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QUANTITATIVE RELATIONSHIPS OF THE ROTATORIA PLANKTON IN LAKE BALATON DURING 1965–1966

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This paper reports the events preceding the situation in 1967 (ZÁNKAI and PONYI, 1970). The examinations were carried out with the aim to obtain an answer to the question whether the low individual numbers in the years before 1967 had been characteristic, or only the above year was unfavourable for the growth of the Rotatoria plankton.

Materials and methods

Collections were made once monthly from June to October in 1965, and from May to November, 1966. The places of sample takings were the same in both years, the numbers of sampling sites, however, differed. In 1965 the samples were collected from one point of each of the transversal sections (marked with 0), whereas in 1966 from three points of each of them. The detailed description of the transversal sections, the points of sample takings as well as the methods of sampling and treatment of the material have been presented in previous publications (SEBESTYÉN, 1960; ZÁNKAI and PONYI, 1970).

In the figures the letters for marking the transversal sections are indicated on the abscissas. Within each of the transversal sections the succession of the sampling points is the following: $M_1\ M_0\ M_2\ K_0\ K_1\ K_2\ G_1\ G_0\ G_2\ A_1\ A_0\ A_2\ E_0\ E_1\ E_2$.

Results

Examinations in 1965 revealed the presence of only 12 species, varieties and forms respectively in the transversal sections representing the whole area of the lake *(Table I)*. Among the species the following five dominated:

TABLE I

The quantitative distribution of number per liter of Rotifera plankton at one sampling site of each of the five transversal sections between June and Sept. in 1965

Species	Data of collection	M.	K.	G.	A.	E.
Bdelloidea sp.	X. 13—14	1				
Collotheca balatonica VARGA	VIII. 4.					1
Kellicottia longispina KELLICOTT	VI. 9—10			3	1	2
	VII. 1— 2	1				2
	VIII. 3— 4	5	4	2		
	IX. 7— 8	2	10	3		
	X. 13—14		2	4		2
Keratella cochlearis (GOSSE)	VI. 9—10	1	1	12	15	19
	VII. 1— 2	2			4	13
	VIII. 3— 4	245	91	26	21	8
	IX. 7— 8	33	7	14	23	84
	X. 13—14		5	25		45
Keratella cochlearis macracantha f. *micracantha* LAUTERNORN	VII. 1	1				
	VIII. 3		4			
	X. 14					1
Keratella tecta (GOSSE)	VI. 9—10		1	1	2	2
	VII. 1— 2	1			4	24
	VIII. 3— 4	105	61	26	22	14
	IX. 7— 8	22	4	7	2	15
	X. 13—14	1	5	15		10
Keratella quadrata (O. F. MÜLLER)	VI. 9—10		1	1	1	2
	VII. 1— 2	2			1	1
	VIII. 3— 4	21	15			
	IX. 7— 8	13	2	4		
	X. 13—14		1	2		
Lecane affinis (LEVANDER)	X. 13	1				
Polyarthra vulgaris CARLIN	VI. 9—10		2		10	
	IX. 7— 8				46	61
	X. 13—14	19	79	244		101
Pompholyx sulcata HUDSONN	VI. 10			4	13	5
	VII. 2				96	38
	VIII. 3			1	22	48
	IX. 7			20	82	13
	X. 13			19		6
Trichocerca pusilla (JENNINGS)	IX. 7	4				
	X. 13	1				2
Synchaeta oblonga EHRBG.	X. 13	16	50	6		

The samples collected at the sites K, G (1. VIII) and A (13. X) were broken.

Keratella cochlearis, K. c. tecta, K. quadrata, Polyarthra vulgaris, Pompholyx sulcata.

On the basis of the averages of the numbers per liter of individuals in the five months investigated it can be stated that highest numbers occurred along transversal section "G" representing the central areas of the lake *(Table II)*.

TABLE II

Total numbers per liter of Rotatoria of the individual transversal sections of the lake expressed as the averages of 5 (1965) and 7 (1966) months

	M	K	G	A	E
1965	100	86	110	92	104
1966	137	170	195	154	152

Following the changes of the total numbers (i/lit.) of Rotatoria in the individual months of 1965 it is seen that there was only one maximum during August in the Bay of Keszthely. The situation along transversal section "K" was similar to some extent. Here the higher maximum in August was followed by a second one in October. Along the transversal sections of the north-east basin ("E", "A") and along transversal section "G", the slight increase in numbers in summer was followed by a greater maximum in autumn *(Fig. 1)*.

