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THE BIOMASS OF ROTATORIA IN LAKE BALATON

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The investigations on Lake Balaton having been recommenced since 1965, have estimated the horizontal distribution of Rotatoria plankton over the whole lake (P.-ZÁNKAI and KERTÉSZ, 1967; P.-ZÁNKAI and PONYI, 1970; 1971; 1972), and on the other hand, they were connected to the former works (SEBESTYÉN, et al., 1951; SEBESTYÉN, 1953) concerning the quantitative and qualitative relationships of the Rotatoria in the open water in front of Tihany.

The present paper was intended at describing the changes of Rotatoria biomass on the basis of comparisons with the former investigations based on the data of population density obtained during 1965—67.

Methods

The volume-values determined by SEBESTYÉN (1958) were used for our calculations, namely those of the "forms of warm water" according to the possibilities, since the samples were collected from May to November in each year. The specific weight of the animals was taken for unity and the biomass was expressed in mg wet weight/m^3.

During 1966—67, three parallel samplings were made, therefore, the values of the number of individuals per liter obtained during the evaluation of the samples, were averaged when calculating the biomass. For comparisons, the data of SEBESTYÉN (1958) concerning the months from May till November were also averaged and expressed in the same unit of measure.

According to our previous investigations (P.-ZÁNKAI and KERTÉSZ, 1967; P.-ZÁNKAI and PONYI, 1970; 1971; 1972), the lake can be divided into two areas considering the qualitative and quantitative relations of Rotatoria, namely the south-eastern part, i.e. the Keszthely Bay and its surrounding (segments "M" and "K"), as well as the north-eastern basin to the line of Ságpuszta—Balatonszemes (segments "G", "A" and "E"). The data of population density of segments "M" and "K" were averaged and the biomass values calculated from them were compared with the averages of segments "G", "A" and "E". This way, the changes of Rotatoria biomass are treated in view of the two main areas of Lake Balaton.

Results

The biomass of *Keratella cochlearis* showed a maximum in August of all three years in the area "M + K" *(Table I.)*. In the other part of the lake ("G + A + E"), the density of population increased twice during both 1966 and 1967, the values of May were four or nearly five times higher than those of August, respectively. During the same time, the south-western part of the lake displayed only a single mass development. In 1965, very high density of individuals as well as values of biomass were found in the Keszthely Bay and its surrounding, which in absence of parallel samplings is assumed to be a result of collecting from shoals. The distribution of this species can be regarded as uniform over the entire lake during the years of investigations.

TABLE I

Quantitative distribution of Keratella cochlearis along five transversal sections of Lake Balaton
($w = 1.22 \cdot 10^{-4}$ mg fresh)

Date	i/m³ Collecting place		Biomass (fresh) mg/m³	
	M + K	*G + A + E*	*M + K*	*G + A + E*
1965, VI.	1 000	20 700	0.1	2.5
VII.	2 100	8 500	0.2	1.0
VIII.	168 000	27 500	20.5	3.3
IX.	20 000	40 300	2.4	4.9
X.	2 500	35 000	0.3	4.3
average:	38 720	26 400	4.7	3.2
1966, V.	13 000	149 000	1.6	18.2
VI.	25 300	309 000	3.1	3.8
VII.	58 200	39 800	7.1	4.8
VIII.	61 000	36 100	7.4	4.4
IX.	16 000	19 400	1.9	2.4
X.	23 200	25 700	2.8	3.1
XI.	3 100	16 000	0.4	1.9
average:	28 542	44 271	3.4	5.5
1967, V.	21 000	130 000	2.6	15.9
VI.	21 000	28 000	2.6	3.4
VII.	29 200	16 200	3.5	1.9
VIII.	60 500	33 600	7.4	4.1
IX.	4 800	6 900	0.6	0.8
X.	1 800	18 100	0.2	2.2
average:	23 050	38 800	2.8	4.7
average of three years	23 189	36 823	3.6	4.4

The species *Keratella cochlearis tecta* was formerly considered to be an autumnal form in Lake Balaton on the basis of its occurrence (SEBESTYÉN, 1958). However, it displayed a characteristic summer development during the three years, the values of biomass were the highest in July and mainly in August *(Table II)*. The density of population increased only once during the three years overall the lake, the rates of which and the biomasses were different

TABLE II

Quantitative distribution of Keratella cochlearis tecta along five transversal sections of Lake Balaton ($w = 1.31 \cdot 10^{-4}$ mg fresh)

