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INVESTIGATIONS ON THE GROWTH AND POPULATION-STRUCTURE OF BREAM (*ABRAMIS BRAMA* L.) AT DIFFERENT AREAS OF LAKE BALATON, THE ASSESSMENT OF MORTALITY AND PRODUCTION

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According to the fishery statistics of Lake Balaton the bream (*Abramis brama* L.) represents the majority — about 70—80 per cent — of the annual catch, by weight it is about 900—1100 tons (Biró and Elek, 1970). In consequence of its dense population on the level of nekton among the non-predatory fish it has an important, ecological role.

Relating to its growth in Lake Balaton some data were published by Wunder (1930), Woynárovich (1958), and Ribiánszky and Woynárovich (1962). Recently, Pénzes (1966; 1968) made further comparative studies on some Hungarian bream populations amongst them on those inhabiting Lake Balaton. Data published by the above-mentioned authors must be completed because of the rapid changes occurring in the fish-fauna of Lake Balaton and in the living conditions of fish observed during the last years. Our present knowledge is insufficient from the points of population structure and the local differences of growth. Ratios of mortality and survival are entirely unknown as well as the annual production of the average biomass. Growth, length-distribution and age-composition of bream were studied on the basis of samples collected at different parts of Lake Balaton. The aims of our investigations were as follows:

1. Determination of growth of scales and of standard length of bream in comparison with earlier data and the analysis of growth at five different parts of the lake.

2. Gathering informations on the changes in fish stock taken place after the fish destruction in 1965 and on the exploitation of the stock by fishing as well as the effects on the growth of eutrophication and probable food-competition.

3. Comparison of population dynamics and growth of bream inhabiting Lake Balaton with that of the various European bream populations. Determination of some basic population parameters, i.e. length-distribution, age-composition, mortality and production.

Material and methods

The material of our investigations was sampled from among the fish caught with 1200 m long nets of 3.5 — 4 cm mesh size randomly on the fishery stations of Siófok, Tihany, Balatonszemes, Fonyód and Keszthely in July, 1972—73 *(Figs 1—2)*. Their standard and total length and weight were measured. 10—20 scales were detached from the area above the lateral line behind the posterior margin of the left pectoral fin of 881 fish in 1972. In July, 1973 we made length and weight measurements on 1403 breams to learn the length-distribution of the stock. Of the scales collected in 1972, 4—8 well developed specimens were placed between slides. Using a millimetre divided ruler we measured the radii of winter rings and the total caudal radii of scales at a 50 times magnification (then these values were given in millimetres). Ageing was made by counting the number of completely developed annuli found on the scales. Detailed scale investigations were carried out on 453 breams and simple age-determinations were made on 720 specimens. On the

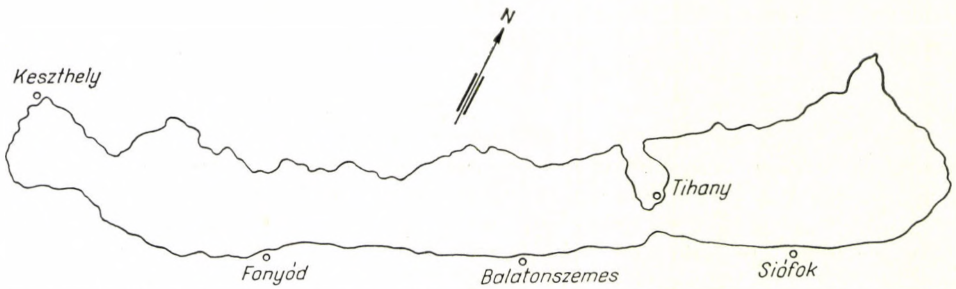


Fig. 1. Position of fishery stations of Lake Balaton where the material was collected

Fig. 2. 3—4 summer-old breams from Lake Balaton (Siófok)

basis of measured length and weight data the length–weight relationship was calculated according to HUXLEY (1924) (cit. BEVERTON and HOLT, 1957) with the use of a computer typ. IMP-360. The regression between the standard lengths and the total caudal radii of scales was determined by the least square method. The intercept of the line on the abscissa was taken into consideration as a correction factor in the back-calculation of fish lengths (FRASER, 1916). The growth of breams at different areas of the lake was graphically represented by the FORD-WALFORD's method (WALFORD, 1946). We applied BERTALANFFY's (1938; 1957) growth-model for correct comparison of the growth rates using the back-calculated standard lengths. Mortality was determined by RICKER's (1958) method. Biomass and production were assessed according to RICKER and FOERSTER (1948) and RICKER (1958) for the most intensively harvested 3+ to 7+ age-groups. The instantaneous coefficients of growth in weight necessary to the assessment of production were calculated after CHAPMAN (1968) and TESCH (1968). In the present study the results of our observations made on altogether 2123 breams are summarized.

Results

1. *Data on catch statistics*

Surveying the data on catch statistics referring to bream between 1950—71 it can be seen that the tendency of yearly catches — within some limits of fluctuation — decreased till 1965 and began to increase *(Fig. 3)*. In the consecutive years between 1950—71 the calculated kg/ha values show that on the basis of the average catches the past 22 years may be divided into three periods. The first one includes the years of 1950—52 when the average annual catch amounted to about 20 kg (*Fig. 3,* line A) while the second one 1953—64 when about 22 kg were caught and its value decrease annually by 0.58 kg (*Fig. 3,* line B). The third period falls between 1965 and 1971 when the average annual catch reached about 16 kg/ha (*Fig. 3,* line C).

