ANNAL. BIOL. TIHANY	41	217–234	HUNGARIA 1974

INVESTIGATION WITH COMPUTER ICL SYSTEM 4 ON THE MORPHOMETRY AND COMPOSITION OF THE POPULATION OF *DREISSENA* SHELLS FROM THE UPPER SEDIMENT LAYER OF LAKE BALATON

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Received: 2nd April, 1974

The appearance, rapid increase and spread of *Dreissena polymorpha* are discussed in SEBESTYÉN's (1934) study. According to this report the first specimen of *Dreissena* was collected by chance in the autumn of 1932 in the so-called Kis-öböl (bay) nearby the Biological Research Institute (ENTZ and SEBESTYÉN, 1933). During the summer and autumn of 1933 it so extensively proliferated in this area that its number of individuals surpassed that of the Unionida. Since 1933 it must have been very frequent in the north-eastern basin of the lake. In the August of 1934 it also appeared in the south-western basin (Keszthely Bay) too. On the basis of these data, since 1934 *Dreissena* has been regarded a wide-spread species in the entire lake.

This wide distribution has two reasons: 1. The water is shallow (average depth 3 m); it is known that in other shallow lakes (WIKTOR, 1963; STAŃCZYKOWSKA, 1964; 1966) its optimal distribution is at a depth of 2—5 m, thus, obviously Lake Balaton, as far as water depth is concerned, is very favourable for zebra-mussel to spread. 2. The living (ENTZ, 1932; MOON, 1934) and dead Unionida shells (PONYI, 1971) in the open water sediment offer an excellent place to zebra-mussels to attach themselves to.

The first specialists to ecologically investigate clams in Lake Balaton were ENTZ (1932), ENTZ and SEBESTYÉN (1933), SEBESTYÉN (1934) and MOON (1934). Their studies discussed particularly the age, growth, moving and the circumstances of spread of *Anodonta* and *Unio* species. The ecology of *Dreissena* is rarely mentioned and even then only extent of spread is recorded. But the studies on the mussel-shell drifts of Lake Balaton (ENTZ et al., 1942; SEBESTYÉN, 1942; 1943) also offer valuable informations on this subject.

In the recent years attention was focused again on *Dreissena*. There are two reasons for this:

1. It was proved that the rate of siltation of the lake can be well estimated with the help of this clam.

2. Investigations on the remains of animal origin, so that of *Dreissena*, in the latest sediment layer (upper 15 cm) can inform us about the biological changes occurring in recent years (PONYI, 1971). The investigation of this period (past 80—100 years) is of high importance since it makes it possible,

after comparing it with the present conditions, to forecast probable biological changes in the future.

As far as we know nobody has analysed dead *Dreissena* shells with computer, thus we cannot make reference to any other studies. We could, however, use Russian and Polish biologists' results (Mikheev, 1966; Stańczykowska, 1961; 1964; 1966; Sorokin, 1966; Wiktor, 1963; Zhadin, 1946; etc.) considerable from the point of view of ecology, in the lack of which the evaluation of data on clam shells would have been more difficult.

The aim of our work was to analyse the size of zebra-mussel shells and to draw conclusions on the composition of the dead population. Namely, on the basis of the above-mentioned literary data, we supposed that there could be a close connection between the size of shell, the abundance and compositions of population and the conditions prevalent in the lake. This question is of current interest because since the 1940s, especially in the plankton association, a readily demonstrable change has occurred. At present the south-western corner of the lake, Keszthely Bay demonstrates a trophyty characteristic of a fish-pond (Herodek and Tamás, 1974). We think that the change occurring in the suspended food source so important to the clams affected the composition and density of number of individuals of the population.

Material and methods

The samples were collected from three points of each of the five transversal sections *(Fig. 1)*. The detailed description of the sampling sites is given in several earlier publications (e.g. Ponyi, 1968).

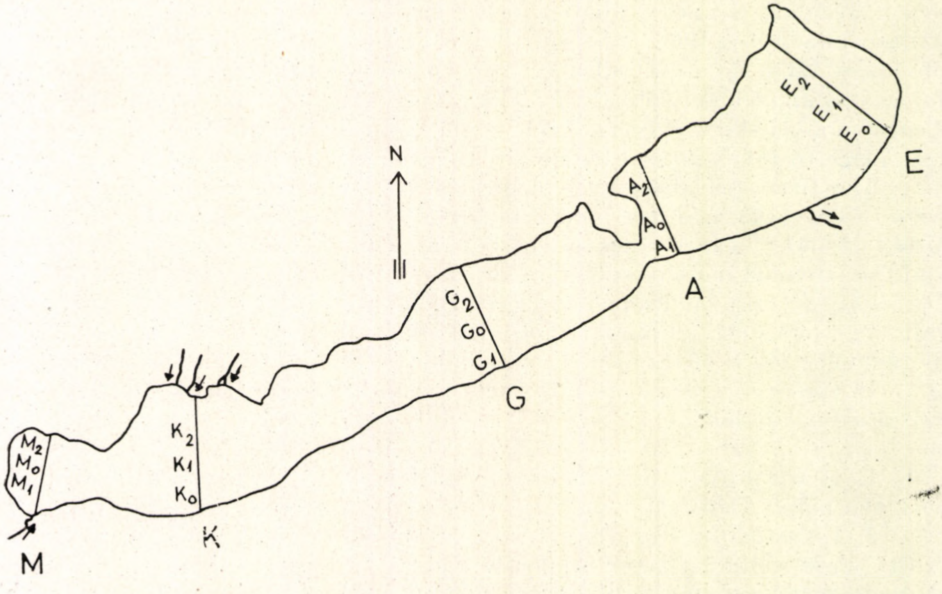

Fig. 1. Collecting sites in Lake Balaton

The mud samples were taken with Ekman-Birge dredge from May 1966 till October 1968. Sectionally 230—250 samples were taken which equals to a mud surface of 21.18 m^2. Passing the mud through a seeve, we found 26 568 *Dreissena* shells. First, according to their superficial appearance, we divided them into three age-groups:

"shabby" = old shells (abbrev. "k")
"mat" = middle-aged shells (abbrev. "m")
"glossy" = young shells (abbrev. "f")

It is to be noted that the age-scheme we use here must not be taken for the age of the individuals. It is for certain that group "shabby" includes those shells which died in 1934 too, while the "glossy" shells must be the remains of recently died animals. We also believe that the sequence of shabby, mat and glossy shells constitute a chronological order and comprise in a grand total a period of 33 years.