Date	i/m³ Collecting place		Biomass (fresh) mg/m³	
	$M + K$	$G + A + E$	$M + K$	$G + A + E$
1965, VI.	0	1 700	0	0.2
VII.	1 100	14 000	0.1	1.8
VIII.	83 000	330 000	10.9	4.3
IX.	3 100	12 500	0.4	1.6
average:	20 040	13 860	2.6	1.7
1966, V.	0	5 400	0	0.8
VI.	7 800	15 000	1.0	2.0
VII.	101 000	48 700	13.3	6.4
VIII.	199 000	31 900	26.0	4.2
IX.	6 100	9 300	0.8	1.2
X.	14 000	9 300	1.8	1.2
XI.	2 100	5 500	0.3	0.7
average:	47 142	17 871	6.1	2.3
1967, V.	0	3 100	0	0.4
VI.	11 000	18 000	1.4	2.4
VII.	23 000	12 300	3.0	1.6
VIII.	43 300	21 700	5.7	2.8
IX.	7 800	8 900	1.0	1.2
X.	3 100	7 200	0.4	0.9
average:	14 700	18 866	1.9	1.5
average of three years	27 294	14 532	3.5	1.8

on the two areas of the lake. The very low biomass values of the south-western part characterized by two segments, observed in July, increased to their high multiple by July and August, then decreased again nearly to the former values by September. The increase of biomass was of much lower rate in the other region of the lake, during the last year of investigation no maximum appeared, the mass was uniformly distributed during the period of June—September. Comparing the yearly averages, large differences between the two areas of water were found only in 1966. This results in twice as high biomass in the Keszthely Bay and its surroundings when comparing the averages of three years.

The population density of *Keratella quadrata* was higher in the north-eastern areas of water ("G + A + E") during the spring and autumn of all the three years (May, June in 1965; October, November) than in the Keszthely Bay and its surrounding *(Table III)*. Considerable masses of this species appeared just during the spring and autumn months on this part of the lake. This result supports the finding of SEBESTYÉN (1958) who regards this species an early spring form on the basis of collections across segment "A", as well as the occurrence of population maxima. However, during the summer periods (e.g. July—September of 1966 and 1967), the biomass of the species was 2—24 times higher in segments "M + K", than in the other regions. The

TABLE III

Quantitative distribution of Keratella quadrata along five transversal sections of Lake Balaton ($w = 6.61 \cdot 10^{-4}$ mg fresh)

Date	i/m³ Collecting place		Biomass (fresh) mg/m³	
	M + K	*G + A + E*	*M + K*	*G + A + E*
1965, VI.	510	1 300	0.3	0.9
VII.	2 100	1 100	2.2	0.7
VIII.	18 000	0	11.9	0
IX.	7 500	1 300	5.0	0.8
X.	510	1 100	0.3	0.7
average:	5 724	960	3.9	0.7
1966, V.	1 600	4 500	1.1	3.0
VI.	50 700	2 100	33.5	1.3
VII.	16 700	2 100	11.0	1.3
VIII.	25 700	4 000	17.0	2.7
IX.	24 000	2 300	15.9	1.5
X.	16 700	7 400	11.0	4.9
XI.	810	4 300	0.5	2.8
average:	19 458	3 814	12.8	2.5
1967, V.	21 000	57 000	13.9	37.7
VI.	9 100	3 100	5.9	2.0
VII.	9 500	4 300	6.3	2.8
VIII.	18 000	2 400	11.9	1.6
IX.	6 300	410	4.2	0.3
X.	510	2 300	0.3	1.5
average:	10 735	12 101	7.1	7.6
average of three years	11 969	2 812	7.9	3.4

average values of three years showed a more than double difference between the two areas of water in favour of the Keszthely Bay and its surrounding.

The biomass of *Polyarhtra vulgaris* strongly varied during the three years following each other on both areas of water *(Table IV)*. A certain regularity was only observed over the entire lake during all three years, in so far as the population increased during the autumn. Apart from that, the values of biomass were high in June in the Keszthely Bay and its surrounding, as well as in May and August in the north-eastern part. The former investigations in segment "A" (SEBESTYÉN, 1953) indicated the months July—August as well as May, December and September when this species reached the highest numbers per liter. Comparing the yearly averages of biomass values found in the two areas of the lake reveals that this species occurs in larger mass in segments "G—E". The difference is sometimes small (1966) but it can even reach a double level.