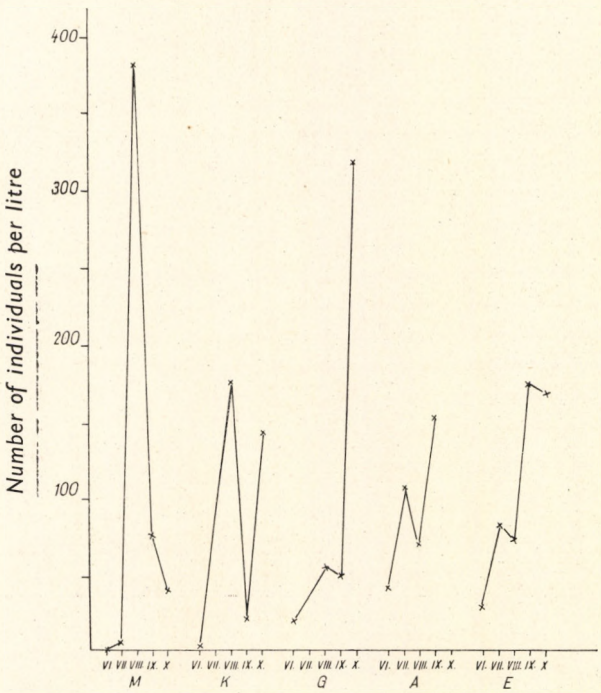

Fig. 1. Monthly changes of total numbers per liter of Rotatoria at one point of each of the transversal sections in 1965

This variation in total numbers is due to shifting in the population dynamism of dominating species. Thus, the August maximum at Keszthely ("M") was first of all yielded by the contribution of 245 i/litre of *Keratella cochlearis*, while at the same time along transversal section "G" and in the north-east basin, numbers of 26—21—8 i/litre of this organism were registered. Just the opposite situation was observed in September, when a gradual decrease in numbers of *K. cochlearis* from the transversal section towards the Bay of Keszthely was observed.

There were also considerable differences in the population density of *K. c. tecta* during August between the Bay of Keszthely and its surroundings resp. and the other areas of Lake Balaton *(Table I)*. Values of the total population density were especially increased along two transversal sections in the north-east basin by the contribution of the summer (June) maximum of *Pompholyx sulcata*. Greater individual numbers per liter of *Polyarthra vulgaris* were registered in September and especially during October everywhere but in the Bay of Keszthely. Its reproduction appears to have been monocyclic in 1965. The quantitative distribution in the lake of *Keratella quadrata* was not uniform. This species occurred in greatest numbers in the south-east basin *(Table I)*.

Besides the dominating species, *Bdelloidea* sp. and *Lecane affinis* of the species found only in a few specimens may be regarded as tychoplanktic elements.

The 7-month averages of the individual numbers per liter collected at three sampling sites of each of the five transversal sections during 1966 show the greatest numbers occurred in the central area (transversal section "G") of the lake, and the smallest ones in the Bay of Keszthely, while the population density along the two transversal sections of the north-east basin was the same *(Table II)*.

Averaging the numbers per liter obtained at each of the points of the transversal sections during the whole examination period it is seen that differences exist between the sampling points at both the northern and southern shores and the sampling places along the longitudinal axis of the lake. It is seen, that the population density of Rotatoria was higher near to the shores in the vicinity of the Bay of Keszthely and Szigliget (transversal sections "M" and "K" respectively) than along the longitudinal axis of the lake. Higher values were obtained at sampling points in the middle of transversal section "A", and near the southern shore on transversal section "G". No considerable differences were observed along transversal section "E" *(Table III)*.

Average values of total numbers per liter of Rotatoria on the transversal sections show that the dynamism of the populations in the two basins was

TABLE III

7-month averages of total numbers pro litre of Rotatoria at different points of the transversal sections in 1966

M_1	M_0	M_2	K_0	K_1	K_2	G_1	G_0	G_2
165	136	148	187	155	169	217	188	182
A_1	A_0	A_2	E_0	E_1	E_2			
139	166	156	166	169	170			

different *(Fig. 2)*. In the Bay of Keszthely and along transversal section "K" the spring rise in population density did not come about, instead a very great increase in summer (August) and a smaller one in autumn occurred. In the central part of the lake (transversal section "G") there were likewise two increases in population density. The high increase in August, however, did not

