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Dominance and Change in the Numbers of Mosquito Larvae of the Biting Mosquitoes Sub-family (Culicinae) in the Szigetköz Region

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In the region of Szigetköz (North-West Hungary) mosquito larvae were regularly collected at 64 sites in 16 villages of 4 districts every week between 1–30 September, 1999. As a result we identified the larvae of 19 mosquito species, among them 93.68% were *Aedes vexans* Meig. and 5.11% were *Culex pipiens pipiens* L. The numbers of the mosquito larvae to be collected at site proves the heterogenity of the biotops in the districts. We collected 5718 larvae in district I, 2401 larvae in district II, 1170 in district III, 232 344 in district IV. District IV reflects the effect of the Danube floods i.e. the flood area was overflown with perched water and the water temperatures often rose above 30 °C. These factors contributed to the dominance of *Aedes vexans.* Regular inspections, the knowledge of the species and the identification of the larvae development enabled us to set the date of optimal biological protection.

Keywords: Biting mosquitoes, larvae dominance, Anopheles, Aedes, Culex species.

The species of the sub-family of biting mosquitoes are vexatious and their blood sucking activity causes human indisposition. They are especially unpleasant and irritating from May to October. They find humans, warm-blooded animals, reptiles and amphibia with the help of their well-developed optical, chemical, maybe heat and moisture sensoring organs. They are to be found everywhere, like houses, restaurants, nature, we meet them if we walk or go on holiday, go wandering, working or hunting, fishing and doing any other activities. Some of their species spread the pathogens of serious diseases (Lőrincz and Mihályi, 1937a; 1937b; 1938; Makara and Mihályi, 1943; Mihályi, 1955; Günther et al., 1970).

Mosquitoes may occasionally occur in such high numbers that they make almost any human activity impossible. It very often happens in Lapland, Alaska, Greenland and Siberia. People can hide from them in case they fully cover their bodies as mosquitoes are able to fly into body openings (mouth, ears, nose) easily (Günther et al., 1970).

Mosquitoes are to be found everywhere on Earth. 2500 species could have been identified and classified so far and not all of them are blood suckers. Most of the species live under hot climate conditions. The most densely habitated areas are in Africa, Southern Europe, Middle and South America (Günther et al., 1970).

Among the fully developed insects the female mosquitoes feed on blood, though they eat the nectars of the flowers as well. Among human blood-suckers the biting mosquitoes (*Aedes vexans* Meig., *A. cantans* Meig., *A. caspius* Pall., *A dorsalis* Meig., *A. flavescens* Müll., *A. sticticus* Meig.), the common gnat (*Culex modestus* Fic., *C. pipiens*

pipiens L.) the marsh gnat (as it is called in Hungary), (*Mansonia richiardii* Fic.) species have an important role (Fászl, 1878; Kertész, 1904; Makara and Székely, 1940; Mihályi, 1941; 1959; Mihályi et al., 1952a; 1952b; 1953a; 1953b; 1954; 1956; Mihályi and Sztankay-Gulyás, 1963; Kecskeméti and Tóth, 1981; Mihályi and Zoltay, 1956; Tóth, 1979; 1991; Tóth and Sáringer, 1997).

Mosquitoes go through full metamorphose, they lay their eggs on water, on wet ground or plants, respectively. The eggs of Anopheles species float on the water surface in rafts or individually and have exochorion with air chambers. Culex, Theobaldia and Mansonia genera lay their eggs in rafts on water surfaces. Aedes and some Theobaldia species lay their eggs one by one on wet ground or plants and are able to survive for long months and will hatch after having been overflowed and if the water temperature is favourable for the species. The larvae of the species laying eggs on the water surface hatch after 2–3 days of embryonic stage (Mihályi and Sztankay-Gulyás, 1963).

Hatched larvae fully develop in 5–10 days (Aedes), or in 6–10 months (Theobaldia, Mansonia) depending basically on the water temperatures. Their jaws are covered with brush like hair, which enables them to keep water moving and to filter their food from the water, which contains tiny animal and plant organisms. Larvae can develop only in water. The most suitable habitats are stagnant or slowly floating waters, marsh waters, rainwater containers, cisterns, puddles in cellars, tree holes filled with water, etc. Mosquitoes cannot stand floating or rippling waters therefore they cannot breed in rivers, large open waters or in lakes but in very small numbers (Mihályi and Sztankay-Gulyás, 1963; Günther et al., 1970).

The horse-shoe shaped pupae are very vivid and rush away in case the water surface reflects a shadow or if it vibrates (Mihályi and Sztankay-Gulyás, 1963).

The species overwinter in different stages according to the species characteristics. Most Aedes species overwinter as eggs, at a very small rate as larvae. *Anopheles bifurcatus* and *Theobaldia morsitans* overwinter as larvae. There are some species like *Anopheles maculipennis* and *Culex pipiens pipiens* of which fertilised females overwinter. It is not known whether some species may overwinter at pupae stage (Mihályi, 1955; Günther et al., 1970).

We can expect different mosquito swarming according to their conditions after overwintering. So the order of swarming species follows the overwintering scheme i.e.: larvae, imagoes or eggs. Species overwintering at the stage of imago are less important within the mosquito population in our country, so we should focus on species overwintering at the stage of eggs or larvae (Kuroli, 1999).

Under our present circumstances the only way of preventing or avoiding the unpleasant conditions for humans and animals caused by these species is either to destroy them or to decrease the number of the species within the population (Sáringer, 1980; 1983a; 1983b; 1988). Carrying out treatments in the course of protection effectively requires a very precise site mapping of the territories. Further it requires the detection of their biotope, the determination of their roles in the very territory, the proportion of the species in the population, the features of their development and the possible numbers of generations, which differ from species to species (Kuroli, 1999). Priority should be given to biological control among the available ones (Becker, 1986; Erőss, 1988; Entwistle et al., 1993; Sáringer et al., 1998). They can be applied especially effectively in spring (April and May) and in autumn. During the year insecticides should be applied which give the most possible protection to the other mosquito species living in the same biotop, but adjusted to the peak swarming period of the blood-sucking species (Kölüs and Tóth, 1979; Tóth, 1979; 1996; Sáringer et al., 1984). The effect of *Bacillus sphaericus* and *B. thuringiensis* applied against the larvae of *Culiseta longiareolata* Macq. proved to be more significant if the concentration and the temperature was increased (Katheb-Bader et al., 1999).