Following STAŃCZYKOWSKA (1964) we also measured the length, breadth and height of each of the *Dreissena* shells. These three measurements were multiplied to yield a morphometric variable. The volume (mm^3) obtained in this way, on the one hand, characterizes the state of dead *Dreissena*, and on the other hand, the data can be easily used for computer analysis.

The mathematical data of samples from 3—3 points of the transversal sections were congregated in one statistical sample. The five samples obtained in this way according to their age, were divided into 3—3 groups giving 15 statistically comparable samples used in our further investigations. Most of our computations were made with statistical analysis. When calculating the values of abundance we did not fail to regard that shells at our disposal are equal to half as much animal. The density of individuals must be interpreted with regard to this fact.

From the statistical program of computer ICL System 4 (Hungarian Association for Telecommunication) we used the hystogram program and the analysis of variance by two factors. On the one hand, the hystogram program offered information on the structure of the 15 samples of the population, on the other hand, it offered basis to further investigations. In each of the samples the program classified the transformed coefficients according to order of size, from 0 to $+\infty$. It decomposed the width of variation into nine equal intervals and gave the observed frequency of the intervals. It must be noted that the intervals of different samples are not of the same size since their width of variation also differ. However, in order to make further comparative analyses on the basis of variables obtained and ordered according to their size we took intervals of the same size. The observed frequency reflecting the structure of population is given in per cent. The hystogram program also represent the distributions graphically on the basis of which we gained informations on their type to further computer analysis.

After investigating the distribution of samples and the structure of the populations we made the analysis of variance by two factors. To the computations we applied the logarithm of the morphometric variables since that showed an approximately normal distribution.

The model of analysis of variance is as follows:

$$X_{ij} = u + a_i + b_j + (ab)_{ij} + E_{ij}$$

where "i" represents the places of samples taken horizontally, i.e. transversal sections M, K, G, A and E *(Fig. 1)*, while "j" represents the data of shells aged "k", "m" and "f". The preceding is marked factor "A", while the latter factor "B". Consequently, the number of places of factor "A" is $i = n_A = 5$, the number of ages of factor "B" is $j = n_B = 3$. The program printed the usual table of variance and the averages as follows:

$\bar{X}_{...}$ = average of all the observations
$\bar{X}_{i..}$ = averages of factor "A"
$\bar{X}_{j.}$ = averages of factor "B"
$\bar{X}_{ij.}$ = averages of the 15 samples separately.

The probability of the significant differences (SD) calculated was $P = 0.1$ per cent.

Results

The structure of the population investigated

The hystogram program printed from 0 to $+\infty$ the observed frequency in the intervals of the 15 samples. With regard to the difference in the number of elements of the samples *(Table I)* we made the comparison easier by converting the values to per cent. The program also printed the shape of distribution graphically. It was established that the distributions were not normal but showed a kind of discrete shapes.

On the basis of *Table I* the conclusion can be drawn that, independently of the collecting site, the structures of populations are more or less identical within the age-groups. If we average the data of the three age-groups on the five transversal sections *(Fig. 2)* it can be clearly seen that the structures of the old (= "k") and young (= "f") populations are almost identical, while the third, aged "m", significantly differs from both.

As has been mentioned the size of intervals is not identical but their number in the different samples which raise difficulties in further comparisons. We will consider only the order of 100—700 mm³ in each of the samples and examine them with identical width of interval. These selected percentual frequencies are given in *Table II*. The variability is well approximated by all frequencies in the interval examined implying that the sample of lower percentual value in the interval has a wider variability. *Table III* shows the different variability both horizontally and in the three age-groups.

The difference in the structure of the population is readily comprehensible by conferring *Fig. 4*. In the figure we averaged the intervally observed frequencies of age-groups "k", "m" and "f" given in *Table II* and reflected it with a cummulative curve. The curve of age-group "f" irregularly differs from the older age-groups. This phenomenon may be explained by the significant change of environmental conditions.

The results of the analysis of variance showed differences in the structure of the samples examined. Further on these will be investigated starting from the thought that the average well characterizes the normal distribution. Since our distributions were not normal, we transformed them with logarithmical transformation. The analysis of variance was carried out by means of the logarithms of morphometric variables (mm³).

TABLE I

The observed frequency in the intervals of the 15 samples printed by the hystogram program from 0 to + ∞. The percentual values are reduced. Capital letters, e.g. "M", represent the transversal sections, while small letters, e.g. "f" represent the age-group. Values are given in mm^3

M_f *sample*

Interval	Limits	%
0	0— 48.64	7.1
1	48.64— 447.69	80.4
2	447.69— 846.74	7.5
3	846.74—1245.78	1.8
4	1245.78—1644.83	0.8
5	1644.83—2043.88	0.6
6	2043.88—2442.93	0.2
7	2442.93—2841.98	0.8
8	2841.98— +∞	0.8

K_f *sample*

Interval	Limits	%
0	0— 60.47	12.8
1	60.47— 407.97	74.4
2	407.97—1355.47	8.4
3	1355.47—2002.97	2.0
4	2002.97—2650.47	0.8
5	2650.47—3297.97	1.2
6	3297.97—3945.47	0.2
7	3945.47—4592.97	0.0
8	4592.97— +∞	0.2

G_f *sample*

Interval	Limits	%
0	0— 39.10	13.3
1	39.10— 267.79	63.6
2	267.79— 496.49	9.9
3	496.49— 725.18	4.9
4	725.18— 957.87	3.1
5	957.87—1182.56	2.1
6	1182.56—1411.25	1.1
7	1411.25—1639.94	0.7
8	1639.94— +∞	1.3