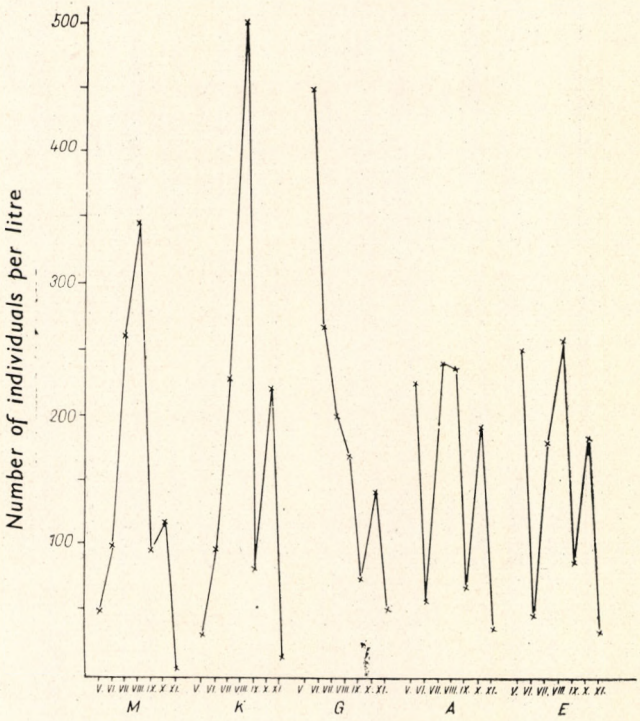

Fig. 2. Monthly changes of total numbers per litre of Rotatoria, expressed as the averages of three points of each of the transversal sections in 1966

take place. The high individual numbers in May gradually decreased until October. Three values were registered in each of the two sections in the northeast basin: one in spring (May), in summer (August), and autumn (October) respectively.

During the period of sample takings 26 species varieties and forms were found. Four species *(Keratella cochlearis, K.c. tecta, K. quadrata, Polyarthra vulgaris)* were found to occur in almost every transversal section and every examination period and one species *(Pompholyx sulcata)* was always missing from the Bay of Keszthely except in June. These were the dominating species in the Rotatoria plankton of Lake Balaton in the period ranging from May to November, 1966. The monthly changes of their population was the following:

The very small numbers of *Keratella cochlearis* along transversal section "M" in May shows a gradual increase which lasts until July, and falls to zero by November. There was increase in population numbers on two occasions registered along transversal sections "K" and "A" (months VII and X, and months V and VII resp.), and onece along "G" and "E" (month V) *(Fig. 3)*.

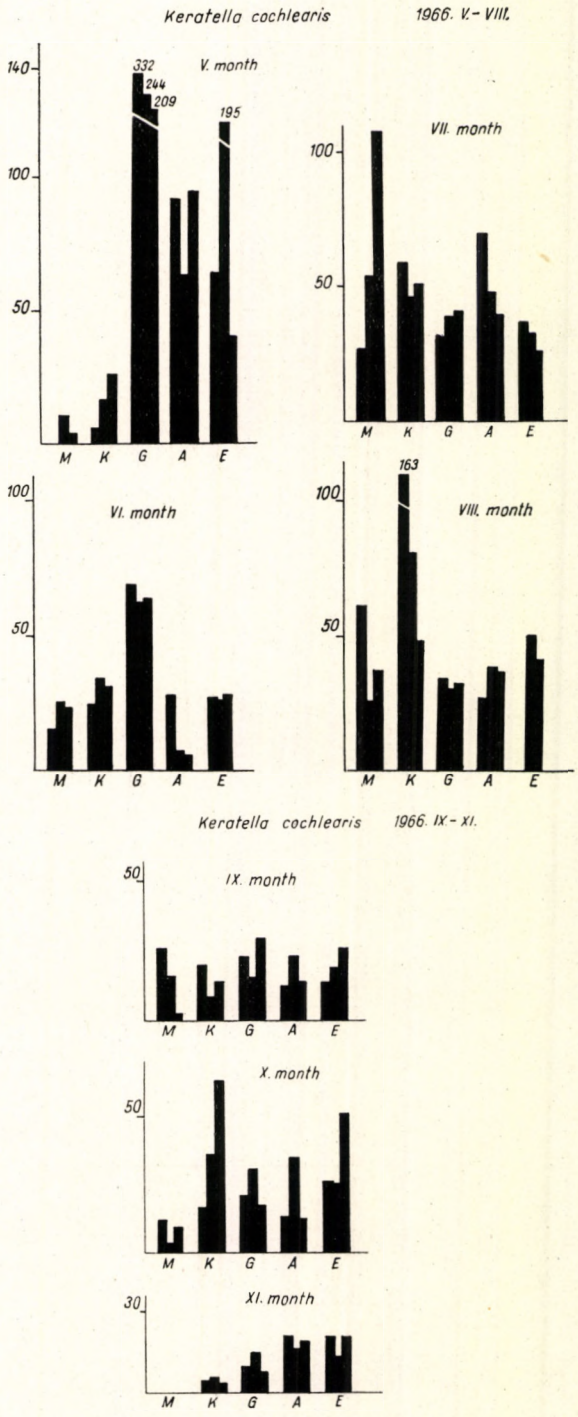

Fig. 3. Monthly changes of numbers per litre of *Keratella cochlearis* at three points of each of the transversal sections

There was only one increase in population of *Keratella cochlearis tecta* along transversal section "M" starting from zero in May and increasing to a maximum by August, and showing subsequently a considerable decrease *(Fig. 4)*. It appears that the great numbers per litre along transversal section "K" in summer are followed by another small increase in the autumn (month X).