2. *Length distribution*

The standard lengths of breams in our material caught in Lake Balaton varied between 12—35 cm *(Figs. 4—5)*, for their length distribution areal fluctuations are characteristic. In the environs of Siófok the specimens of 14—19 cm length are chiefly caught and at the same time specimens above 20 cm are scarcer here. In the district of Tihany the specimens of 18—23 cm dominate. At Balatonszemes specimens of 18—23 cm predominate and their number continually diminishes up to 30 cm. At Fonyód a significant per cent of the catches comprised specimens between 17—22 cm, but specimens up to 30 cm are also frequent. In Keszthely Bay the overwhelming majority of fish ranged from 16 to 21 cm but those between 23—28 cm are also frequent, their distribution appears bimodal. The length distribution of fish regionally differs. The largest specimens, according to our measurements, are caught in the environs of Balatonszemes and Keszthely, their age being mostly between 2+ and 4+. Older than 7+ fish was not found and this fact can partly be attributed to the intensive fishing. In the length distribution of the stock, the role of the older fish (7+ and older) is insignificant. The measured standard

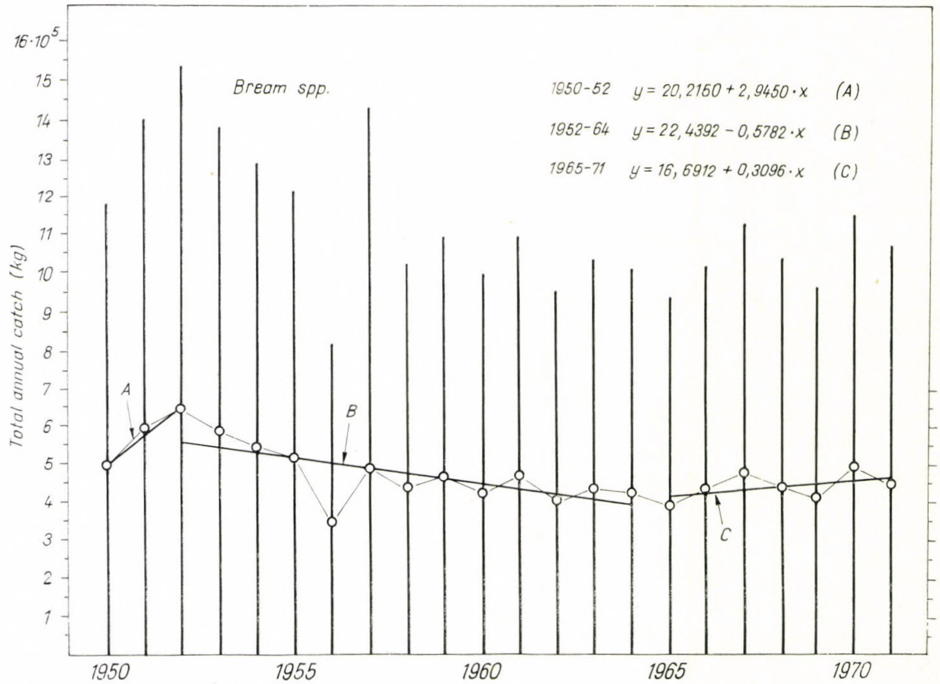


Fig. 3. Annual catches of bream in Lake Balaton in 1950—71. Vertical lines indicate the total catch in kg; circles the catches in kg/ha. Lines A, B and C show the calculated regression of catches in kg/ha values (y) in the function of consecutive years (x)

lengths of the different age-groups in our bream material significantly fluctuated and the deviation from the mean reached $\pm 4-5$ cm. On the basis of measured standard lengths the average for the entire Lake Balaton shows a smoothed growth pattern *(Fig. 6)*.

3. *Length–weight relationship*

The allometric coefficient was found to be 3.3 *(Fig. 7)*. This average is evidently varying topographically and seasonally, which is primarily in close connection with the condition and food consumption. The effect of *Ligulosis* on the length–weight relationship from our material, which in some age-groups can be significant, has not been determined yet.

4. *Growth of scales in relation to the standard length and age*

About 60—70 per cent of the examined scales were well and symmetrically developed. Deformations, damages and regenerated spots were found in about 30—40 per cent. The relationship between the standard lengths and the total caudal radii of scales is well represented by the calculated linear regression *(Fig. 8)*. A stepped, sigmoid curve exists between the standard lengths and the average annuli distances established for the different age-groups. This sigmoid curve reflects the exponential pattern of growth in standard length *(Fig. 9)*.