The biomass of *Pompholyx sulcata* showed the largest difference between the two areas, since it was negligible in the Keszthely Bay and its surrounding, whereas even 20 mg/m³ occurred in other regions *(Table V)*. It is a characteristic species of summer development, its maximal masses occur during July

TABLE IV

Quantitative distribution of Polyarthra vulgaris along five transversal sections of Lake Balaton ($w = 3.83 \cdot 10^{-4}$ mg fresh)

Date	ind/m³ Collecting place		Biomass (fresh) mg/m³	
	M + K	*G + A + E*	*M + K*	*G + A + E*
1965, VI.	1 000	3 300	0.4	1.3
VII.	0	0	0	0
VIII.	0	0	0	0
IX.	49 000	35 700	18.8	13.7
X.	49 000	172 000	18.8	65.9
average:	19 800	42 200	7.6	16.2
1966, V.	21 000	91 900	7.7	35.2
VI.	23 800	5 700	9.1	2.2
VII.	3 200	29 000	1.2	11.1
VIII.	9 500	52 100	3.6	21.0
IX.	36 000	25 900	13.8	9.9
X.	75 700	11 300	29.0	43.2
XI.	6 400	12 900	2.4	7.3
average:	25 085	48 114	9.5	18.5
1967, V.	23 000	29 000	8.8	11.1
VI.	31 000	18 000	11.9	6.9
VII.	2 800	22 100	1.1	8.5
VIII.	9 100	64 000	3.4	24.5
IX.	5 800	31 200	2.2	11.9
X.	51 500	43 400	19.7	16.6
average:	20 533	34 616	7.8	13.2
average of three years	21 806	41 643	8.3	16.0

tnd August. Its distribution was uniform in segments "G—E" during all the ahree years on the basis of comparisons of the yearly average biomass values.

Both the density of individuals and the biomass of *Kellicottia longispina* are uniformly low in both parts of the lake. Its highest mass appears in May in accordance with former literary data (SEBESTYÉN, 1953; 1958) .The yearly averages show no significant differences between the two areas, whereas the comparisons of the years revealed small differences only.

Discussion

During the three years of investigations, the *Polyarthra vulgaris* occupied the first place among the Rotatoria of the open water of the lake as regards biomass values. It was followed by *Keratella quadrata* and *Pompholyx sulcata (Tables III, IV* and *V)*, i.e. the mass is formed by a species of medium volume but high density as well as by an other one of large volume and relatively of lower number of individuals. According to former investigations (SEBESTYÉN, 1958), *Polyarthra* and *Pompholyx* showed the highest biomass values even during other years in the north-eastern basin of the lake.

TABLE V

Quantitative distribution of Pompholyx sulcata along five transversal sections of Lake Balaton
($w = 3.11 \cdot 10^{-4}$ mg fresh)

Date	i/m³ Collecting place		Biomass (fresh) mg/m³	
	$M + K$	$G + A + E$	$M + K$	$G + A + E$
1965, VI.	0	7 300	0	2.3
VII.	0	67 000	0	20.8
VIII.	0	35 500	0	11.0
IX.	0	38 300	0	11.9
X.	0	12 500	0	3.9
average:	0	32 120	0	9.9
1966, V.	210	47 000	0.1	14.6
VI.	17 000	56 000	5.3	17.4
VII.	700	54 100	0.2	16.8
VIII.	0	64 500	0	20.1
IX.	0	17 000	0	5.3
X.	830	7 300	0	2.3
XI.	0	810	0	0.2
average:	2 677	35 244	0.8	10.9
1967, V.	3 000	25 100	0.9	7.8
VI.	2 000	36 000	0.6	11.2
VII.	1 500	69 000	0.5	21.4
VIII.	0	30 300	0	9.4
IX.	0	17 700	0	5.5
X.	0	14.300	0	4.4
average:	1 083	32 066	0.3	9.9
average of three years	626	33 143	0.4	16.2

However, *Keratella quadrata* has never been of such a high density. Since at each three points of each three segments nearly uniform number of individuals per liter were obtained, one can exclude the possibility of collecting from shoals, and one has to accept the wide propagation of this species over the entire area of water.

Systematic quantitative investigations of Rotatoria plankton involved only the open water area in front of Tihany (segment "A") before 1965. According to our results having been obtained so far, this segment represents well the area of the whole north-eastern basin, and on the other hand, its Rotatoria fauna is similar to that of the line Ságpuszta—Balatonszemes (segment "G") both qualitatively and quantitatively. Therefore, one can conclude on the basis of changes appearing in segment "A" that similar phenomena also occur in the larger part of the open water of the lake ("G + A + E").