It was also proved by investigations that, Alsystin 48 EC containing triflumuron, which inhibits chitin synthesis, destroys the young, freshly shed larvae of *Culex pipiens pipiens* and elongates their developing period. 74–87% of the treated larvae could not transform into imago (Rehimi and Soltani, 1999).

In Sopron the bio-preparation containing *Bacillus thuringiensis* var. *israelensis* was applied with an efficiency of 78.85 % in June and 80.37% in August. The agent killed 83–84% of the mosquito larvae, which were put into an isolator (Kuroli, 1999).

Materials and Methods

We marked out the places of the future site mappings for the breeding period of 1999 (1st April – 30th September), after a discussion with the consignees, the mayors or the representatives of the villages. We also used the topographical maps of the related administrations in Szigetköz for the final marking out the sites. During this activity we kept us to the basic concept and applied site mapping in 4 administration areas of 16 villages. Altogether 64 sites were marked out, where data were collected regularly every week at fixed times.

Marking out the sites we took professional aspects into consideration with special care for ecological differences as they influence the development and change in the numbers of mosquito larvae. Therefore we evaluated the role of the habitat and biotope and that of the lakes, rivers, gravel pits filled with water and areas temporarily waterlogged owing to floods.

Considering the above-mentioned aspects 4 villages were marked out in 4 districts:

District I	Mosonmagyaróvár
	Halászi
	Máriakálnok
	Dunasziget
District II	Püski
	Kisbodak
	Dunaremete
	Lipót
District III	Hédervár
	Kimle

	Mecsér
	Ásványráró
District IV	Vámosszabadi
	Nagybajcs
	Kisbajcs-Szőgye
	Vének

Site mapping was carried out on 64 sites once on a fixed day per week from 1st April to 30th September, 1999. For sampling we used dipping nets stretched on a circular frame. Larvae caught in 4–5 dipping were put into a container. The samples were then labelled according to place of origin and date for the sake of proper evaluation. This method enabled us to clearly distinct the collected data according to habitat and biotope and to make conclusions that reflect real natural processes.

Samples were prepared in the laboratory of the University's Plant Protection Department. The mosquito larvae and pupae were selected from the mixed samples with the help of a magnifier. The selected samples were then preserved in phials filled with alcohol of 75%. The data were recorded on tags and put together with the larvae and pupae into the phials, which were sent to Zirc, where Dr. Tóth, S., a mosquito specialist, identified the species. The identification was carried out according to the systematic works listed in the reference literature. As a result of the identifications we got into the procession of data, which proved evidence for the occurrence of the species, their dominance relations seasonally, changes in their numbers and for the evaluation of different biotope and habitats.

Absolute data on collected larvae were summarised in tables and the proportion of the species groups, the dominance of the species and the seasonality of their occurrence was represented in diagrams *(Figs. 4, 5, 6).*

Evidence and conclusions can be made for timing the biological control, the gradation of imago swarming to be expected and for setting the optimal date of the air control based on the information about the living environment, the climate (rainfall and temperature) and the data of collections *(Fig. 7).*

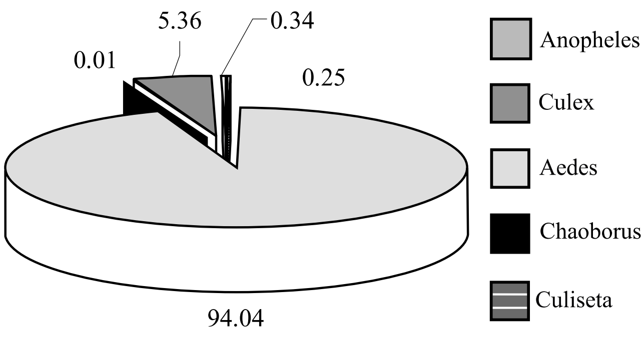

Fig. 4. Dominance relations of mosquito genera living in Szigetköz (given in %)

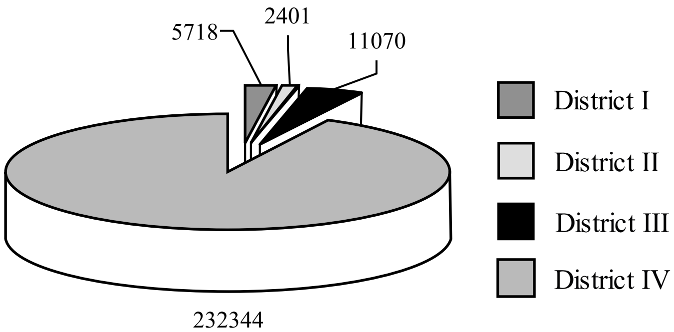

Fig. 5. Numbers of mosquito larvae collected in site mappings in the inspected areas