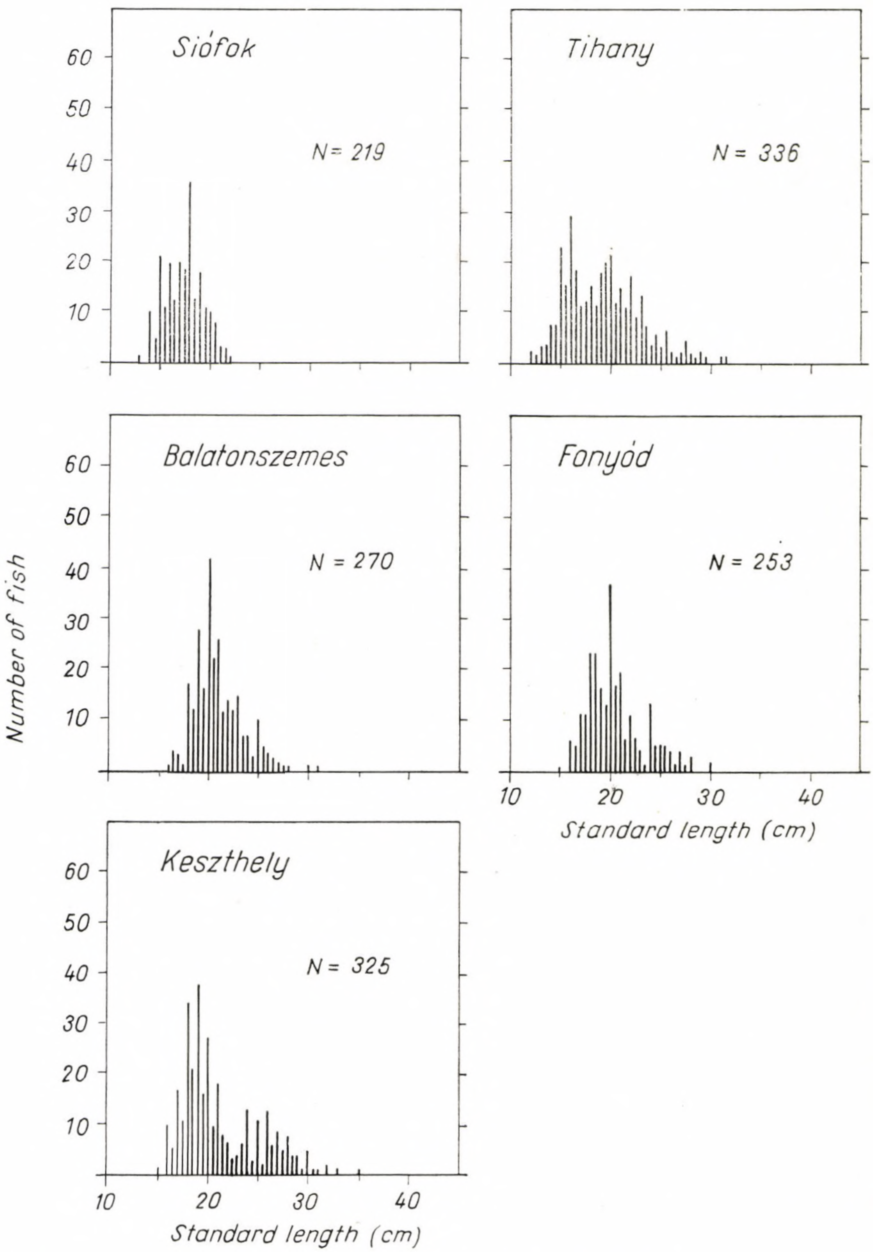


Fig. 4. Length-distribution histograms of bream collected at different areas

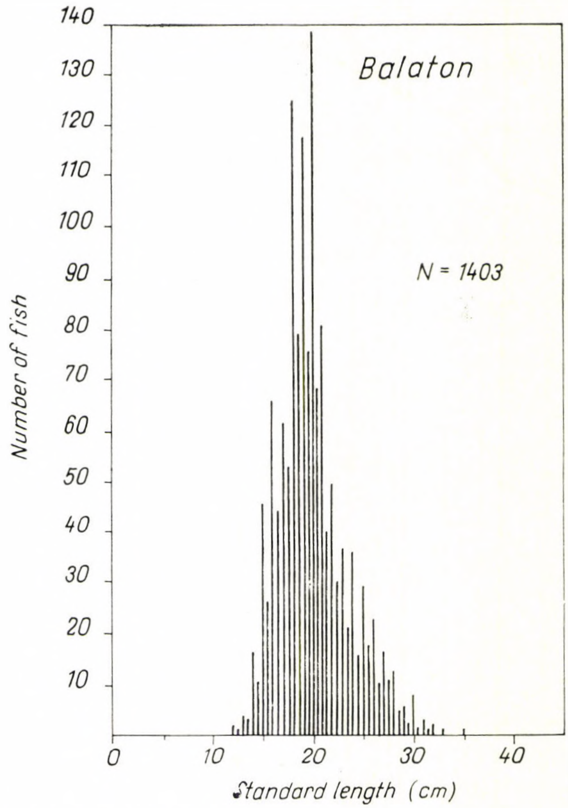


Fig. 5. Length-distribution of all breams investigated (N = 1403 specimens)

5. *Growth in standard length*

Estimating the yearly increments by using the back-calculated standard lengths, no essential, or great differences were observed amongst the different areas of the lake. However, according to the growth of fish caught at five investigated areas of Lake Balaton definite deviations both in shape and rate of growth were registered *(Table I, Fig. 10)*. The average growth in length from 1+ to 7+ age-groups in Lake Balaton is almost uniform, however, the limits (minimum—maximum values) within age-groups are rather significant *(Table II)*. From the measured weights and back-calculated standard lengths it seems that in the south-western basin, i.e. in environs of Fonyód and in Keszthely Bay, the breams have higher mean weights and they grow faster than in other parts of the lake. Similar results were found when the growth of different age-groups were analysed by year-class strengths *(Fig. 11)*. In this case the growth is also rather smoothed, nevertheless, it is conspicuous that the differences of measurements in 2+ and 3+ age-groups were relatively small, except the material from Fonyód in 1972. The back-calculated standard lengths in different areas were graphically represented according to FORD—WALFORD's (1946) method. Plotting the lengths in t-times (l_t) in the function

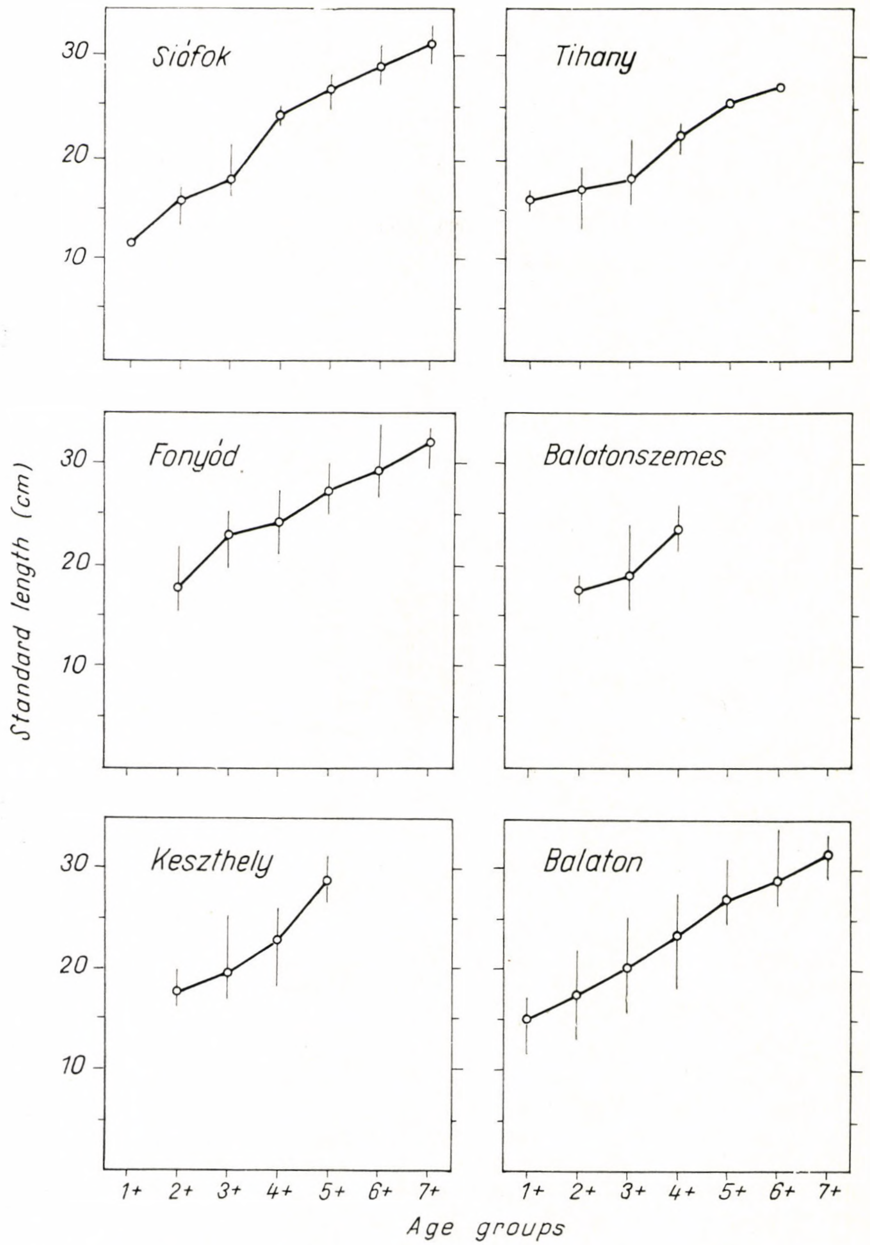


Fig. 6. Measured average standard lengths in the time of scale collections (circles) and the minimum-maximum lengths in the age-groups at different areas of Lake Balaton