A_f *sample*

Interval	Limits	%
0	0— 45.38	11.4
1	45.38— 382.47	67.6
2	382.47— 719.57	13.4
3	719.57—1056.67	5.3
4	1056.67—1393.76	1.1
5	1393.76—1730.87	0.7
6	1730.87—2067.97	0.1
7	2067.97—2405.06	0.2
8	2405.06— +∞	0.2

E_f *sample*

Interval	Limits	%
0	0— 51.42	12.7
1	51.42— 332.97	55.3
2	332.97— 614.52	19.1
3	614.52— 896.06	7.4
4	896.06—1177.61	1.1
5	1177.61—1459.16	3.1
6	1459.16—1740.71	0.1
7	1740.71—2022.25	0.1
8	2022.25— + ∞	1.1

M_m *sample*		
Interval	Limits	%
0	0— 186.08	6.4
1	186.08— 596.32	32.5
2	596.32—1006.56	27.4
3	1006.56—1416.81	12.6
4	1416.81—1827.05	8.9
5	1827.05—2237.29	5.8
6	2237.29—2647.53	2.9
7	2647.53—3057.77	1.8
8	3057.77—$+\infty$	1.7

K_m *sample*		
Interval	Limits	%
0	0— 124.04	8.9
1	124.04— 556.90	47.6
2	556.90— 989.75	25.2
3	989.75—1422.61	7.7
4	1422.61—1855.47	5.8
5	1855.47—2288.32	2.7
6	2288.32—2721.18	1.2
7	2721.18—3154.04	0.7
8	3154.04—$+\infty$	0.2

G_m *sample*		
Interval	Limits	%
0	0— 119.41	4.5
1	119.41— 684.49	63.4
2	684.49—1249.56	22.5
3	1249.56—1814.63	6.8
4	1814.63—2379.70	0.7
5	2379.70—2944.77	0.9
6	2944.77—3509.84	0.4
7	3509.84—4074.91	0.1
8	4074.91—$+\infty$	0.7

A_m *sample*		
Interval	Limits	%
0	0— 117.45	6.5
1	117.45— 604.12	47.2
2	604.12—1090.78	30.9
3	1090.78—1577.45	9.9
4	1577.45—2064.12	2.5
5	2064.12—2550.78	1.5
6	2550.78—3037.45	0.5
7	3037.45—3524.12	0.7
8	3524.12—$+\infty$	0.3

E_m *sample*		
Interval	Limits	%
0	0— 204.55	9.7
1	204.55— 622.41	39.7
2	622.41—1040.27	26.6
3	1040.27—1458.12	13.7
4	1458.12—1875.98	5.2
5	1875.98—2293.84	1.3
6	2293.84—2711.69	1.3
7	2711.69—3129.55	1.3
8	3129.55—$+\infty$	1.2

M_k *sample*		
Interval	Limits	%
0	0— 66.81	8.8
1	66.81— 813.00	80.6
2	813.00—1559.19	6.9
3	1559.19—2305.38	2.5
4	2305.38—3051.57	0.8
5	3051.57—3797.76	0.2
6	3797.76—4543.95	0.1
7	4543.95—5290.14	0.1
8	5290.14—$+\infty$	0.0

K_k *sample*		
Interval	Limits	%
0	0— 78.50	10.8
1	78.50— 544.21	64.8
2	544.21—1009.93	14.3
3	1009.93—1475.64	4.9
4	1475.64—1941.36	2.7
5	1941.36—2407.07	1.2
6	2407.07—2872.79	0.3
7	2872.79—3338.50	0.5
8	3338.50—$+\infty$	0.5

G_k sample			A_k sample		
Interval	Limits	%	Interval	Limits	%
0	0— 64.67	11.2	0	0— 92.03	11.6
1	64.67— 497.65	67.7	1	92.03— 541.07	57.7
2	497.65— 930.63	15.2	2	541.07— 990.12	16.7
3	930.63—1363.60	3.1	3	990.12—1439.17	7.4
4	1363.60—1796.58	1.2	4	1439.17—1888.22	3.4
5	1796.58—2229.56	0.7	5	1888.22—2337.26	1.9
6	2229.56—2662.53	0.4	6	2337.26—2786.31	0.4
7	2662.53—3095.51	0.3	7	2786.31—3235.36	0.5
8	3095.51—$+\infty$	0.2	8	3235.36—$\times\infty$	0.4

E_k sample		
Interval	Limits	%
0	0— 106.64	9.6
1	106.64— 705.69	62.5
2	705.69—1304.74	18.4
3	1304.74—1903.78	5.6
4	1903.78—2502.83	2.5
5	2502.83—3101.88	0.5
6	3101.88—3700.93	0.4
7	3700.93—4299.97	0.2
8	4299.97—$+\infty$	0.3

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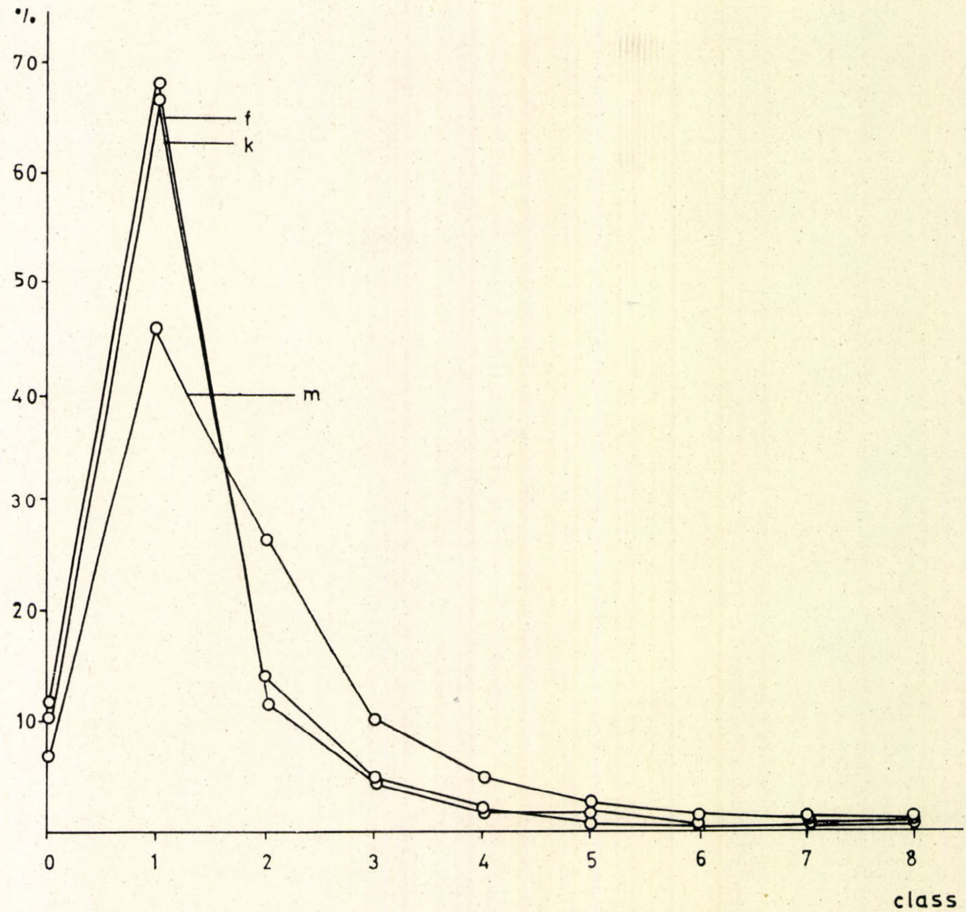