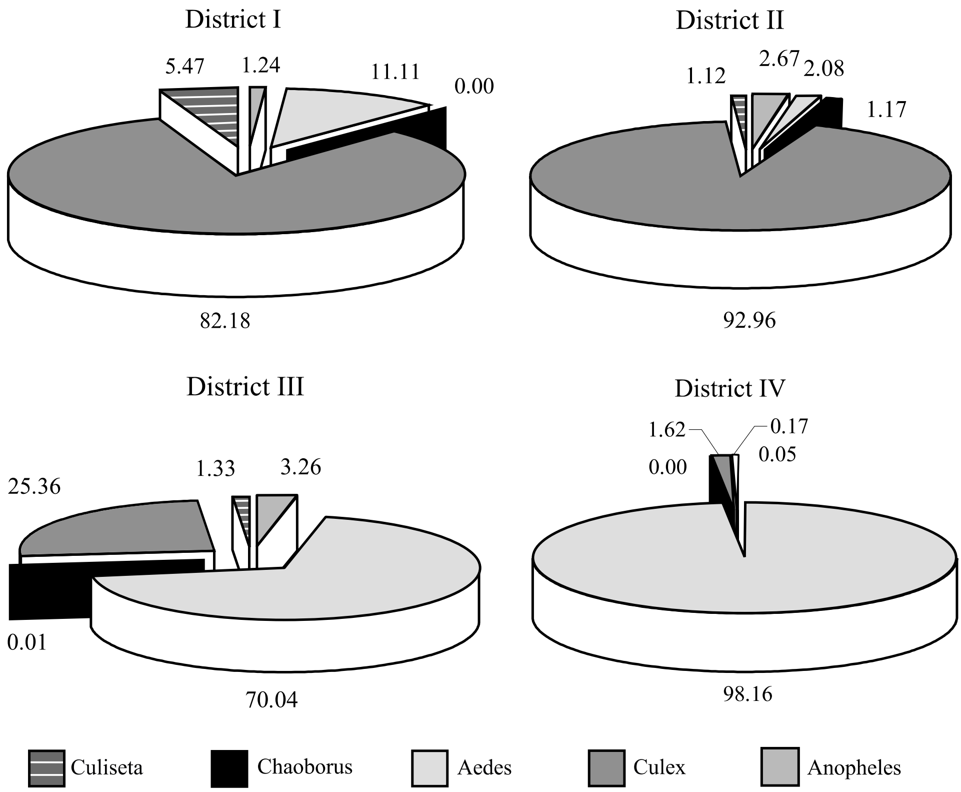

Fig. 6. Dominance relations of mosquito genera living in the districts (given in%)

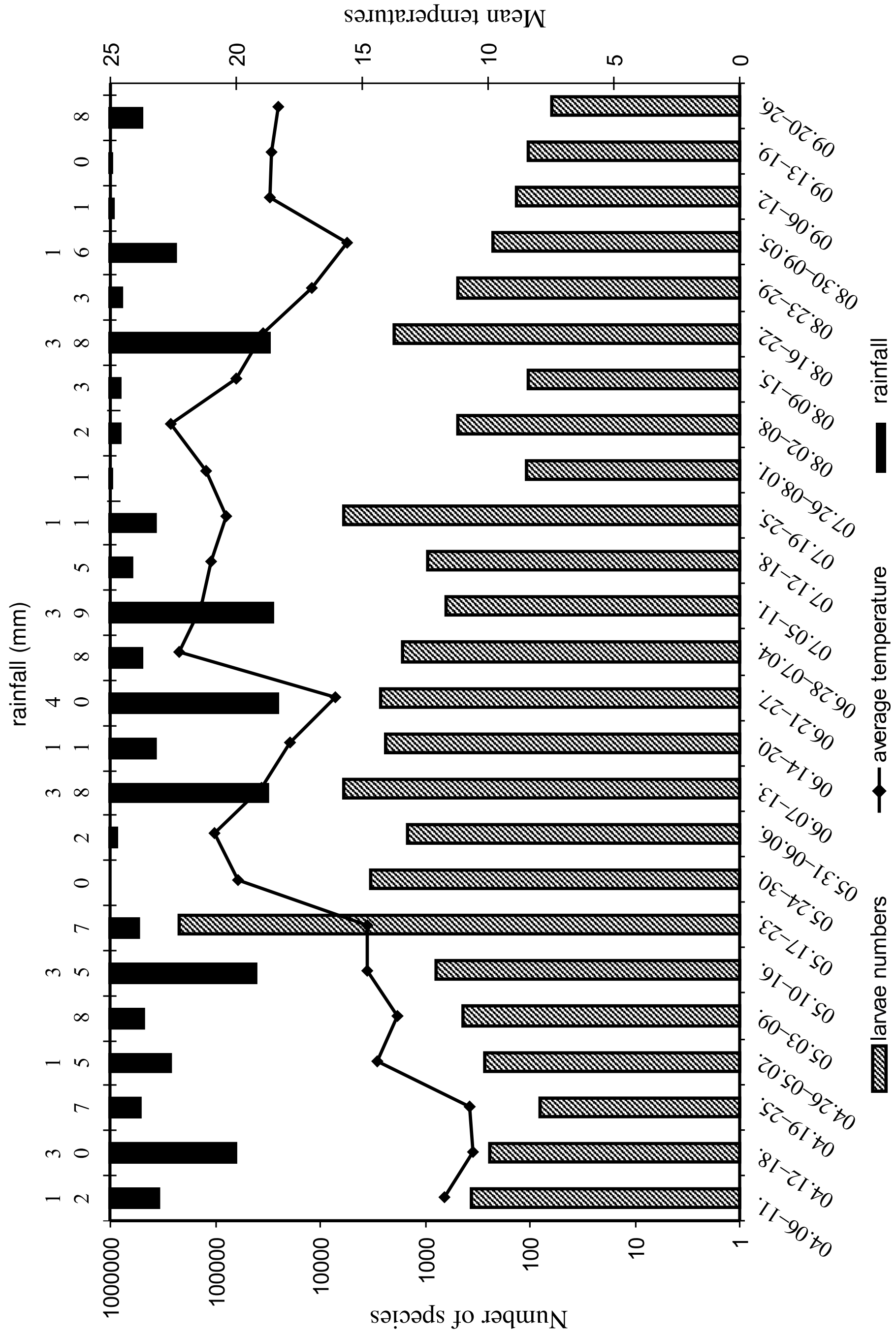

Fig. 7. Numbers of mosquito larvae collected in site mappings

Results and Discussion

Tables 1–5 contain the data on samples collected every week in site mapping in the region of Szigetköz. *Table 1* contains the total data on mosquito species representing the total area of Szigetköz. *Tables 2–5* contain data on the districts (I–IV).