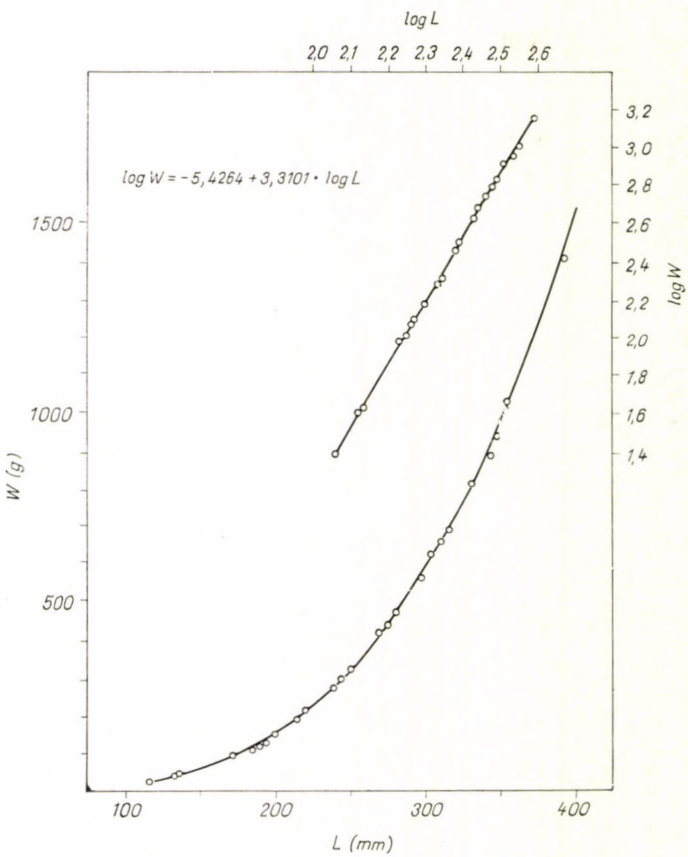


Fig. 7. Length–weight relationship of bream in Lake Balaton (L = standard length in mm; W = weight in g)

TABLE I

Back-calculated standard lengths (cm) of bream in different parts of the lake

	Standard lengths						
	l_1	l_2	l_3	l_4	l_5	l_6	l_7
Siófok	7.7	12.1	16.1	20.7	23.9	26.4	28.8
Tihany	8.2	13.8	15.5	21.2	23.1	25.9	—
Balatonszemes	8.5	13.0	16.4	21.1	—	—	—
Fonyód	8.3	13.5	18.3	21.2	24.5	27.0	29.7
Keszthely	7.8	12.6	16.3	20.1	23.7	25.1	—
Average for Lake Balaton	8.1	13.0	16.7	20.8	24.1	26.6	29.3

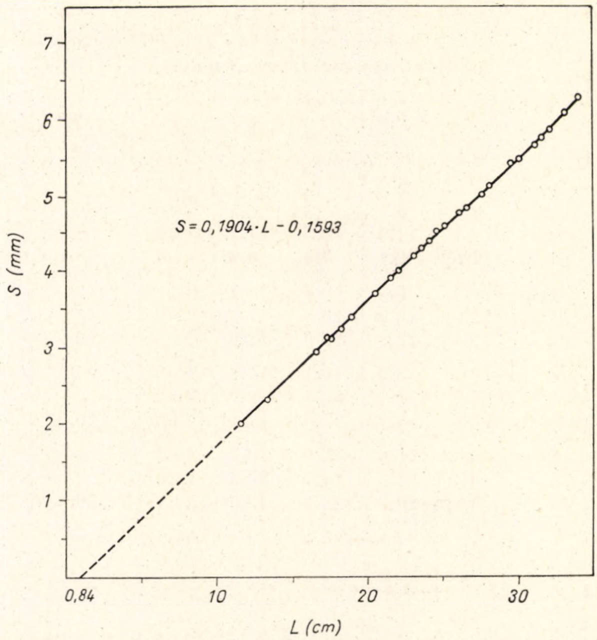


Fig. 8. Linear regression of the caudal radii of scales (S in mm) in the function of standard length (L in cm)

of one-year-later values (l_{t+1}), the dots determine a straight line of which the intercept by the diagonal line passing through the origin at an angle of 45 degrees, gives a theoretically attainable, maximum length *(Figs 12—15).* The numerical vaues of L_∞ for Lake Balaton differ by areas and on an average it is 47.4 cm *(Fig. 16).* From our data the other parameters of BERTALANFFY's growth-model were also determined, as well as the origin of the exponential curves (t_0 = prenatal age) and the rates of growth (K = slope). Representing the exponential growth curves by using the K parameters, a correct comparison can be made referring to the rates of growth observed in different parts of the lake *(Fig. 17).* Thus, in the environs of Siófok and Fonyód the rates of growth in standard length are very similar and the K-values are the same (K = 0.12). In the surroundings of Tihany, the growth is more rapid (K = 0.18), while in Keszthely Bay, it is the most intensive (K = 0.23) amongst the studied areas. Maximum length is in inverse proportion to the numerical value of the prenatal age (t_0). The average growth-model calculated for Lake Balaton can be placed in line with the Siófok—Fonyód and of the Tihany—Keszthely models. Consequently, it represents topographically the middle transversal section of the lake. Evaluating the growth in length by different methods, it can be established that the estimated numerical values hardly differ from one another as it was shown above by the calculated averages for Lake Balaton *(Table III).* The same result was obtained when the previous comparison of the observed values was made at five different areas, separately. It is evident that bream in Lake Balaton grows intensively compared to those of several European waters *(Fig. 18).*