In order to be able to compare the recent biomass data with the former ones, the values of segment "A" were separated from the other two segments belonging to the north-eastern basin. Analyzing the changes of biomass of certain species present in the plankton with higher number of individuals *(Table VI)*, one can establish that the mass of *Keratella cochlearis* increased as compared to that of years 1936—49, it remained practically unchanged from

TABLE VI

Changes of Rotifera biomass in the water-area in front of the Biological Institute (transversal section "A")

Year	*Keratella cochlearis*	*Keratella c. tecta*	*Keratella quadrata*	*Polyarthra vulgaris*	*Pompholyx sulcata*	*Kellicottia longispina*	*Trichocerca pusilla*	Total biomass mg/m³
1936	1.1	0.3	0.7	1.5	2.5	0.4	0	6.5
1937	1.0	0.4	1.3	2.3	3.1	0.6	0	8.7
1938	2.2	0.4	2.0	1.5	4.3	1.7	0	12.1
1947	0.8	3.5	1.3	17.6	4.0	0.4	1.4	29.0
1949*	0.8	1.0	0.7	2.7	1.5	1.3	0.4	8.4
1951	6.3	6.1	1.3	15.3	9.6	0.2	2.1	40.9
1965**	2.4	1.1	0.3	5.4	13.2	0	0	22.4
1966	6.0	2.2	1.5	19.5	11.7	0.6	0.5	42.0
1967	4.3	1.3	8.0	10.2	9.8	1.4	0.5	35.5

* an unusual subsidence of the open water during that time
** relatively few samplings

1951. A similar pattern was shown even by *Pompholyx sulcata*. The biomass of *Keratella c. tecta* increased until 1951 and started to decrease only during recent years, whereas that of *Keratella quadrata* was practically unchanged from the first year of investigation, apart from the higher value of 1967 which however, could not be evaluated because of the absence of further investigations. The *Polyarthra* from the 1940s, the *Kellicottia* during the whole period of investigations occur in the Rotatoria plankton with a nearly constant mass. *Trichocerca pusilla* could be collected in almost identical masses since its propagation to the open water (SEBESTYÉN, 1953; 1958).

The total biomass of Rotatoria continuously increased until 1951 in segment "A" representing the larger part of the lake. Since that time a stagnation has appeared instead of a further increase, the reason is unknown. However, different hypotheses can be outlined (cf. PONYI and P.-ZÁNKAI, 1972, pp. 136—137).

Summary

Among the most frequent rotifers of the lake three species *(Polyarthra vulgaris, Keratella quadrata* and *Pompholyx sulcata)* represent the highest biomass values.

On the basis of average biomasses of years 1965, 1966 and 1967, *Polyarthra vulgaris* is of the highest importance showing a value of 8.3 and 14.1 mg/m³ in the Keszthely Bay and its surrounding as well as in the other parts of the lake. *Keratella quadrata* and *Pompholyx sulcata* display different distribution of biomass in the two areas: the former occurred in 7.9 mg/m³ in the samples taken from the Keszthely Bay and its surrounding (segments "M+K"), the latter in 0.4 mg/m³. In the segments representing about two thirds of the lake (segments "G + A + E"), the former showed 3.5 while the latter 10.3 mg/m³ biomass value.

In the larger part of the open water (segments "G + A + E"), the total biomass of the Rotatoria gradually increased till the 1950s from 6.5 up to 40.9 mg/m³, then it remained at nearly identical level until 1967 (38.7 mg/m³).

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KEREKESFÉRGEK (ROTATORIA) BIOMASSZÁJA A BALATONBAN

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Összefoglalás

A tó leggyakoribb kerekesférgei közül biomassza értéket tekintve 3 faj *(Polyarthra vulgaris, Keratella quadrata, Pompholyx sulcata)* a legjelentősebb.

1965, 1966 és 1967 évek átlagos biomasszája alapján a legfontosabb a *Polyarthra vulgaris*, melynek értéke a Keszthelyi-öböl és környékén 8,3, a többi részen 14,1 mg/m^3 volt. A *Keratella quadrata* és a *Pompholyx sulcata* biomasszájának megoszlása a tó két vízterületén eltérő; az előbbi faj biomasszája a Keszthelyi-öböl és környékén vett mintákban (M + K terület) 7,9 mg/m^3, az utóbbié 0,4 mg/m^3 volt. A tó kb. kétharmad részét reprezentáló G + A + E szelvényeken a *Pompholyx* biomassza értéke 10,3 mg/m^3, a *Keratella quadrata*-é 3,5 mg/m^3 volt.

A tó nyíltvizének nagyobbik részén (G + A + E szelvények) az 1930-as évektől kezdődően a kerekesférgek összes biomasszája az 1950-es évekig fokozatosan emelkedett 6,5 mg/m^3-ről 40,9 mg/m^3-ig, majd ettől kezdve 1967-ig közel azonos szinten maradt (38,7 mg/m^3).