Total data show that *Aedes vexans* dominated among the species being present. It was to be observed throughout the breeding period set for site mapping. The other *Aedes* species were present in smaller numbers and mainly in the first part of the breeding period. Their occurrence seemed to be sporadic during the year except for the larvae of *Aedes sticticus,* which were collected in the middle of the breeding period.

Culex pipiens pipiens clearly dominated among the Culex species being continuously present from 19 April *(Table 1)* together with *Culex territans* but in substantially smaller numbers. The numbers of *Culiseta annulata* was almost the same as that of *Culex territans.*

It is remarkable that the species of *Anopheles maculipennis* were to be observed throughout the breeding season and in even numbers in the biotope.

Table 1 shows well that *Aedes vexans* was present in the largest numbers between 17–23 May and later on between 19–25 July but in smaller numbers in flooded areas. The outraging high numbers prove that the effect of the floods in Austria increased the water level even in the flood area, i.e. outside the Danube dam the shallow meadow was overflowed by 60–80 cm of water. As a result larvae hatched from all viable eggs in large numbers. Though the water covered the fields for a short period it was long enough for the larvae to develop and to transform into pupae and reach the imago stage. The fields were waterlogged only for a week from 19–25 July, which was long enough for an undisturbed development rhythm being necessary for the transformation into pupae. All this happened because the water temperature basically determines the rapidity of the development and the time needed. The temperatures of these stagnant waters reached or even exceeded 30 °C in this period.

Data in *Tables 2–5* prove that not every surface waters is suitable for larvae developing in large numbers. The total fauna of the species collected at site, confirm their presence during the whole breeding season, but proportional data reflect main differences. Therefore the dominance of *Culex pipiens pipiens* and the regular appearance of *Anopheles maculipennis* in the districts I–II was confirmed, too. It also proves that *Aedes vexans* and the other *Aedes* species can be found in smaller numbers in these territories, further it proves that they can only dominate in numbers if the ground surfaces are temporarily covered with water (waterlogged) because these species lay their eggs on the ground. In district III there were mosquitoes to be found from species representing *Aedes vexans* and *Culex pipiens pipiens.* The fauna of *Anopheles maculipennis* was to be regarded very remarkable in this district. In district IV the numbers of *Culex pipiens pipiens* was synchronous with the data coming from the other districts, which are valid for the change in the numbers of mosquitoes. We should mention *Aedes vexans,* which appeared in unusually large numbers. This is confirmed by the data on the period of 17th May – 6th June *(Table 5).*

Table 1

Numbers of larvae of mosquito species in Szigetköz

Date of collection month/week	Numbers of larvae of species living in waters																			
	Anopheles claviger Meig.	*Anopheles maculipennis* Meig.	*Aedes cantans* Meig.	*Aedes caspius* Pall.	*Aedes cataphylla* Dyar	*Aedes cinereus* Meig.	*Aedes excrucians* Walk.	*Aedes flavescens* Müll.	*Aedes rossicus* Dolb.	*Aedes rusticus* Rossii	*Aedes sticticus* Meig.	*Aedes vexans* Meig.	*Chaoborus* sp.	*Chironomidae* sp.	*Culex modestus* Fic.	*Culex pipiens pipiens* L.	*Culex territans* Walk.	*Culiseta annulata* Schr.	*Uranotaenia unguiculata* Edw.	Totally
04.06–11.			178		48			51	35	2	2	38	2	2						358
04.12–18.		20	134		15			7	6	1		41	21							245
04.19–25.		3	23		1		2	32	9			7				2		1		80
04.26–05.02		37		4						2		52	6			163	1	2		267
05.03–09.		17							1			121				8	9	274		430
05.10–16.		12	1								2	401				376	3			795
05.17–23.		11									181	220439				155	10	6		220802
05.24–30.		38							1		39	2995				247	1	1		3322
05.31–06.06.		53				2					3	90				1308		32		1488
06.07–13.		31									2	4273			1	1467	2	179		5955
06.14–20.		14									48	264			6	1931	4	76		2343
06.21–27.		18										88				2523	3	21		2653
06.28–07.04.		105				3					4	67			2	1369	29	44		1623
07.05–11.		4													38	576		20		638
07.12–18.		27							4		28	741			20	88	22			930
07.19–25.		26							2		2	5469				331	70	23		5923
07.26–08.01.		7									1	6				39	47	8		108
08.02–08.		40				1						2			10	303	130	4		490
08.09–15.		15													6	20	25	37		103
08.16–22.	6	37										200			1	1694	7	14		1959
08.23–29.		26		5							8	308			22	85	3	37	2	496
08.30–09.05.	3	20										2				99	99	3		226
09.06–12.	2	15										15			3	30	20	49		134
09.13–19.	1	7										22				15	31	27		103
09.20–26.	9	2										1			9	18	11	12		62
09.27–10.03.																				
Totally:	21	585	336	9	64	6	2	90	58	5	320	235642	29	2	118	12847	527	870	2	251533