TABLE II

Back-calculated standard lengths (cm) from scales (average for Lake Balaton)

Standard lengths		Age-groups							Average	Difference	W (g)
		1+	2+	3+	4+	5+	6+	7+	(cm)		
l_1	A	5.6	4.6	4.1	4.6	5.3	5.2	5.8	—	—	—
	B	11.7	12.1	12.7	11.9	10.5	11.7	13.9	—	—	—
	C	9.5	8.5	7.8	8.1	7.6	8.2	8.7	8.1	—	7.8
l_2	A		10.1	8.4	9.7	10.3	8.1	10.8	—	—	—
	B		16.4	17.7	15.9	14.9	17.4	19.0	—	—	—
	C		13.7	12.4	12.9	12.2	12.6	13.8	13.0	4.9	37.2
l_3	A			12.6	13.9	14.1	11.8	14.9	—	—	—
	B			22.0	21.0	20.8	22.7	22.7	—	—	—
	C			16.4	17.0	17.0	17.1	18.0	16.7	3.7	85.3
l_4	A				16.6	17.9	16.7	18.3	—	—	—
	B				23.8	24.7	24.3	24.2	—	—	—
	C				20.6	21.0	20.6	21.0	20.8	4.1	176.5
l_5	A					21.5	19.4	21.7	—	—	—
	B					27.1	29.3	27.7	—	—	—
	C					24.4	23.9	24.1	24.1	3.3	287.2
l_6	A						23.1	24.1	—	—	—
	B						31.0	29.4	—	—	—
	C						26.5	26.8	26.6	2.5	398.3
l_7	A							26.0	—	—	—
	B							32.8	—	—	—
	C							29.3	29.3	2.7	548.5

A = minimum-, B = maximum-, C = average standard length.

TABLE III

Comparison of standard lengths (cm) of bream back-calculated by different methods (average for Lake Balaton)

Age-group	Actual age (year)	Standard lengths		
		From scales Fraser's method	WALFORD-plot	BERTALANFFY's model
0+	0.46	—	—	2.8
1+	1.46	8.1	5.7	8.2
2+	2.46	13.0	12.8	12.7
3+	3.46	16.7	17.2	17.0
4+	4.46	20.8	20.4	20.7
5+	5.46	24.1	24.0	24.0
6+	6.46	26.6	26.9	26.7
7+	7.46	29.3	29.1	29.2

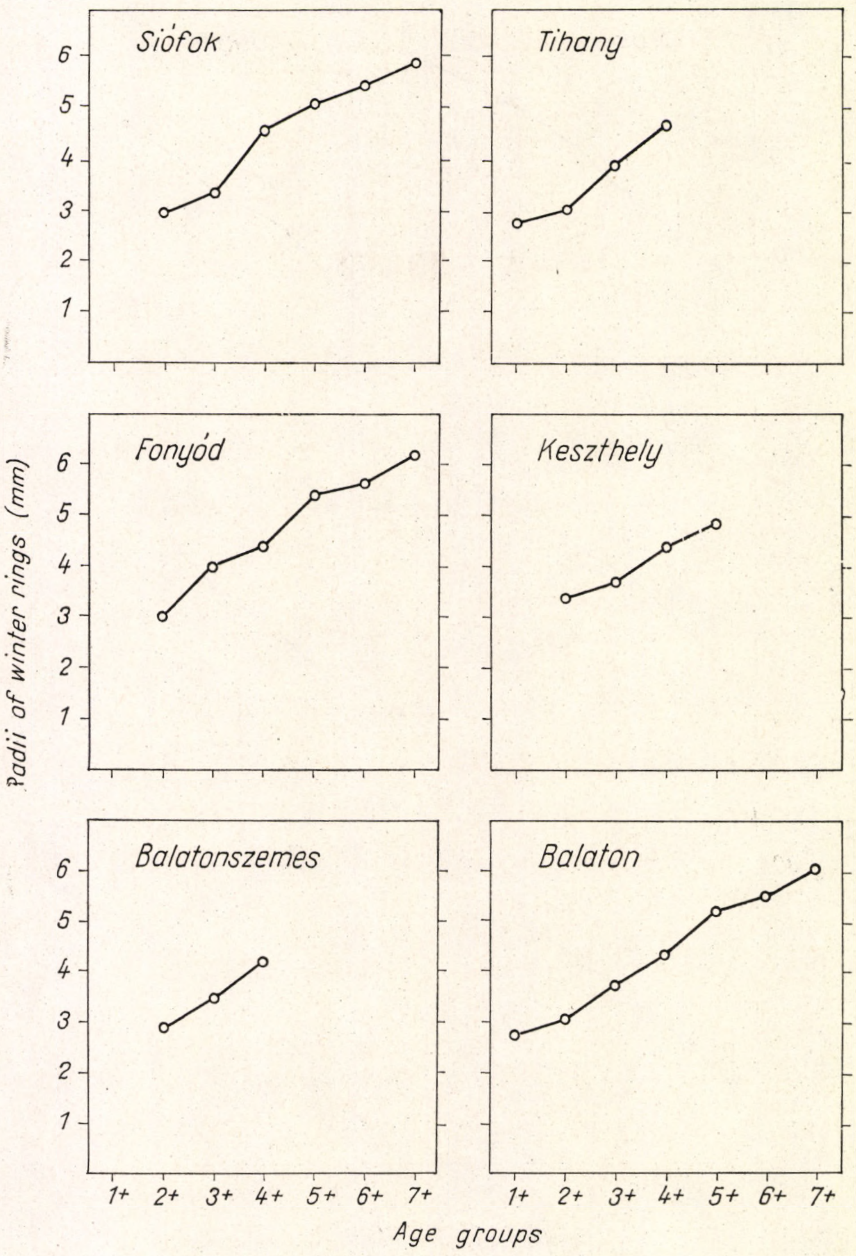


Fig. 9. Measured average distances of annuli in age-groups of bream collected at different areas of the lake