The changes in population along transversal section "G" were similar. The changes in numbers of the species in the north-east basin may be characterized with a one-peaked curve (July). As regards its horizontal distri bution, its percentual contribution to the Rotatoria plankton is much greater in the south-west basin than in other areas of the lake.

Keratella quadrata (Fig. 5) is of about uniform density in the Bay of Keszthely in the period between June to October. By November, however, a decrease in number (i/litre) was registered. Its number per litre along transversal section "K" increases until August, thereafter decreases gradually reaching a value as low as one i/litre by November. Along transversal section C "G") in the middle of the lake and along two sections in the north-east basin, it contributed in about uniform distribution and with low numbers to the production of the Rotatoria plankton during the whole investigation period, except October. On the basis of its horizontal distribution two areas in the lake may be distinguished (areas bounded by "M" + "K" and "G"— "E" transversal sections, respectively).

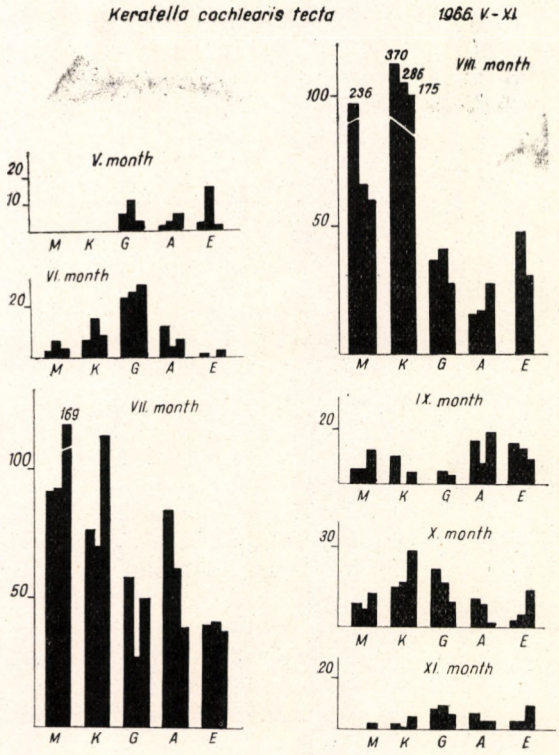

Fig. 4. Monthly changes of numbers per liter of *Keratella cochlearis tecta* at three points of each of the transversal sections

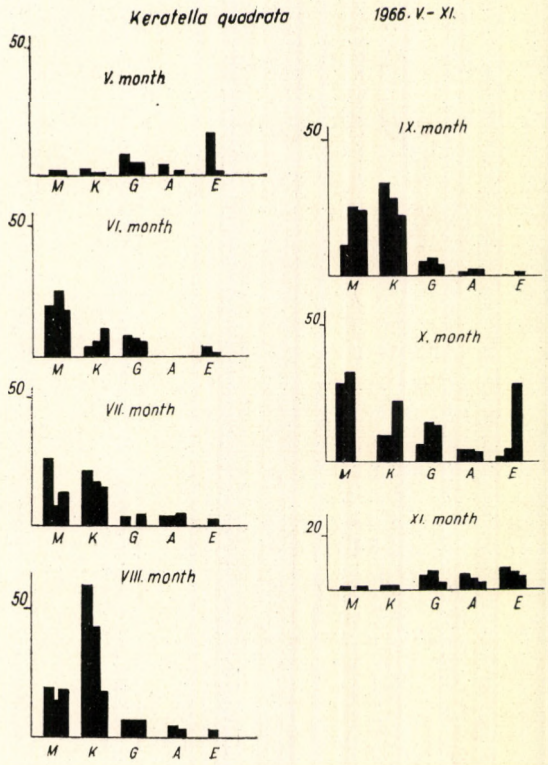

Fig. 5. Monthly changes of numbers per litre of *Keratella quadrata* at three points of each of the transversal sections

Polyarthra vulgaris. A definite increase in spring and autumn occurred in the Bay of Keszthely, and along transversal sections "G" and "E", showing the species to be dicyclic in these areas *(Fig. 6)*. Along transversal section "K" no increase in population took place in spring, and only one maximum in autumn was observed (monocyclic reproduction). Along transversal section "A" there were two or perhaps three increases in May, August and October. Considering its population density, this species seems to have greater importance in the areas bounded by transversal sections "G" — "E" (e.g.) in months V, VII, VIII, etc.)

