**, 380-386.

L'vov, D. K., Skvortsova, T. M., Gromashevskii, V. L., Berezina, L. K. and *V. I. Iakovlev* (1985). [Isolation of the causative agent of Karelian fever from Aedes sp mosquitoes] [Article in Russian] *Vopr. Virusol.* **30**, 311-313.

Labuda, M., Kožuch, O. and *M. Grešíková* (1974). Isolation of West Nile virus from Aedes cantans mosquitoes in west Slovakia. *Acta virol.* **18**, 429-433.

Leaf, A. (1989). Potential health effects of global climate and environmental changes. *N. Engl. J. Med.* **321**, 1577–1583.

Lundström, J. O. (1999). Mosquito-borne viruses in Western Europe: a review. *J. Vector Ecol.* **24**, 1-39.

McMichael, A. J., Woodruff, R. E. and *S. Hales* (2006). *Climate change and human health*: present and future risks. The Lancet **367**, 859-869.

Morović, M. (1980). Vrste komaraca u Vojvodini i njihovo suzbijanje. *Agrohemija* **3(4)**.

Murgue, B., Zeller, H. and *V. Deubel* (2002). The ecology and epidemiology of West Nile virus in Africa, Europe and Asia. *Curr. Top. Microbiol. Immunol.* **267**, 195-221.

Patz, J. A., Epstein, P. R., Burke, T. A. and *J. M. Balbus* (1996). Global Climate Change and *Emerging Infect. Dis.* JAMA **275**, 217-223.

Paupy, C., Delatte, H., Bagny,L., Corbel, V. and *D. Fontenille* (2009). *Aedes albopictus*, an arbovirus vector: From the darkness to the light. *Microbes Infect.* **11**, 1177-1185.

Petric, D., Zgomba, Ignjatović-Ćupina, A., Pajovic, I., Merdic, E., Boca, I., Klobucar, A. and *N. Landeka* (2006). Invasion of the *Stegomyia albopicta* to a part of Europe, pp. 58, *Abstracts of the SOVE 15th European Meeting*, Serres, Greece.

Petrić, D. (1989). *Sezonska i dnevna aktivnost komaraca (Diptera, Culicidae) u Vojvodini.* Doctoral dissertation., pp. 138, Poljoprivredni fakultet. Univerzitet u Novom Sadu, Novi Sad.

Petrić, D., Zgomba, M., and *Ž.Srdić* (1986). *Culex pipiens spp. erectus nova podvrsta u entomofauni Jugoslavije*, Zbornik sažetaka radova. Entomološki kongres, Vršac.

Petrić, D., Pajović, I., Ignjatović-Ćupina, A. and *M. Zgomba* (2001). *Aedes albopictus* (Skuse, 1894), nova vrsta komarca (Diptera: Culicidae) u entomofauni Jugoslavije. *Biljni lekar* **29(6)**, 547-548.

Ponçon, N., Toty, C., L'Ambert, G., le Goff, G., Brengues, C., Schaffner, F. and D. Fontenille (2007). Population dynamics of pest mosquitoes and potential malaria and West Nile virus vectors in relation to climatic factors and human activities in the Camargue, France. *Med. Vet. Entomol.* **21**, 350-7.

Reinert, W. C. (1989). The New Jersey Light Trap: An Old Standard for Most Mosquito Control Programs. *Proc. N. J. Mosq. Control Assoc.* **67**, 17-25.

Reiter, P. (1998). *Aedes albopictus* and the world trade in used tires, 1988-1995 : The shape of things to come? *J. Am. Mosq. Control Assoc.* **14**, 83-94.

Shope, R. (1991). Global Climate Change and Infectious Diseases. *Environ. Health Perspect.* **96**, 171–174.

Srdić, Ž., Petrić, D. and *M. Zgomba* (1986). Les moustiques (diptera: Culicidae) et la demoustication en Vojvodine (Yugoslavie). *Rapports generaux et communications IVe Congres sur la protection de la santa humaine et des cultures en milieu tropical*. 489-494.

Sudarić, B. M., Merdić, E., Vrućina, I., Merdić, S., Zahirović, Ž., Turić, N. and *Ž. Jeličić* (2008). Results of ten years mosquito (Diptera: Culicidae) monitoring in Osijek, Croatia. *Entomol. Croat.* **12**, 67-78.

Sudarić, B. M., Merdić, E., Turić, N., Jeličić, Ž., Zahirović, Ž., Vrućina, I. and *S. Merdić* (2009). Seasonal dynamics of mosquitoes (Diptera: Culicidae) in Osijek (Croatia) for the period 1995-2004. *Versita* **64**, 760-767.

Talbalghi, A., Moutailler, S., Vazeille, M. and *A. B. Failloux* (2010). Are *Aedes albopictus* or other mosquito species from northern Italy competent to sustain new arboviral outbreaks? *Med. Vet. Entomol.* **24**, 83-87.

Traavik, T., Mehl, R. and *R. Wiger* (1985). Mosquito-Borne Arboviruses in Norway: Further Isolations and Detection of Antibodies to California Encephalitis Viruses in Human, Sheep and Wildlife Sera. *J Hyg (Lond)* **94**, 111-122.

Turell, M. J., Lundström, J. O. and *B. Niklasson* (1990). Transmission of Ockelbo virus by Aedes cinereus, Ae. communis, and Ae. excrucians (Diptera: Culicidae) collected in an enzootic area in central Sweden. *J. Med. Entomol.* **27**, 266-268.

Vazeille, M., Jeannin, C., Martin, E., Schaffner, F. and *A. B. Failloux* (2008). Chikungunya: A risk for Mediterranean countries? *Acta Trop.* **105**, 200-202.

Vukasović, P., Martinović, A. and *M. Popović* (1953). Prilog proučavanju varijeteta *Anopheles maculipennis* Meig. (Anophelinae, Culicidae) u Pančevačkom ritu i okolini. *Bull. Mus. Hist. Nat. Belgrade* **B**, 5-6.

Zdenek, H. (2008). Mosquito-borne viruses in Europe. *Parasitol. Res.* **103**, S29–S43.