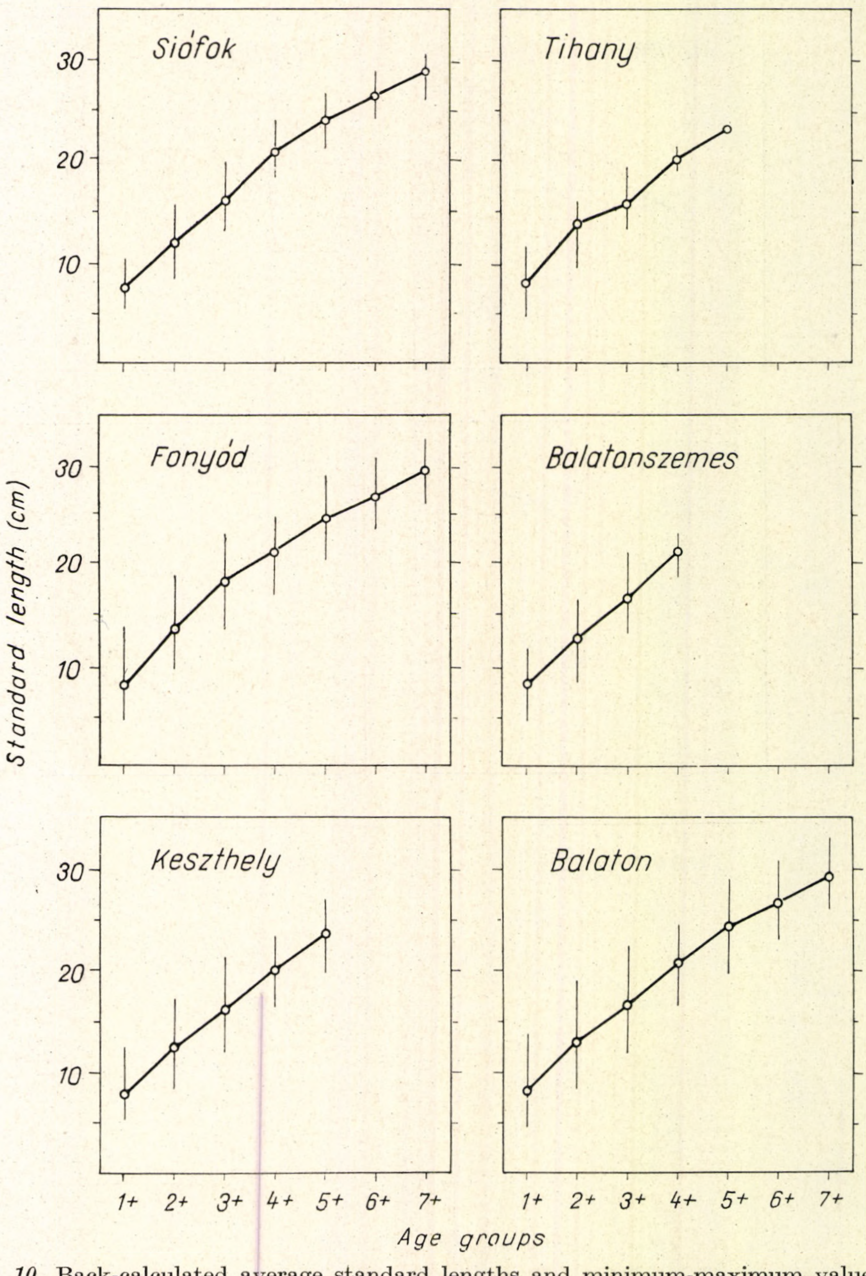


Fig. 10. Back-calculated average standard lengths and minimum-maximum values at different parts of Lake Balaton and the average for the entire lake calculated on the basis of five different areas