Pompholyx sulcata was numerous along both transversal sections of the north-east basin in May. After a decrease in number in June, an increase in July followed reaching a maximum by August *(Fig. 7)*. During the subsequent months its population density was low. Along transversal section "G" in the south-west basin there was only one increase in numbers (month VI). Average numbers of 30 i per litre were observed also along transversal section "K" in that month which is explainable by the effect of the prevailing wind of the lake.

Other species. Besides the above five species occurring in greatest numbers and density, the other 21 *(Table IV)* seem to play with their low numbers a subordinate role in the Rotatoria plankton of the lake. Most of these species

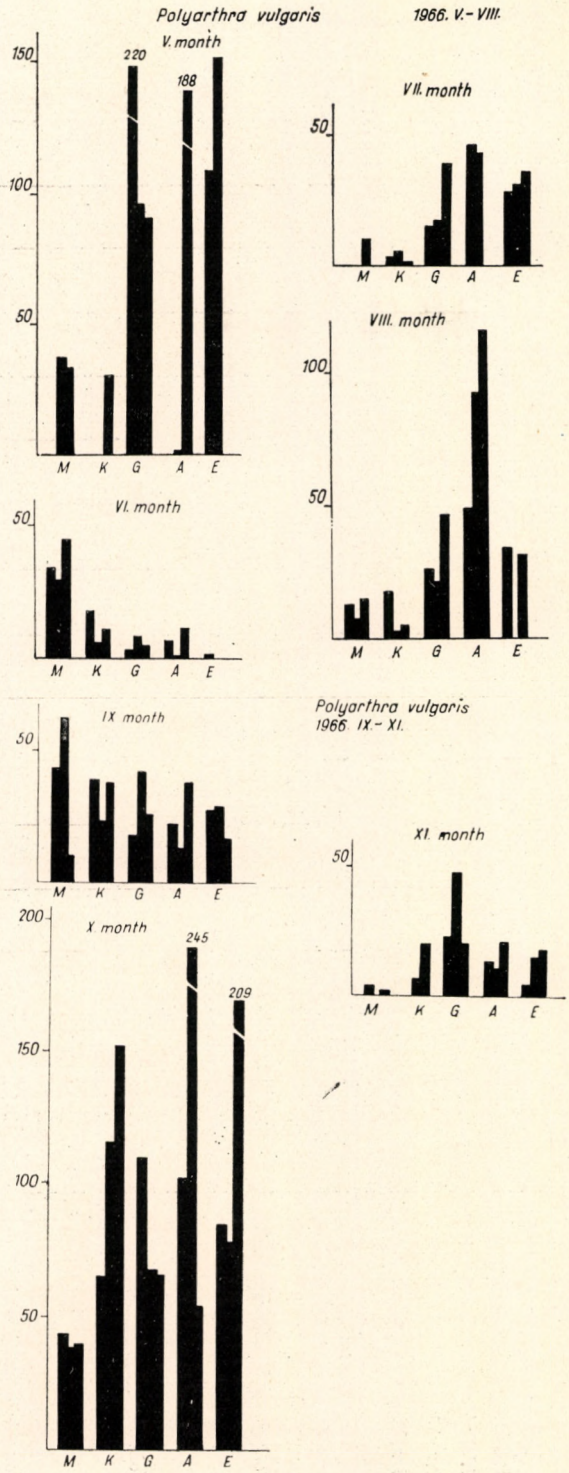

Fig. 6. Monthly changes of numbers per litre of *Polyarthra vulgaris* at three points of each of the transversal sections

TABLE IV

Quantitative data of the number of individuals per litre of infrequent species in 1966