Table 2

Numbers of larvae of mosquito species in district I

Date of collection month/week	Numbers of larvae of species living in waters																			Totally
	Anopheles claviger Meig.	*Anopheles maculipennis* Meig.	*Aedes cantans* Meig.	*Aedes caspius* Pall.	*Aedes cataphylla* Dyar	*Aedes cinereus* Meig.	*Aedes excrucians* Walk.	*Aedes flavescens* Müll.	*Aedes rossicus* Dolb.	*Aedes rusticus* Rossii	*Aedes sticticus* Meig.	*Aedes vexans* Meig.	*Chaoborus* sp.	*Chironomidae* sp.	*Culex modestus* Fic.	*Culex pipiens pipiens* L.	*Culex territans* Walk.	*Culiseta annulata* Schr.	*Uranotaenia unguiculata* Edw.	
04.06–11.			147		48									1						196
04.12–18.			117		15			3	1											136
04.19–25.		1	12					2												15
04.26–05.02		4														146				150
05.03–09.									1			1						270		272
05.10–16.												1				347				348
05.17–23.												183				106				289
05.24–30.		2										12				67		1		82
05.31–06.06.		18														32				50
06.07–13.																434		2		436
06.14–20.																965				965
06.21–27.												88				250		11		349
06.28–07.04.		9														606				615
07.05–11.																377				377
07.12–18.												2								2
07.19–25.		2														1				3
07.26–08.01.		2														3				5
08.02–08.		12														299				311
08.09–15.																18		3		21
08.16–22.	5	6														794				805
08.23–29.		6													22	10	2	3	2	45
08.30–09.05.		2														83	91	1		177
09.06–12.																1	17	5		23
09.13–19.		2															22	13		37
09.20–26.																	6	3		9
09.27–10.03.																				
Totally	5	66	276		63			5	2			287		1	22	4539	138	312	2	5718

Table 3

Numbers of larvae of mosquito species in district II

Date of collection month/week	Numbers of larvae of species living in waters																			
	Anopheles claviger Meig.	*Anopheles maculipennis* Meig.	*Aedes cantans* Meig.	*Aedes caspius* Pall.	*Aedes cataphylla* Dyar	*Aedes cinereus* Meig.	*Aedes excrucians* Walk.	*Aedes flavescens* Müll.	*Aedes rossicus* Dolb.	*Aedes rusticus* Rossii	*Aedes sticticus* Meig.	*Aedes vexans* Meig.	*Chaoborus* sp.	*Chironomidae* sp.	*Culex modestus* Fic.	*Culex pipiens pipiens* L.	*Culex territans* Walk.	*Culiseta annulata* Schr.	*Uranotaenia unguiculata* Edw.	Totally
04.06–11.								1					2							3
04.12–18.												40	20							60
04.19–25.																				
04.26–05.02												6	6							12
05.03–09.																				
05.10–16.		1																		1
05.17–23.		1																2		3
05.24–30.																				
05.31–06.06.		10														13				23
06.07–13.		2														756		1		759
06.14–20.																350				350
06.21–27.		14														2	1	2		19
06.28–07.04.		3														208				211
07.05–11.																				
07.12–18.		2										3				1				6
07.19–25.		2																		2
07.26–08.01.																	2			2
08.02–08.		3															4			7
08.09–15.																				
08.16–22.	1	15														857				873
08.23–29.		1														4				5
08.30–09.05.		1														5	2	2		10
09.06–12.																				
09.13–19.	1	4														3	9	14		31
09.20–26.	3														8	2	5	6		24
09.27–10.03.																				
Totally	5	59						1				49	28		8	2201	23	27		2401

Table 4

Numbers of larvae of mosquito species in district III

Date of collection month/week	Numbers of larvae of species living in waters																			Totally
	Anopheles claviger Meig.	*Anopheles maculipennis* Meig.	*Aedes cantans* Meig.	*Aedes caspius* Pall.	*Aedes cataphylla* Dyar	*Aedes cinereus* Meig.	*Aedes excrucians* Walk.	*Aedes flavescens* Müll.	*Aedes rossicus* Dolb.	*Aedes rusticus* Rossii	*Aedes sticticus* Meig.	*Aedes vexans* Meig.	*Chaoborus* sp.	*Chironomidae* sp.	*Culex modestus* Fic.	*Culex pipiens pipiens* L.	*Culex territans* Walk.	*Culiseta annulata* Schr.	*Uranotaenia unguiculata* Edw.	
04.06–11.										1										1
04.12–18.		20											1							21
04.19–25.								1				5								6
04.26–05.02		15																		15
05.03–09.		10															8	2		20
05.10–16.		11	1														3			15
05.17–23.		8									38	68				49	10	4		177
05.24–30.		32							1			594				71	1			699
05.31–06.06.		22				2					3	83				1206		23		1339
06.07–13.		11										31			1	30	2	42		117
06.14–20.		6									48	264				38	4	17		377
06.21–27.		3														71		8		82
06.28–07.04.		79									2	67			2	287	29	37		503
07.05–11.		1														74		1		76
07.12–18.		25							4		27	478			20	65	22			641
07.19–25.		6							2		2	5462				315	70	4		5861
07.26–08.01.		5									1	5				36	45			92
08.02–08.		20				1						2			10	4	125			162
08.09–15.		7													5	2	23	2		39
08.16–22.		16										200			1	43	3			263
08.23–29.		19		5							8	308				65		1		406
08.30–09.05.	3	17										2				11	6			39
09.06–12.	2	15										15			3	28	3	5		71
09.13–19.		1										22				12				35
09.20–26.	6	1										1			1	4				13
09.27–10.03.																				
Totally	11	350	1	5		3		1	7	1	129	7607	1		43	2411	354	146		11070