Fig. 2. Structure of population of the three age-groups on the basis of mean values of observed frequency of the 15 samples

our distributions were not normal, we transformed them with logarithmical transformation. The analysis of variance was carried out by means of the logarithms of morphometric variables (mm^3).

The results of the computer analysis were as follows:

Variances	SQ	DF	MQ	F	DF
Factor A	7.3578	4	1.8395	11.2667	(4. 870)
Factor B	66.1825	2	33.0913	202.6842	(2. 870)
AB interaction	5.0578	8	0.6322	3.8723	(8. 870)
Error	142.0407	870	0.1633		
Total	220.6389	884			

TABLE II

(explanation see in the text)

Interval mm³ / Sample	100—200	200—300	300—400	400—500	500—600	600—700	Total
	%						
M_f	33	19	8	5	2	1	68
K_f	26	19	7	4	3	5	64
G_f	21	13	4	2.5	2.5	3	47
A_f	28	14	7	5	4	3	61
E_f	17	9	6	7	7	3	49
M_m	13	7	7	9	7	10	50
K_m	8	12	9	9	10	8	56
G_m	11	14	12	12	9	7	65
A_m	12	12	11	7	8	9	59
E_m	8	11	5	10	12	11	57
M_k	23	22	10	7	6	3	71
K_k	20	16	12	7	6	5	66
G_k	23	14	14	8	7	4	70
A_k	16	16	9	12	9	5	67
E_k	13	15	8	12	8	6	62

M, K, G, A, E = transversal sections.
"f", "m", "k" = age-groups.

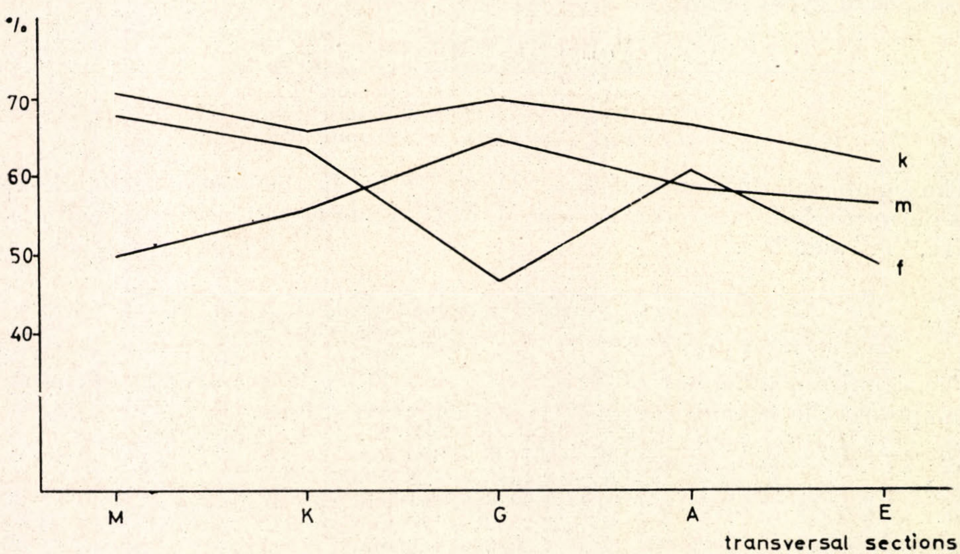

Fig. 3. Variability of the three populations of different age along the longitudinal axis of the lake

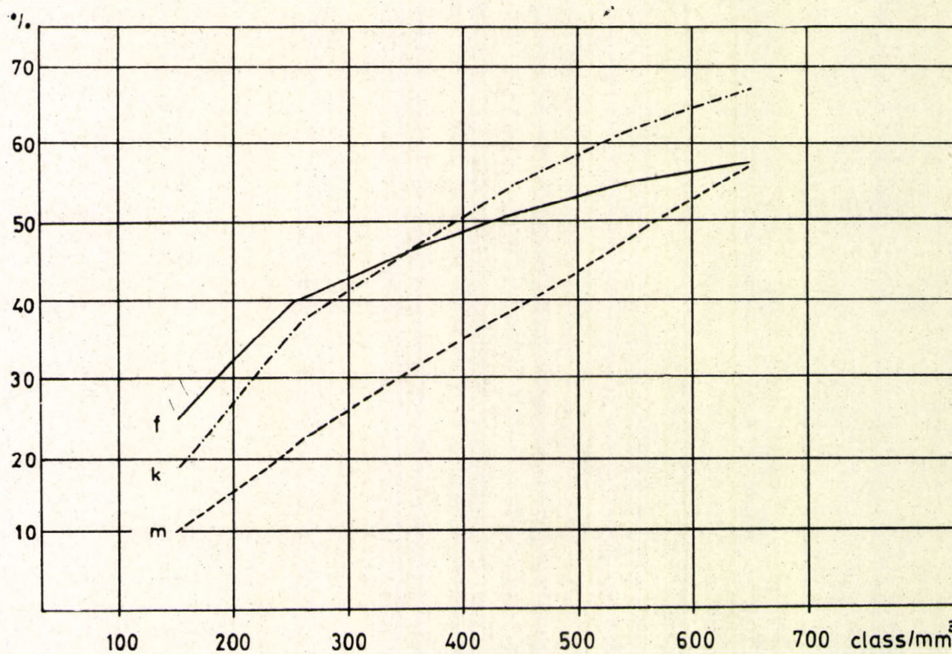

Fig. 4. Cumulative curves reflecting the structure of the population of the three age-groups on the basis of averages of transversal sections