Species	Data of collection	M			K			G			A			E		
		M_1	M_0	M_2	K_0	K_1	K_2	G_1	G_0	G_2	A_1	A_0	A_2	E_0	E_1	E_2
1. *Asplanchna girodi* GOSSE	V. 17—18							1					2			1
	VIII. 24														3	
	IX. 22											1			3	
2. *Asplanchna priodonta* GOSSE	X. 18						1									
3. *Bdelloidea* sp.	VII. 26					1										
4. *Brachionus angularis* GOSSE	V. 17									2						
5. *Brachionus sessilis* VARGA	VII. 26—27				1		2	3		6	5	1		4	4	6
	VIII. 23—24							1	1		2	1	3		1	
	IX. 21—22															
6. *Chephalodella gibba* (EHRBG.)	VIII. 23			4												
	X. 18				2											
7. *Collotheca balatonica* VARGA	VI. 14—15								3							1
	VII. 26—27							2			5					
	VIII. 23—24							1					3			
	IX. 21—22							2		2	1			1		
	X. 19										1					
8. *Collotheca* sp.	V. 18												1			
	VI. 15														1	
	IX. 22										1		1	1		
	X. 18—19					1									1	
	XI. 15								1							
9. *Conochilus unicornis* ROUSSELET	V. 17									5						
	VIII. 24											1				
10. *Filinia longiseta* (EHRBG.)	VI. 14				3											
11. *Kellicottia longispina* KELLICOTT	V. 17—18			5	4	7	6	5	8	3	9	12	8	6	16	4
	VI. 14—15		2	3	7	6	7	9	14	5	2	1	6	5		2
	VII. 26—27		6		8	5	1	3	9	4	3	4	4		2	1
	VIII. 23—24		4	4	8	4	4	2	5		1		1		1	1
	IX. 21—22	4	1	2		5	1	2	7		2	1	1	2	4	2

	X. 18—19							1	2	2			1		1	1
	XI. 15—16					1		1	1			1			1	1
12. *Keratella cochlearis macracantha* LAUTERBORN	V. 17									2						
	VI. 14						1									
13. *Keratella cochlearis macracantha* f. *micracantha* LAUTERBORN	VII. 1		1													
	VIII. 23			4	4											
	IX. 22												1			
	X. 18—19					3			1							2
	XI. 15—16								1					1	1	
14. *Polyarthra major* BURCKHARDT	V. 17		2													
	VI. 4		4													
	IX. 21		1													
	X. 18	24						1								
15. *Synchaeta kitina* ROUSSELET	VIII. 23.		18	22	15											
	IX. 21					2										
	X. 18—19			9		9					10	4				
16. *Synchaeta oblonga* EHRBG.	VI. 14	7	4	7												
	VII. 26		9	26	9	2	26		1	2						
	VIII. 23	64	17	49	26	32	4									
	IX. 21	20	8	2												
	X. 18—19	39	28	24			87			4	29	26				
	XI. 15	1		2		1	2	4	1	2						
17. *Trichocerca inermis* (LINDER)	VII. 26				7											
18. *Trichocerca pusilla* (JENNINGS)	V. 18															1
	VI. 14		2	3			1									
	VII. 6—27		32	45	51	28	61	61	49	52	19	7		29	13	2
	VIII. 23—24	88	29	82	80	50	27	24	26	43	4	18	15		51	29
	IX. 21—22				2	2	4	4	3	4	1	3	2	6		2
	X. 18—19						3					1			1	1
19. *Trichocerca rattus* (O. F. MÜLLER)	VII. 26		6													
	VIII. 23		33													
20. *Trichocerca rousseletti* (VOIGT)	VII. 26—27		6	42											6	1
	VIII. 23	17		22												
	IX. 21—22								1		1	1				
	X. 18									2						
21. *Trichocerca stylata* (GOSSE)	VII. 27										1					