Table 5

Numbers of larvae of mosquito species in district IV

Date of collection month/week	Numbers of larvae of species living in waters																			
	Anopheles claviger Meig.	*Anopheles maculipennis* Meig.	*Aedes cantans* Meig.	*Aedes caspius* Pall.	*Aedes cataphylla* Dyar	*Aedes cinereus* Meig.	*Aedes excrucians* Walk.	*Aedes flavescens* Müll.	*Aedes rossicus* Dolb.	*Aedes rusticus* Rossii	*Aedes sticticus* Meig.	*Aedes vexans* Meig.	*Chaoborus* sp.	*Chironomidae* sp.	*Culex modestus* Fic.	*Culex pipiens pipiens* L.	*Culex territans* Walk.	*Culiseta annulata* Schr.	*Uranotaenia unguiculata* Edw.	Totally
04.06–11.			31					50	35	1	2	38		1						158
04.12–18.			17					4	5	1		1								28
04.19–25.		2	11		1		2	29	9			2				2		1		59
04.26–05.02		18		4						2		46				17	1	2		90
05.03–09.		7										120				8	1	2		138
05.10–16.											2	400				29				431
05.17–23.		2									143	220188								220333
05.24–30.		4									39	2389				109				2541
05.31–06.06.		3										4242				57		9		76
06.07–13.		18									2					247		134		4643
06.14–20.		8													6	578		59		651
06.21–27.		1														2200	2			2203
06.28–07.04.		14				3					2					268		7		294
07.05–11.		3										258			38	125		19		185
07.12–18.											1	7				22				281
07.19–25.		16										1				15		19		57
07.26–08.01.																		8		9
08.02–08.		5															1	4		10
08.09–15.		8													1		2	32		43
08.16–22.																	4	14		18
08.23–29.																6	1	33		40
08.30–09.05.																				
09.06–12.																1		39		40
09.13–19.																				
09.20–26.		1														12		3		16
09.27–10.03.																				
Totally	0	110	59	4	1	3	2	83	49	4	191	227699	0	1	45	3696	12	385	0	232344

Peak numbers were to observe between 17th–23th May, which was especially high. There were 220,188 larvae collected in this period. *Figure 1* represents the larvae density at the habitats. Heavy rainfalls, followed by a flood contributed to the rapid increase in the numbers of larvae, when the fields outside the dam were overflowed. The hatched larvae

Fig. 1. Mosquito larvae living in large numbers at the breeding sites

developed very quickly, which was also confirmed by continuously falling numbers of mosquitoes. After the flood receded the conditions of larvae development ceased to exist. *Figure 2* shows a flood area with trees, though the area dried out completely, the flood level was to be seen on the trunks of the trees. Further evidence can be seen in *Fig. 3,* which shows a continuous receding leaving stagnant puddles here and there from time to time and they ensure favourable breeding conditions for mosquitoes. A new, but smaller-size flooding in district IV enabled the larvae to develop between 12th–18th July. During this second flooding, which lasted only one week, smaller territories were overflowed. *Aedes vexans* developed synchronously in district III and IV, but in the latter one the site offered breeding conditions for one more week, so the peak numbers of the larvae fell on the period of 19th–25th July. The permanent overflowing in Szigetköz ensured the conditions of a biotope throughout the year. From time to time puddles or ponds with stagnant water form and offer excellent breeding conditions. Studying this phenomena might contribute to settling and carrying out a comprehensive “mosquito control programme” in Szigetköz. The differences from other biotope are related to the special geological capabilities of

Fig. 2. Dried territories after the flood receded

Fig. 3. Stagnant waters after the flood receded

Szigetköz, i.e. there are some hundred meters pebble layers (200–600 m) beneath the surface, which help to develop stagnant water tables depending on the water level of the Danube for shorter or longer periods of time. Stagnant waters are habitats which ensure breeding conditions for the development of mosquito larvae (e.g. *Aedes vexans*) during a short period but of course always depending on water temperatures. We should also mention that in the course of site mapping we found areas which were overflowed only for 2–3 days. It is especially important, because the development of embryos starts under the seemingly favourable conditions, but if the conditions cease to exist their development will not finish and the embryos or maybe the hatched larvae will die.

After the identification of the mosquito larvae collected at 64 sites *Aedes* species were to be found in the largest numbers and *Aedes vexans* dominated (94.04%) among them. *Culex pipiens pipiens* was dominating among the Culex species sharing 5.36% of the larvae population. The species Anopheles, Chaoborus and Culiseta species had a very low share in the mosquito population. Concerning public health aspects the occurrence of Anopheles maculipennis cannot be left out of account *(Fig. 4).*

The mosquitoes collected at the sites greatly differed in numbers as a result of different biotope conditions *(Fig. 5).* In the future one has to consider the conditions of habitats, which the development of mosquito larvae is bound to. Therefore it is inevitable to study the surface waters (rivers, creeks, canals, gravel pits, ground water, temporarily waterlogged fields, etc.) and to explore the permanent and temporary habitats. Air mapping and inspection of the relevant territories would greatly help in solving the task. Based on the results of the year 1999 and considering the data in *Fig. 5,* we may conclude that district IV offered the most favourable conditions with regard to habitats. The number of larvae collected in this district (IV) amounted 232,344, which give an evidence. There were 5,718 larvae in district I, 2,401 larvae in district II, and 11,070 larvae in district III collected and identified.

The distribution of the larvae species was different in the districts. In districts I and II the species Culex dominated by 82.20% and 92.96%, respectively, in the population. In districts III and IV Aedes species dominated by 70.04% and 98.10%, respectively *(Fig. 6).* These data confirm the fact, when the territories are under water (waterlogged), where the Aedes species laid their eggs before, mosquito larvae would hatch in large numbers and a temporary mosquito invasion would start following an imago swarming initiated by a flood.

Data collected every week were compared with the data on the development of rainfall and mid-summer temperatures. *Figure 7* represents the numbers of mosquitoes calculated on logarithm values. Logarithm was used because of the differences in the numbers and for the sake of better representation. The amount of rainfalls in April–May and June–July favourably influenced the breeding conditions at the sites. Of course, we should evaluate them together with the overflowing. The common effect of both facts helped us to collect the largest numbers of larvae between 17th–23rd May. The result of the second flood could be evaluated between 19th–25th July. Herewith we should mention that the mid-July temperature exceeded 20 °C for a long period, which is well shown in *Fig. 7.* Favourable climatic and biotope conditions (stagnant waters with temperatures of 30 °C and above) ensured together that the transformation into imago took as much as one week.