The average of all observations was $\bar{\bar{X}} \ldots = 2.4224$ i.e. 265 mm^3. In the case of factor $A\bar{X}_i \ldots$ is the average of age-groups "f", "m" and "k" at transversal sections M, K, G, A and E.

$$M_{(f,m,k)} = 2.4675 = 293 \text{ mm}^3$$
$$K_{(f,m,k)} = 2.3888 = 245 \text{ mm}^3$$
$$G_{(f,m,k)} = 2.2698 = 186 \text{ mm}^3$$
$$A_{(f,m,k)} = 2.4423 = 277 \text{ mm}^3$$
$$E_{(f,m,k)} = 2.5437 = 350 \text{ mm}^3$$

The significant difference of $\bar{X}$ is $SD_{0.1\%} = 0.14$. In the case of factor B, $\bar{X}_j$ is the average of transversal sections M, K, G, A and E calculated to age-groups "f", "m" and "k":

$$f_{(M,K,G,A,E)} = 2.1514 = 142 \text{ mm}^3$$
$$m_{(M,K,G,A,E)} = 2.7069 = 626 \text{ mm}^3$$
$$k_{(M,K,G,A,E)} = 2.2189 = 208 \text{ mm}^3$$

The significant difference of $\bar{X}_j$ is $SD_{0.1\%} = 0.11$. $\bar{X}_{ij}$ is the average of the 15 samples at the sections and in the age-groupes separately.

$$M_f = 2.2166 = 165 \text{ mm}^3$$
$$K_f = 2.1085 = 128 \text{ mm}^3$$
$$G_f = 1.9088 = 81 \text{ mm}^3$$
$$A_f = 2.2552 = 180 \text{ mm}^3$$
$$E_f = 2.2682 = 185 \text{ mm}^3$$

$$M_m = 2.7733 = 593 \text{ mm}^3$$
$$K_m = 2.6715 = 469 \text{ mm}^3$$

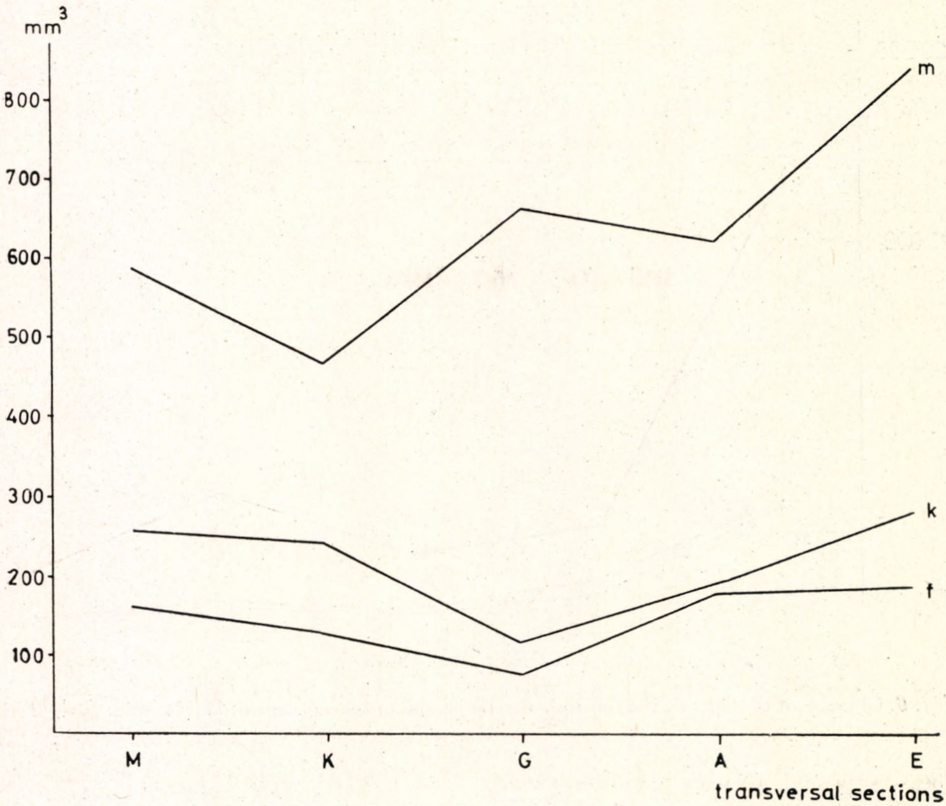

Fig. 5. Change in the mean size of *Dreissena* shells of different age at various places of the lake

$$G_m = 2.8235 = 666 \text{ mm}^3$$
$$A_m = 2.7930 = 621 \text{ mm}^3$$
$$E_m = 2.9230 = 838 \text{ mm}^3$$

$$M_k = 2.4126 = 259 \text{ mm}^3$$
$$K_k = 2.3865 = 244 \text{ mm}^3$$
$$G_k = 2.0770 = 120 \text{ mm}^3$$
$$A_k = 2.2786 = 190 \text{ mm}^3$$
$$E_k = 2.4400 = 276 \text{ mm}^3$$

The significant difference of $\bar{X}_{ij}$ is $SD_{0.1\%} = 0.26$.