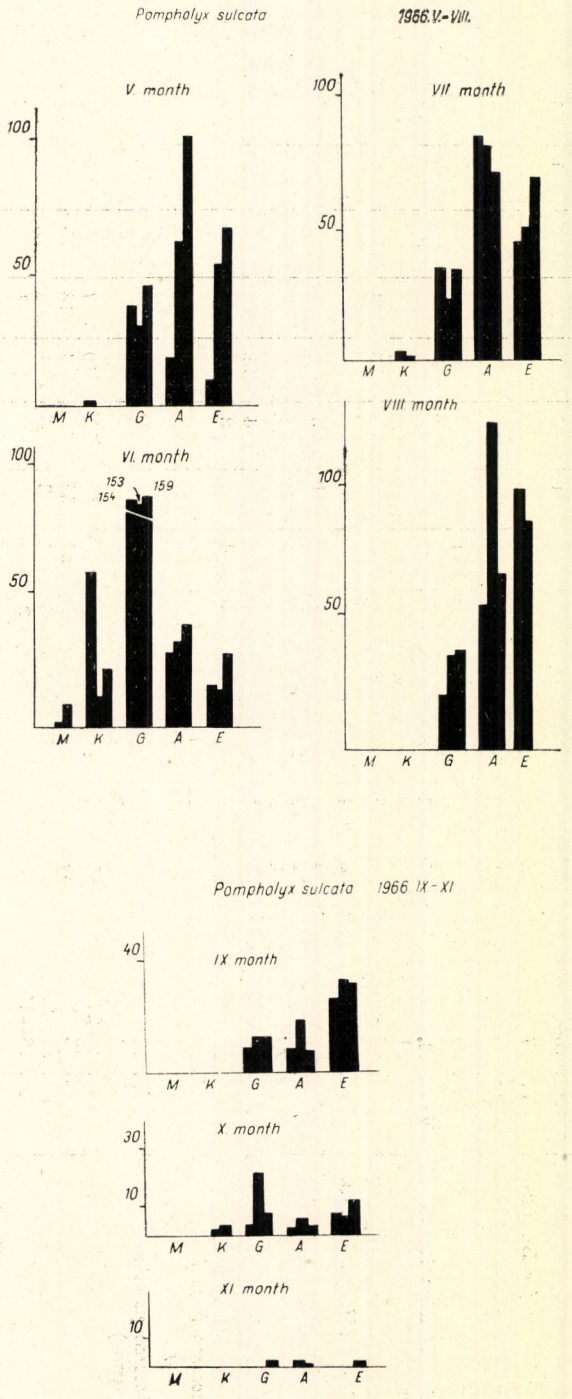

Fig. 7. Monthly changes of numbers per litre of *Pompholyx sulcata* at three points of each of the transversal sections

are planktonic (15 species), some are rather resident of littoral areas (2 species) while others occur both in the littoral zone and in the open water (4 species) and hence cannot be regarded as residents of either this or that biotope. The occurrence in large numbers of some of them is limited only to one or two months, while others appear only sporadically. Their presence in the different areas of the lake is indicative of smaller-greater changes in water quality.

Discussion

Averages of total numbers per litre of Rotatoria collected in identical periods during the three years investigated show that along the tarnsversal sections representing the different water-areas of the lake the density of the population was different *(Table V)*.

TABLE V

Changes in the numbers of Rotatoria plankton in identical periods of 1965—67 (months VI—X)

Year	M	K	G	A	E	yearly average
1965	100	86	110	92	104	98
1966	182	228	173	162	154	180
1967	54	134	157	99	115	112

Lowest numbers were registered in 1965, highest ones in 1966. In the latter year average population density was nearly twice that of the previous year. Although the values were higher in 1967 than in 1965, they approximated more the values of 1965 than those of 1966.

There may be several reasons for the great quantitative differences between the individual years. An attempt was made to relate some of these changes with the quantitative changes of rotifers.

The low population density in 1965 and the great increase during 1966 may have several explanations. Due to the supposed effect of the severe pesticide poisoning in 1965 manifesting in a large-scale fish kill, notable increase in population density was observed only in autumn along transversal sections "G"—"E" and there were no summer maxima in these places, i.e. in the greater area of the lake. Along the same transversal sections in the following years (1966—67) the numbers were always considerably higher in summer than in autumn.

Fluctuations of water level may also affect considerably the population density of plankton and thus that of rotifers (SEBESTYÉN, 1953).

In the period between April and October, 1965 the water level was nearly always by about 20—30 cm higher than the 80 cm mean (TAMÁS, 1967). In 1966, however, water levels of about 100 cm were measured only in August and September, while on other occasions values of about 90 cm in general (TAMÁS, 1969). These fluctuations of water level cannot be regarded notable in the case of Lake Balaton.

Temperature is suggested to have the greatest effect on the changes of the total population. Differences in temperature might have also influenced the low and high individual numbers in 1965 and 1966 respectively. Whereas

at the time of the collections in the period ranging from June to October the average monthly temperatures of the lake water were 18, 23, 22, 21 and 14 °C, respectively, in 1966 temperatures as high as 20 °C were measured in May, and 16,5 °C on the 18th of October.

Comparing the yearly averages of population density data of Rotatoria and the population densities of algae and their averages respectively obtained in identical periods in 1965—1966, no relation was observable between them. The quantitative relationships of algae remained on the same level in 1965 and 1966 (the yearly averages were 303 000 i/liter in 1966, and 305 000 i/liter in 1965) (TAMÁS 1967; 1969). Comparing, however, the high numbers of rotifers along transversal sections "M" and "K" in August of the two years (1965, 1966) and the rate of reproduction of algae producing algal bloom in the same time and place *(Table VI)*, some relationship can be observed. A mass reproduction same as the above of *Asterionella* and *Melosira*, both belonging to phylum Chrysophyta, was observed in 1965. Due to their small size, however, these species are not important as food oranisms. The same holds true for *Aphanizomenon* flos *aquae* v. *klebahnii* causing algal bloom in 1966.