Site mappings under similar conditions and with similar concepts should be carried out in the future as the optimal timing of controls can only be fixed after several years of results. This refers both to the biological control applied against larvae and to insecticide applications against imagoes.

Conclusions

Inspecting the territory we can determine the biotope, the habitats and the size of overflowing. The concentration of cisterns and open water containers should be measured as well.

Biotope conditions are always ensured in permanent waters, but studies proved that relatively small numbers of larvae can develop under such circumstances, so cold waters of rivers and gravel pits do not dominate as breeding places.

In the course of seasonal floods shallow puddles are formed owing to the high level of ground water. They get warm quickly, so eggs laid on the ground hatch and larvae transform into imago within 4–6 days.

Tracing the development rhythm of larvae and the detection of imago swarming could give a proper basis for optimal timing and for controlling (biological and insecticide). It could also involve immediate measurements. Flooding and high temperature together induce rapid development of larvae. In this case biological control should be applied on 2nd or 3rd day following the hatching of larvae, because the larvae are to be found in the most ideal stage ($L_2 - L_3$) for control. Optimal timing of control against imagoes is the beginning of swarming as long as they are near the habitats.

The number of generations is determining in relation to the seasonal distribution. The species of one generation appear early spring in April–May and are members of the mosquito population in June–July. Swarming of other species like *Aedes vexans* can be expected in large numbers seasonally, but not time bounded, when eggs laid on the ground are overflowed.

Further investigations should be carried out in order to clear the role of the species and their course of development. Several years of studies are needed to answer the question of how biotope and habitats influence the dominance of species. Our results confirm the influencing role of different conditions in the districts and the dominance of *Aedes vexans* and *Culex pipiens pipiens.*

Information about the quality and temperatures of waters is needed to evaluate the habitats, so we should carry out measurements continuously.

In algae and/or duckweed grown waters there are no mosquito larvae or only in very small numbers.

Owing to fluctuations of ground water some fields might only be overflowed for 2–3 days, so larvae were able to hatch but died after the water had disappeared. Theoretically the control of the water level meant physical protection at the same time. Though its practical realisation is unimaginable at the moment.

The numbers of *Anopheles maculipennis* is remarkable with reference to health aspects, too.

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Literature

Becker, N. (1986): 10 Jahre Kommunale Aktionsgemeinschaft zur Bekämpfung der Schnakenplage e. V. Biologische Stechmückenbekämpfung – ein Modell am Oberrhein. Verlag Amelung und Hollatz, Heidelberg, 1–89 pp.

Entwistle, P. F., Cory, J. S., Bailey, M. J. and Higgs, S. (1993): *Bacillus thuringiensis.* An Environmental Biopesticide: Theory and Practice. John Wiley and Sons, Chichester – New York – Brisbane – Toronto – Singapore, 1–311 pp

Erőss, J. (1988): Szúnyogirtás larvicid szerekkel (Abate, Viodat, Teknár) (Mosquito control with larvicides /Abate, Viodat, Teknár/). Parasit. Hung. 21, 99–103.

Fászl, I. (1878): Adatok Sopron légyfaunájához (Figures about the fly fauna of Sopron) – A Pannonhalmi Szent Benedek Rend soproni Kath. főgimnasiumának értesítője az 1877/78. tanévről, 6 p.

Günther, K., Hannemann, H. J., Heike, F., Königsmann, E. and Schumann, H. (1970): Urania állatvilág, Rovarok (Urania Animal World, Insects). Gondolat Kiadó, Budapest 399–407.

Katheb-Bader, A., Khyami-Horani, H. and Mohsen, Z. H. (1999): Effect of temperature on the susceptibility of *Culiseta longiareolata* (Macquart) (Dipt.; Culicidae) to two standard strains of biocontrol bacteria. J. Appl. Ent. 123, 629–63l.

Kecskeméti, I. and Tóth, S. (1981): A csípő szúnyog (Culicidae) fauna minőségi és mennyiségi változásai a Balaton északi partján. (Qualitative and quantitative changes in the biting mosquito /Culicidae/ fauna on the northern shore of Lake Balaton. – Recent Results in the Balaton Research II) A Balaton kutatás újabb eredményei II. VEAB Monográfia 16, 211–214.

Kertész, K. (1904): A magyarországi szúnyogfélék rendszertani ismertetése (Taxonomic description of mosquito species of Hungary). Állattani közlemények 3, 1–75.

Kölüs, G. and Tóth, S. (1979): Az ízeltlábú populáció változása a balatoni szúnyogirtás során 1976–1978-ban. (Changes in the arthropodal population in the course of mosquito control at Lake Balaton in 1976–1978) VEAB Értesítő 1, 284–288.

Kuroli, G. (1999): Biológiai csípőszúnyog gyérítés kivitelezéséhez szükséges felmérések és vizsgálatok elvégzése a Szigetköz körzetében (Surveys and investigations carried out for the sake of the biological control of biting mosquito species in the region of Szigetköz). Beszámoló jelentés. Mosonmagyaróvár, 1–77 pp.

Lőrincz, F. and Mihályi, F. (1937a): Adatok a hazai maláriakérdés ismeretéhez. III. Tanulmány az *Anopheles maculipennis* varietasok hazai előfordulására vonatkozólag (Data on the malaria problem in Hungary. III. Study on the occurrence of *Anopheles maculipennis* varieties in Hungary). Népegészségügy, 15–20 pp, 30–42 pp

Lőrincz, F. and Mihályi, F. (1937b): Adatok a hazai maláriakérdés vizsgálatához (*Anopheles maculipennis* tanulmányok). [Contribution to the examination of the malaria question in Hungary (*Anopheles maculipennis* studies)]. Állattani Közl. 35, 1–11.

Lőrincz, F. and Mihályi, F. (1938): Adatok a hazai maláriakérdés vizsgálatához (*Anopheles maculipennis* tanulmányok). [Contribution to the examination of the malaria question in Hungary (*Anopheles maculipennis* studies)]. Állattani Közl. 35, 176–186.