The change of averages in the longitudinal axis of the lake and the age-groups is given in *Fig. 5.* In age-groups "f" and "k" the horizontal change of averages is similar, while in age-group "m" there is a considerable difference at transversal section K. The shell-volume of age-groups "k" and "f" differ from "m". The averages of age-groups "k" and "f" are similar in spite of their age.

Furthermore, we have to answer the question whether the differences are or are not significant in factors A and B. In the longitudinal axis of Lake Balaton, i.e. factor A, summarizing the three age-groups, it was found that the average size of *Dreissena* significantly differs between $M_{f,m,k} - G_{f,m,k}$, $G_{f,m,k} - A_{f,m,k}$, $G_{f,m,k} - E_{f,m,k}$ and $K_{f,m,k} - E_{f,m,k}$.

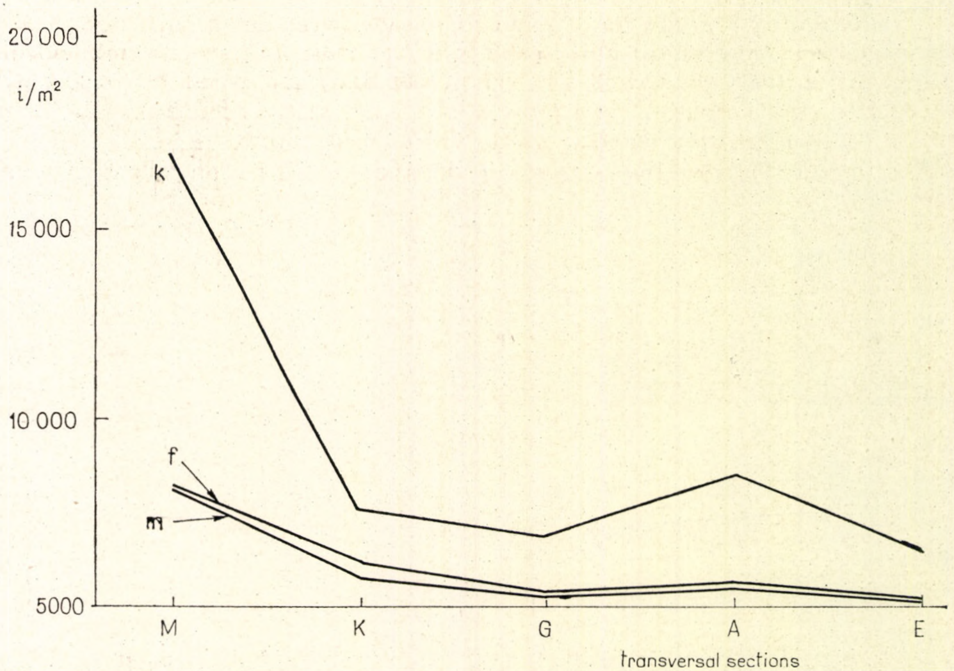

Fig. **6.** Change of density of individuals at the transversal sections of the lake investigated

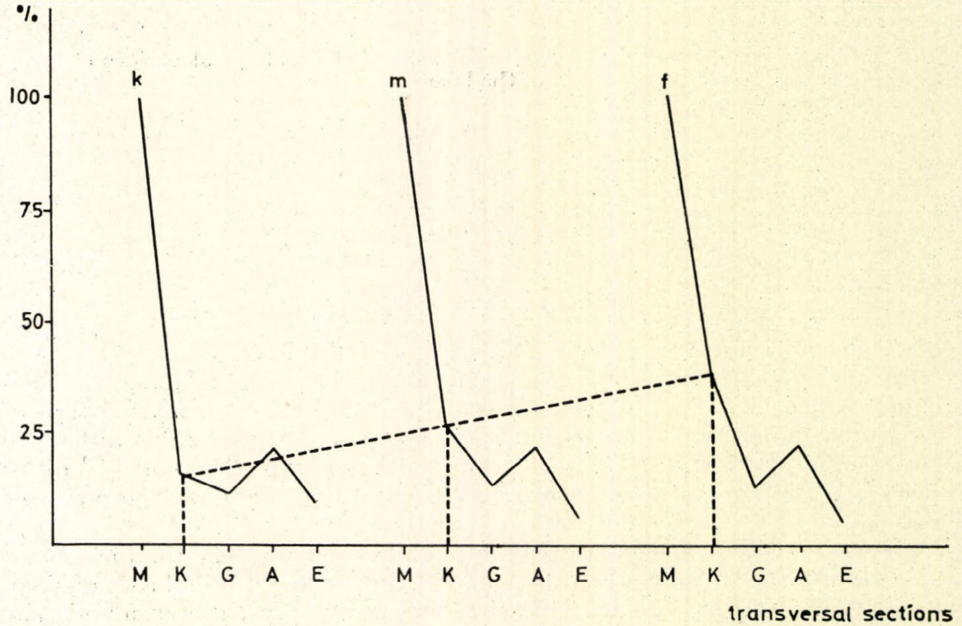

Fig. 7. Change of abundance of the three age-groups given in percent. Basis: transversal section "M"

Examining the change of averages of the three age-groups (factor B), we found that they significantly differ from one another in every combination.

Making the calculations with the proper SD value, it can be established that, as for the averages, age-group "m" conspicuously differs from the other two at each of the transversal sections. Except in section K, there is no significant difference between the averages of "k" and "f". As to the collecting sites, significant differences were found between $M_f - G_f$, $G_f - A_f$, $G_f - E_f$, $M_k - G_k$ and $G_k - E_k$. It refers to the fact that in the longitudinal axis (factor A) of the lake, the averages of shell-volume are less different than those of the three age-groups (factor B). The special separation of age-group "m" is also apparent here, but the data on "k" and "f" show a close similarity.

The change of abundance at the different regions of Lake Balaton is shown in *Fig. 6*. The highest density of the age groups was observed in Keszthely Bay (M). The change of abundance of age-groups "m" and "f" is nearly identical, while that of "k" conspicuously differs. If we denote the absolute value in per cent *(Fig. 7)* taking the data of transversal section M for basis, we can see that the density of shells gradually increases from "old age" ("k") to "juvenile age" ("f"), while at other places (G, A, E) it is nearly standard.