TABLE VI

Quantitative relationship between algal phyla producing algal blooms and rotifers in 1965—1966 (i/liter)

		M	K
VIII. 1965	Chrysophyta	4 178 020	1 149 270
	Rotatoria	381	175
IX.	Chrysophyta	180 030	68 150
	Rotatoria	75	23
VIII. 1966	Cyanophyta	1 121 710	1 475 730
	Rotatoria	344	508
IX.	Cyanophyta	695 460	978 450
	Rotatoria	95	85

Assuming that the values obtained in the above two years are not accidental, but perhaps follow some regularities, then the only explanation to accept is that among the great masses of algae large numbers of ultra- and nannoplankton organisms not examined, granular metabolic- and decomposition-products of algae, and detritus- or $CaCO_3$-particles may amass in such quantities which in some way become favourable for the rotifers. Upon the evidence of literary data *(Hutchinson*, 1967; EDMONDSON, 1965; NAUWERCK, 1963) the rotifers occurring in large numbers in Lake Balaton are feeding on 10—12 μ particles (nannoplanktonic algae, tripton, larger bacteria, etc.). Analyses of the alimentary canal show that *Keratella cochlearis* an *K. quadrata* only feed on algae of 2 μ size and inorganic mineral particles of 1—3 μ size (GLIWICZ, 1969). Further studies on nannoplankt on will most likely lead to the understanding of the periodical growth of rotifers.

Examining the increase of the population of the dominating species in the different years and along different transversal sections it is seen that while with some species a close agreement in values between different years exist,

with others the values differ markedly. For instance, whereas the population of *K. tecta* in the north-east basin of the lake and the Bay of Keszthely increased only on one occasion in each of the three years examined, in the same three years there were two or perhaps even three increases in population observed along transversal sections "G" and "K".

Summary

1. In Lake Balaton the same five species dominated during the periods of examination. The number of accompanying species, however, varied considerably, in 1965 and) 1966 it was seven and **21**, respectively.

2. Monthly averages of total numbers per litre of Rotatoria show that the population density was the highest in the central areas of the lake (110, 195 i/litre), while in the Bay of Keszthely and in the other end of the lake numbers smaller by 9—30% and 6—22%, respectively, were registered.

3. In 1965 an increase in the total population took place twice in the whole lake except in the Bay of Keszthely, and the increases along transversal sections "G"—"E" were smaller in summer than in autumn.

4. In 1966 total numbers per litre of rotifers increased twice and three times in the south-west and northeast basins respectively. In the whole lake the increase in population was greater in summer than in autumn.

5. The population dynamism of the dominating species along the individual transversal sections was not the same in the two years examined. The maximum population density of some species *(Polyarthra vulgaris, K. c. tecta)* was smaller in 1965 than in the following year.

6. Comparison of the results obtained in identical periods of the three years show that whereas the population density in 1966 was the highest, only small quantitative differences existed between the two other years.

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A BALATON ROTATORIA PLANKTONJÁNAK MENNYISÉGI VISZONYAI 1965—66-BAN

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Összefoglalás

1. A Balatonban a vizsgálati idő alatt 5 ugyanazon faj volt a domináló. A kísérő fajok száma viszont erősen ingadozott, 1965-ben 7, 1966-ban 21 volt.

2. Az összes Rotatoria literenkénti egyedszámának havi átlaga azt mutatja, hogy a Rotatoria népesség a tó középső területein a legnagyobb (110, 195 e/l), ugyanakkor a Keszthelyi-öbölben 9—30, a tó másik végén pedig 6—22%-kal kisebb a kerekesférgek mennyisége.

3. 1965-ben a Keszthelyi-öböl kivételével a tó egész területén az össznépesség kétszer emelkedett, a nyári maximumok a „G—E" szelvényeken alacsonyabbak voltak az őszieknél.

4. 1966-ban a délnyugati medencében 2, az északkeletiben 3-szor emelkedett az összes Rotatoria literenkénti egyedszáma. A nyári népességemelkedés az egész tóban magasabb volt, mint ősszel.

5. A domináns fajok populáció dinamizmusa az egyes szelvényeken a két vizsgálati évben nem egyformán történt. Egyes fajok *(Polyarthra vulgaris, K. c. tecta)* népességsűrűségének maximuma 1965-ben kisebb volt, mint az azt követő években.

6. A 3 év azonos vizsgálati időszakának összevetése alapján az 1966-os év igen magas népességsűrűségével tűnik ki, míg a másik két év között kicsik a mennyiségi különbségek.