Makara, Gy. and Mihályi, F. (1943): Rovarok és betegségek (Insects and Diseases). Magyar Orvosi Könyvkiadó, Budapest, 1–394 pp.

Makara, Gy. and Székely, S. (1940): Az *Anopheles maculipennis* és messeae áttelelési módjára vonatkozó vizsgálatok (Studies on the overwintering of *Anopheles maculipennis* and messeae). Állattani Közl. 35, 169–185.

Mihályi, F. (1941): A Balaton-partvidék Culicidái (Culicidae of the coastal region of Lake Balaton). Magyar Biol. Kut. Munk. 13, 168–174.

Mihályi, F. (1955): Igazi szúnyogok. Culicidae (True mosquito species Culicidae). Fauna Hung. 14 (5), 1–40.

Mihályi, F. (1959): Revision der aus dem Karpatenbecken stammenden Stechmücken der ungarischer Dipteren-Sammlungen Rovart. Közl. ser. nova 12, 140–162.

Mihályi, F., Sztankay-Gulyás, M. (1963): Magyarország csípő szúnyogjai (Biting mosquito fauna of Hungary). Akadémiai Kiadó, Budapest 1–229 pp.

Mihályi, F., Soós, Á. and Sztankay, M. (1952a): Ökologie und Ethologie der Culiciden im Ufergebiet des Balaton Sees. Ann. Biol. Univ. Hung. 1, 79–105.

Mihályi, F., Soós, Á., Sztankay-Gulyás, M. and Zoltay, N. (1952b): Préparatifs entomologiques pour la lutte contre les mostiques piquers et le paludisme sur les bords du lac Balaton, I. partie. Acta Biol. Hung. 3, 333–364.

Mihályi, F., Soós, Á., Sztankay-Gulyás, M. and Zoltay, N. (1953a): A Balaton-menti községek szúnyoghelyzete és a gyakorlati védekezés módjai (Mosquito situation in the settlements alongside Lake Balaton and practices of control). A Magyar Tud. Akad. Biol. Oszt. Közlem. 2, 35–94.

Mihályi, F., Soós, Á., Sztankay-Gulyás, M. and Zoltay, N. (1953b): Les Moustiques picueurs dans les localités et les procédés défensifs pratiques, II. partie. Acta Biol. Hung. 4, 1–68.

Mihályi, F., Soós, Á., Sztankay-Gulyás, M. and Zoltay, N. (1954): L'envahissement des Moustiques dans les zones d'inondation du Danube. Acta Zool. Hung. 1, 105–128.

Mihályi, F. and Zoltay, N. (1956): Contributions to the occurrence of Culex pipiens molestus in Hungary. Acta Zool. Hung. 2, 263–268.

Mihályi, F., Soós, Á., Sztankay-Gulyás, M. and Zoltay, N. (1956): Rechecnes informatives sur l'envahissement des Moustiques des regions plates de la Hongrie. Acta Zool. Hung. 2, 245–262.

Rehimi, N. and Soltani, N. (1999): Laboratory evaluation of Alsystin, a chitin synthesis inhibitor, against *Culex pipiens pipiens* L. (Dip., Culicidae): effects on development and cuticle secretion. J. Appl. Ent. 123, 437–441.

Sáringer, Gy. (1980): A balatoni szúnyogirtás (Mosquito control at Lake Balaton). Természet Világa 222, 326–327.

Sáringer, Gy. (1983a): A helikopteres balatoni szúnyogirtás és a környezetvédelem (Mosquito control by helicopter and environmental protection at Lake Balaton). Georgikon 26, 7–10.

Sáringer, Gy. (1983b): A helikopteres balatoni szúnyogirtás hatása az ízeltlábú (Arthropoda) populációra (Effect of mosquito control by helicopter on the arthropodal population at Lake Balaton). METESZ Kiadvány, Keszthely, 59–68 pp.

Sáringer, Gy. (1988): Effect of mosquito control by helicopter on the fauna of the ecosystem treated in Hungary. Acta Phytopath. et Ent. Hung. 23, 231–233.

Sáringer, Gy., Tóth, S., Dévai, Gy., Forró, L., Vásárhelyi, T., Ponyi, J. and Kölüs, G. (1984): A balatoni szúnyogirtás tapasztalatai (Experiences of mosquito control at Lake Balaton). Természet Világa 115, 294–297.

Sáringer, Gy., Szalay-Marzsó, L. and Tóth, S. (1998): Experiences with the use of *Bacillus thuringiensis* subsp. *israelensis* in Hungary at Lake Balaton. Israeli J. Entomol. 32, 79–87.

Tóth, S. (1979): A helikopteres szúnyogirtás entomológiai hatásainak előzetes vizsgálata a Balaton-parton (Preliminary study on the entomological effects of mosquito control by helicopter on the shore of Lake Balaton). A Veszprém Megyei Múzeum Közlem. 14, 245–250.

Tóth, S. (1991): Adatok a mocsári szúnyog, *Mansonia* (Coquillettidia) *richiardii* (Ficalbi, 1889) életmódjához és magyarországi elterjedéséhez (Diptera: Culicidae) (Data on the way of life of the marsh-mosquito, *Mansonia* /Coquillettidia/ *richiardii* /Ficalbi, 1889/ and on its distribution in Hungary/ Diptera: Culicidae). Fol. Must. Hist.-nat. Bakonyiensis 10, 137–178.

Tóth, S. (1996): Környezetkímélő védekezéssel a csípő szúnyogok ellen a Balatonon (Ecological safe protection against biting mosquito at Lake Balaton). Napló, 1996, 18 March.

Tóth, S. and Sáringer, Gy. (1997): Mosquitos of the Lake Balaton and their Control. Acta Phytopath. et Ent. Hung. 32, 377–391.