Discussion

The results undoubtedly prove that *D. polymorpha* shells divided into three age-groups show different morphometrical features. The following question to answer is what the change of shell volume may be attributed to. According to literary data, particularly on *Unio* and *Anodonta* species, the quantity of the suspended food has a conspicuous effect on the size of shells (Entz and Sebestyén, 1933; Israël, 1913; Mentzen, 1926; Lampert, 1925). In the backwaters of River Danube, extremely rich in suspended food, *Anodonta cygnea* specimens even over 20 cm are common (Varanka, 1973; verbal communication), while in Lake Balaton specimens of 10 cm occur only sporadically. In the studies of the above authors similar examples can be found.

In addition to the food concentration the density of the population may also exert effect on the size of shells. Stańczykowska (1964; 1966) found that in Polish lakes, where the population density of *Dreissena* was low, the shells were longer than where it was high. We are not aware of any other environmental factor which enhance or hinder the growth of shells. Although Stańczykowska (1966) tried to correlate several factors (pH, Ca^{2+} content, etc.) with the quantity and biomass of *Dreissena,* she did it without full success. "It seems the lakes bear an effect on the population as a whole", Stańczykowska established (1964, p. 685). And this totalled effect may appear in the rate of trophyty of the lakes, at least in the case of Lake Balaton this seems to be evident. Consequently, the size of shells, to a certain extent, seems to depend on the quantity of organic matter available in the water and sediment surface being closely connected with the trophyty and the alga-production.

After this survey we wish to discuss our results with regard to the change of shell-volume reflecting the events having taken place in Lake Balaton. Or more exactly, we wonder whether it is possible to draw a conclusion from the change of shell-volumes on the course of eutrophication and its temporal and spatial formation.

The occurring density of *Dreissena* shells horizontally shows similarity in the three age-groups *(Fig. 6)*. This shape of distribution may be connected with the organic matter content of the sediment-water interface. While in Keszthely Bay and its surroundings the organic matter content of sediment is 8—9 per cent, in the other parts of the lake it is only half as much (PONYI et al., 1972). This supposition is supported by the similar distribution of living clams in 1966—1968 *(Table III)*. It is also clear from the table that the occurrence of *Dreissena* in the open water depends not only on the frequency of living *Anodonta* and *Unio* specimens but on the formed food.

TABLE III

The percentual frequency of various Mollusca genera in the samples (in per cent)

Transversal section	M	K	G	A	E
Anodonta	37	25	20	14	14
Unio	100	75	37	28	14
Dreissena	100	87	37	57	43

As to the density of individuals, in the three age-groups, the oldest shells ("k") essentially surpass the other two *(Fig. 6)*. This phenomenon may be explained by the rapid multiplication of *Dreissena* (ENTZ and SEBESTYÉN, 1940). Later, owing to various reasons (its enemies and consumers appeared, increased carp stocking?), its quantity diminished to a standard level. In this period the mean size of the shells was relatively small bearing reference to the population (cf. STAŃCZYKOWSKA, 1964, 1966) and probably the small quantity of suspended food. This supposition seems to be supported by the lack of a significant difference between the shell volumes of animals having lived at places of great and low density (*Fig. 5*, curve "k").

The abundance and alteration of age-groups ("m" and "f") behind "k" are almost identical *(Fig. 6)*. However, there is a conspicuous difference between the shell volumes of "m" and the other two ("k" and "f") *(Fig. 5)*. Comparing with that of "k", the intense growth of shell volume of "m", because of the above reasoning, may not be explained with a decrease in abundance, but probably with a significant increase in the suspended food. The frequency of individuals in the youngest age-group ("f"), except transversal section K, is almost perfectly identical with age-group "m" *(Fig. 6)*.

If we denote the change of values of abundance in per cent *(Fig. 7)*, the quantitative increase of *Dreissena* shells in Szigliget Bay (transversal section K) becomes apparent. According to our data the quantity of suspended food seems to increase to east of Keszthely Bay, i.e. an intense eutrophication has begun in Szigliget Bay, too.

The difference in the structure of population of the three age-groups is well represented by the cumulative curves *(Fig. 4)*. When explaining the considerable change of this structure, first of all in the case of age-group "f", we must not disregard the program of stocking more carps reinstated in the 1950s. In the course of it, in addition to the great mass of fry, specimens of respective body weight were stocked (BIRÓ and ELEK, 1970). Apart from breams, carp may also be supposed to have consumed a significant quantity of *Dreissena*, the effect of which in the structure of population can already be proved.

Therefore, in the structure of population of the three age-groups a sharp break was found. Primarily we try to explain this phenomenon with the quantitative and qualitative change of the suspended food. The phytoplankton seems to be responsible for the quantitative changes *(Table IV)*.

TABLE IV

The quantitative change of blue-greens and all other algae in identical months (May—October) of different years (i/litre × 1000)

	1933 (1)	1944 1947 1949 (2)	1951 (2)	1965 1966 1967 (3—5)
Blue-greens	0.6	8.6	31.0	20.2
All other	1.5	32.3	97.7	141.2

1 = ENTZ et al., 1937; 2 = TAMÁS, 1954; 3 = TAMÁS, 1967; 4 = TAMÁS, 1969; 5 = TAMÁS 1972.

It is common knowledge that molluscs also feed on bacteria, detritus and unicellular animals (MONAKOV, 1972). However, according to data on the lake, they are of insignificant value compared to the algae. The quantity of zooplankton is relatively small *(Table V)*, the production of bacteria is half as much as that of algae (HERODEK and TAMÁS, 1974; OLÁH, 1973), and the quantity of detritus is also small in the open-water areas (PONYI et al., 1972; FRANKÓ and PONYI, 1973).