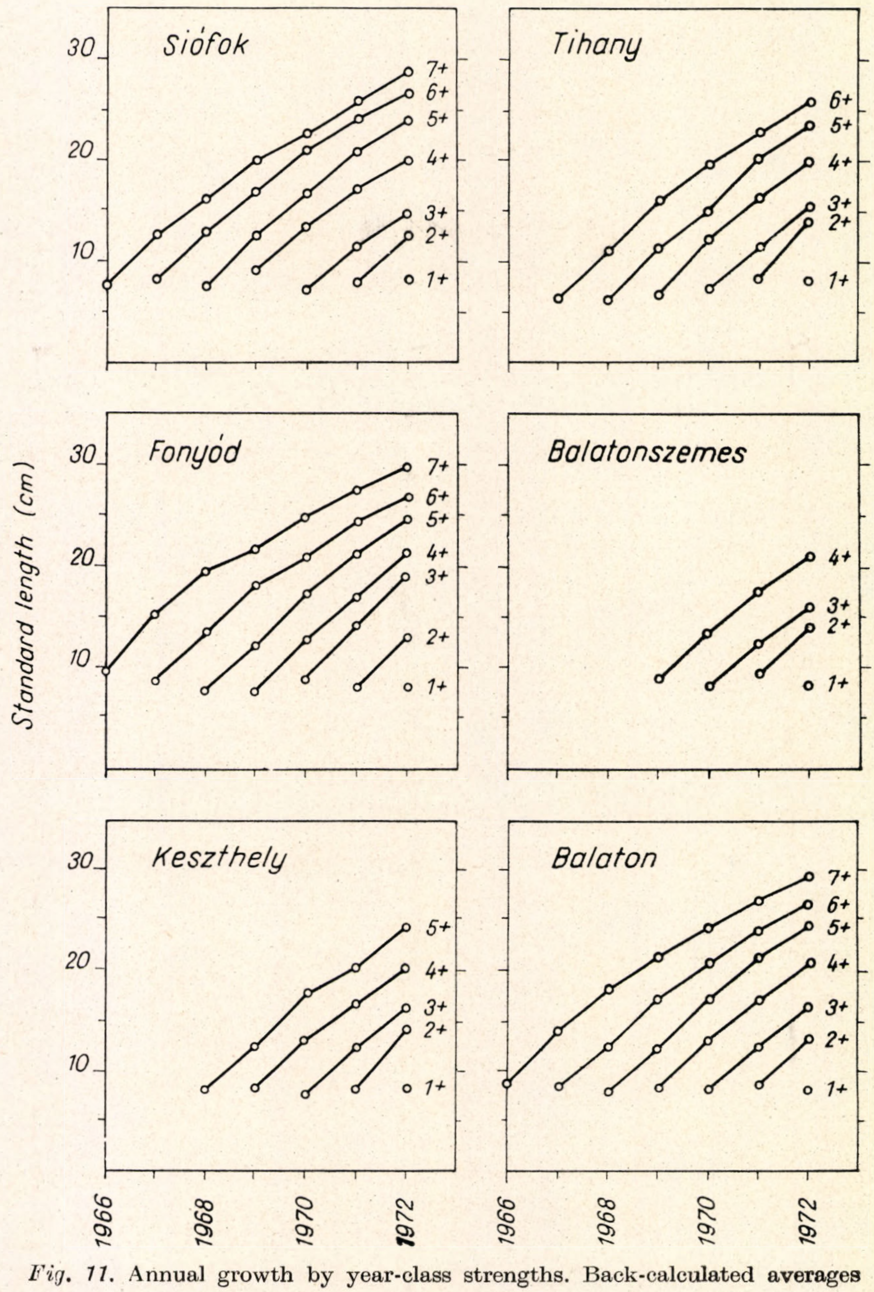
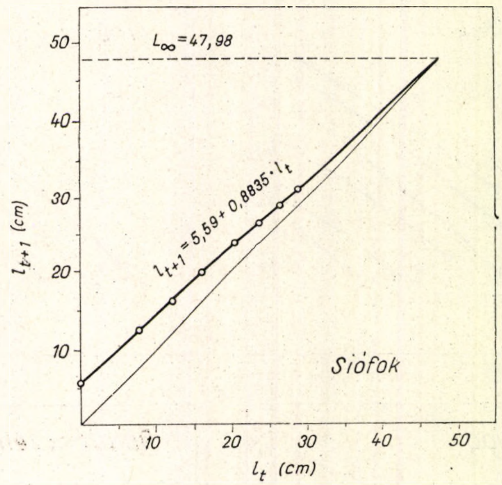
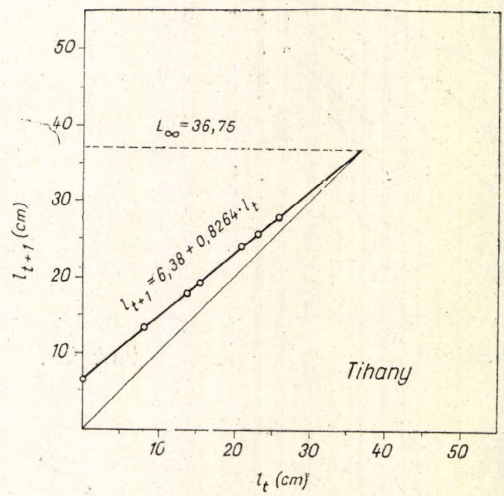
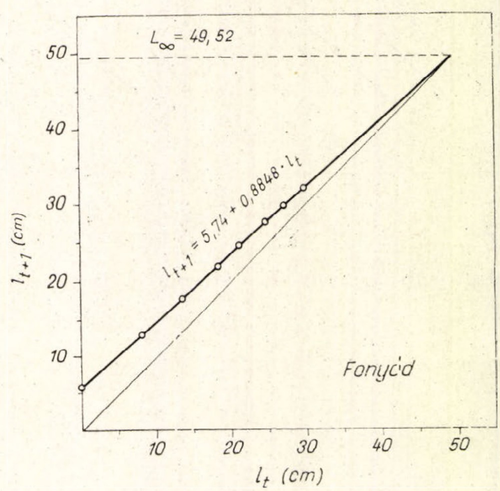
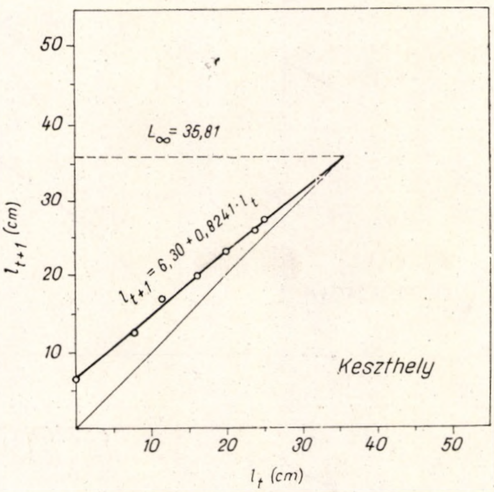


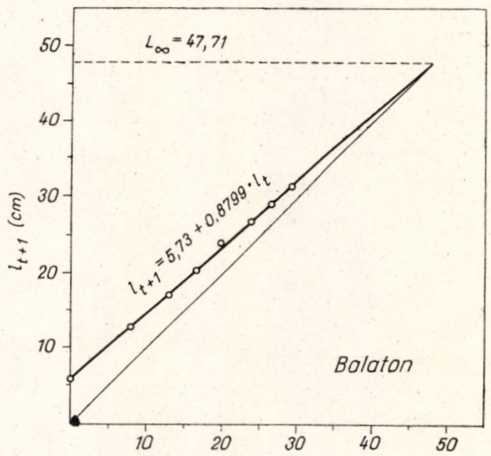
Fig. 11. Annual growth by year-class strengths. Back-calculated averages


$L_\infty = 47,98$
$l_{t+1} = 5,59 + 0,8835 \cdot l_t$
Siófok
l_{t+1} (cm)
l_t (cm)
10
20
30
40
50


$L_\infty = 36,75$
$l_{t+1} = 6,38 + 0,8264 \cdot l_t$
Tihany
l_{t+1} (cm)
l_t (cm)
10
20
30
40
50


$L_\infty = 49,52$
$l_{t+1} = 5,74 + 0,8848 \cdot l_t$
Fonyód
l_{t+1} (cm)
l_t (cm)
10
20
30
40
50





Figs 12—16. Representation of growth in length of bream at different areas of the lake and the average for the entire Lake Balaton (FORD-WALFORD plots). l_t = standard length in every t-period of time (t = 1 year), l_{t+1} = standard length one year later, L_∞ = maximum attainable size in cm