TABLE V

The fluctuation in zooplankton of the open water in front of the Biological Research Institute in several years (annual average, i/litre, SEBESTYÉN, *1953)*

	1936	1937	1938	1947	1949	1951
Protozoa	49	106	284	696	599	642
Rotatoria	16	22	29	85	36	107
Crustacea	58	58	75	74	88	139
Dreissena veligera larvae	11	4	13	7	5	8

Summarizing the results of investigations on the plankton of the lake *(Tables IV, V)*, it may be established that in the middle of the 1940s an important change took place in the structure of plankton, which was due to the increase of diatoms, Dinoflagellates, green algae and the change in the structure of zooplankton. According to SEBESTYÉN (1953) this change took place abruptly. The changes having taken place in the quantity and quality of suspended food seem to be reflected in the growth of volume of *Dreissena* shells. Accordingly the time-limit between age-groups "k" and "m" may be drawn here. This supposition is connected with the observation (SEBESTYÉN, 1953) that the "gradation" of *Dreissena* population had finished by the end of the 1930s. The decrease of *Dreissena* veligera larvae found in the plankton refers to this *(Table V)*. Thus age-group "k", as far as the frequency of individuals is concerned, sharply differs from the other two *(Fig. 6)*.

The other conspicuous change in the plankton may have taken place in the first part of the 1950s when the quantity of algae suddenly increased again *(Table IV)*. Since that time, the number of blue-greens has been significant. The quantitative and qualitative change of suspended food might cause the sudden decrease of volume of *Dreissena* shells. This concentration seems to have surpassed the optimal for clams, on the other hand, the blue-greens did not prove to be "good" food. The limit of age-group "m" and "f" may be drawn at about the middle of the 1950s. So the rate of eutrophication of Lake Balaton seems to have followed the change of shell-size.

Summary

The authors divided into three age-groups (old, middle-aged, young) the 26 600 *Dreissena polymorpha* shells found in the upper sediment layer of five transversal sections of Lake Balaton. The age of shells comprises a period of 33—34 years from their settling in the sediment to the investigations. They investigated the volume of shells from different parts of the lake with an ICL System 4 computer, on the basis of 15 statistically comparable samples they established the following:

1. On the basis of hystogram program the morphometries of shells from the different collecting sites and belonging to different age-groups are more or less identical. The size of old and young shells was nearly the same, but the middle-aged ones significantly differed from both.

2. The results of the analysis of variance showed that the variability of samples is different both in the longitudinal axis of the lake and in the three age-groups. Averaging the observed frequencies of the three age-groups and plotting their cumulative curve it is apparent that the structure of young shell population conspicuously differs from the other two. The mean volume of shells is different in both the longitudinal axis of the lake and the age-groups. From this point of view the old and young age-groups are fairly similar, although, they are separated by a long time. The size of middle-aged shells entirely differs from the other two groups.

3. In each of the three age-groups the density of *Dreissena* shells was most frequent in the south-western corner of the lake (transversal section M). The abundance of middle-aged and young groups was nearly identical in the longitudinal axis of the lake, while that of the old group significantly differed. Denoting the values of abundance in per cent, it is apparent that in one of the water areas of the lake (section K) the density of individuals gradually increased from the "old" age to the "young" one.

4. The authors compared their results obtained from the hystogram program and the analysis of variance by two factors with the biological changes observed in Lake Balaton up to now and with the ecological knowledge

on this species. They established that the different structure of population of the three *Dreissena* age-groups may be connected to the horizontal distribution of the suspended available food in the lake and the increasing eutrophication.

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A BALATON FELSŐ ÜLEDÉKRÉTEGÉBŐL SZÁRMAZÓ *DREISSENA*-HÉJAK MORFOMETRIÁJÁNAK ÉS POPULÁCIÓ-SZERKEZETÉNEK VIZSGÁLATA ICL SYSTEM 4 SZÁMITÓGÉPPEL

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Összefoglalás

A szerzők a Balaton 5 keresztszelvénye felső iszaprétegéből kinyert 26,6 ezer db *Dreissena polymorpha* héjat, azok külső állapota alapján 3 korcsoportra (öreg-, középés fiatalkorú) osztották. A héjak kora a kagylók bekerülésétől számítva a vizsgálat idejéig összességében 33—34 éves időszakot foglalt magában. ICL System 4 számítógéppel vizsgálták a tó eltérő helyeiről származó és különböző időszakokban élt kagylóhéjak térfogat-viszonyait és a 15 statisztikailag összehasonlítható minta alapján a következőket állapították meg:

1. A hisztogram program alapján a különböző gyűjtési helyekről származó, de nem azonos korcsoportba tartozó héjak morfometriái többé-kevésbé azonosak. Az öreg és fiatalkorú kagylóhéjak méretviszonyai szinte teljesen megegyeztek, a középkorúak viszont mindkettőtől jelentősen eltértek.

2. A variancia analízis eredményei azt mutatták, hogy a minták variabilitása mind a tó hossztengelyében, mind a 3 korosztályban különböző. A 3 korcsoport osztályonkénti tapasztalatai gyakoriságát átlagolva és azt kummulatív görbén ábrázolva kitűnik, hogy a fiatal kagylópopuláció szerkezete jelentősen eltér a másik kettőtől. Az átlagos héjtérfogat a tó hossztengelyében és a különböző korcsoportok esetében eltérő. Az öreg és fiatal korcsoport e tekintetben elég közel áll egymáshoz, noha időben a legtávolabbra esnek. A középkorú kagylók méretei élesen eltérnek a másik kettőtől.

3. A *Dreissena* héjsűrűsége mindhárom korcsoportban a tó délnyugati csücskében („M" szelvény) volt a legnagyobb. A középkorú és fiatal korcsoport abundanciája a tó hossztengelyében szinte azonos volt, ugyanakkor az öreg korcsoporté jelentősen eltért azoktól. Az abundancia adatokat %-ban kifejezve kitűnik, hogy a tó egyik vízterületén („K" szelvény) az „öreg kagylókortól" a „fiatal kagylókor" felé fokozatosan nőtt az egyedszámsűrűség.

4. A szerzők a hisztogram program és a két faktoros variancia analízis alapján számított eredményeket összevetették a Balatonban eddig észlelt biológiai változásokkal és e fajjal kapcsolatos ekológiai ismeretekkel. Arra a megállapításra jutottak, hogy a 3 *Dreissena* korosztály eltérő populáció szerkezete összefüggésbe hozható a szuszpendált formált tápanyagok tavi horizontális megoszlásával, valamint a növekvő eutrofizálódás folyamatával.