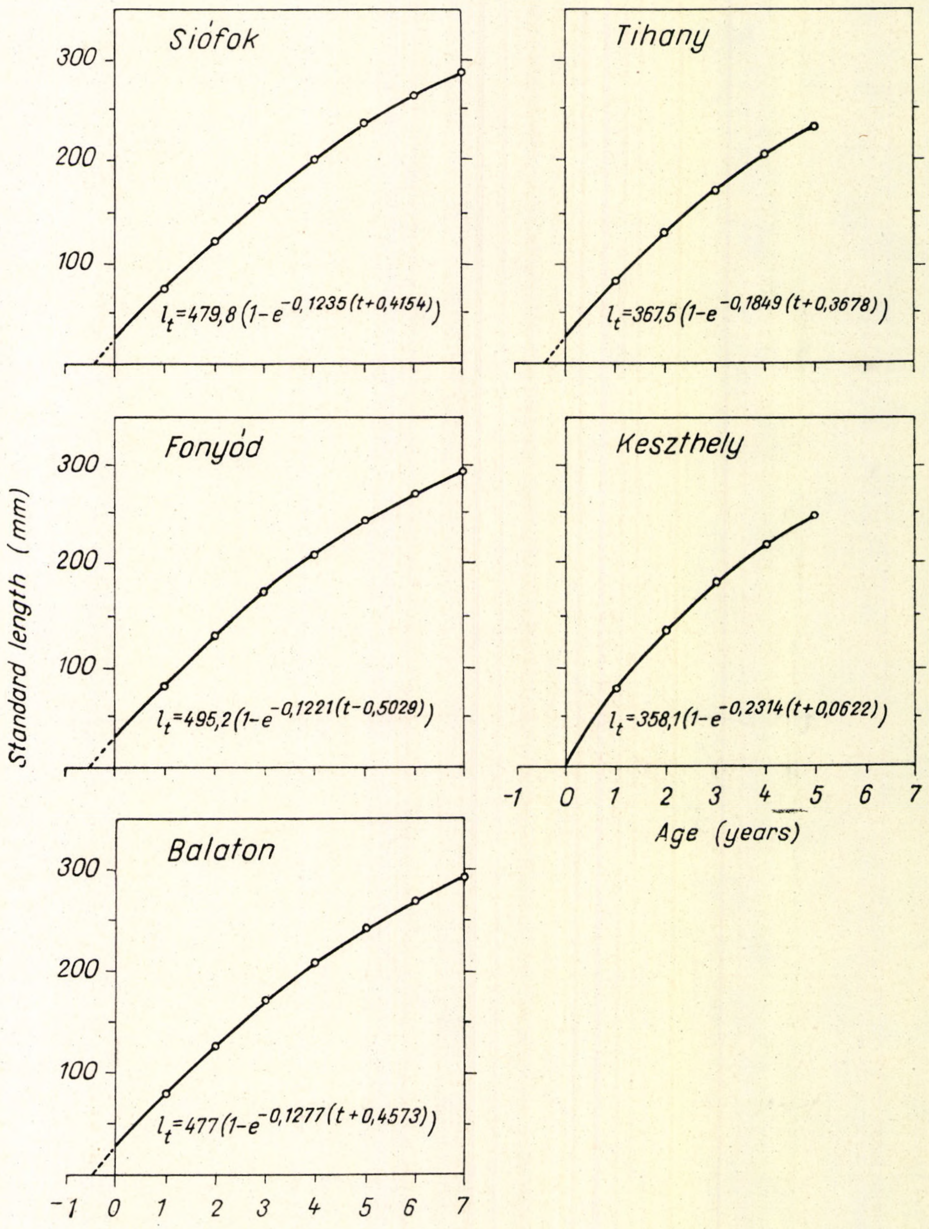


Fig. 17. Representation of the exponential growth in standard length (mm) by BERTALANFFY's (1938, 1957) mathematical model at different areas of the lake and the average for Lake Balaton. l_t = standard length in every t-period of time, where t = 1 year

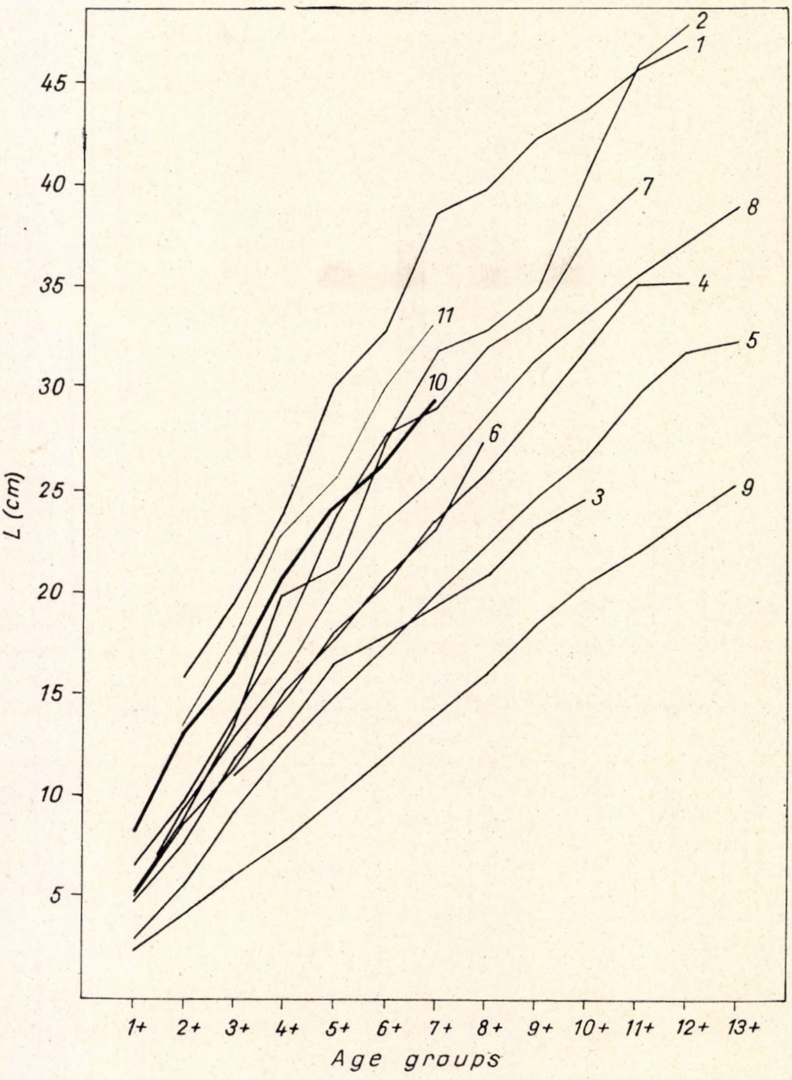


Fig. 18. Comparison of average growth in standard length in Lake Balaton with rate of growth observed in various European waters:

1 = Lake Boden; 2 = Plöner See; 3 = Müggelsee; 4 = average of 36 N-German lakes; 5 = Hjälmaren; 6 = average of 14 Mazurian lakes; 7 = Lake Ladoga; 8 = Rybinsk Reservoir; 9 = Tuusula (No. 1—9: cit. Backiel and Zawisza, 1968); 10 = Lake Balaton (present investigations); 11 = Lake Balaton (Pénzes, 1966; growth represented by directly measured standard lengths)

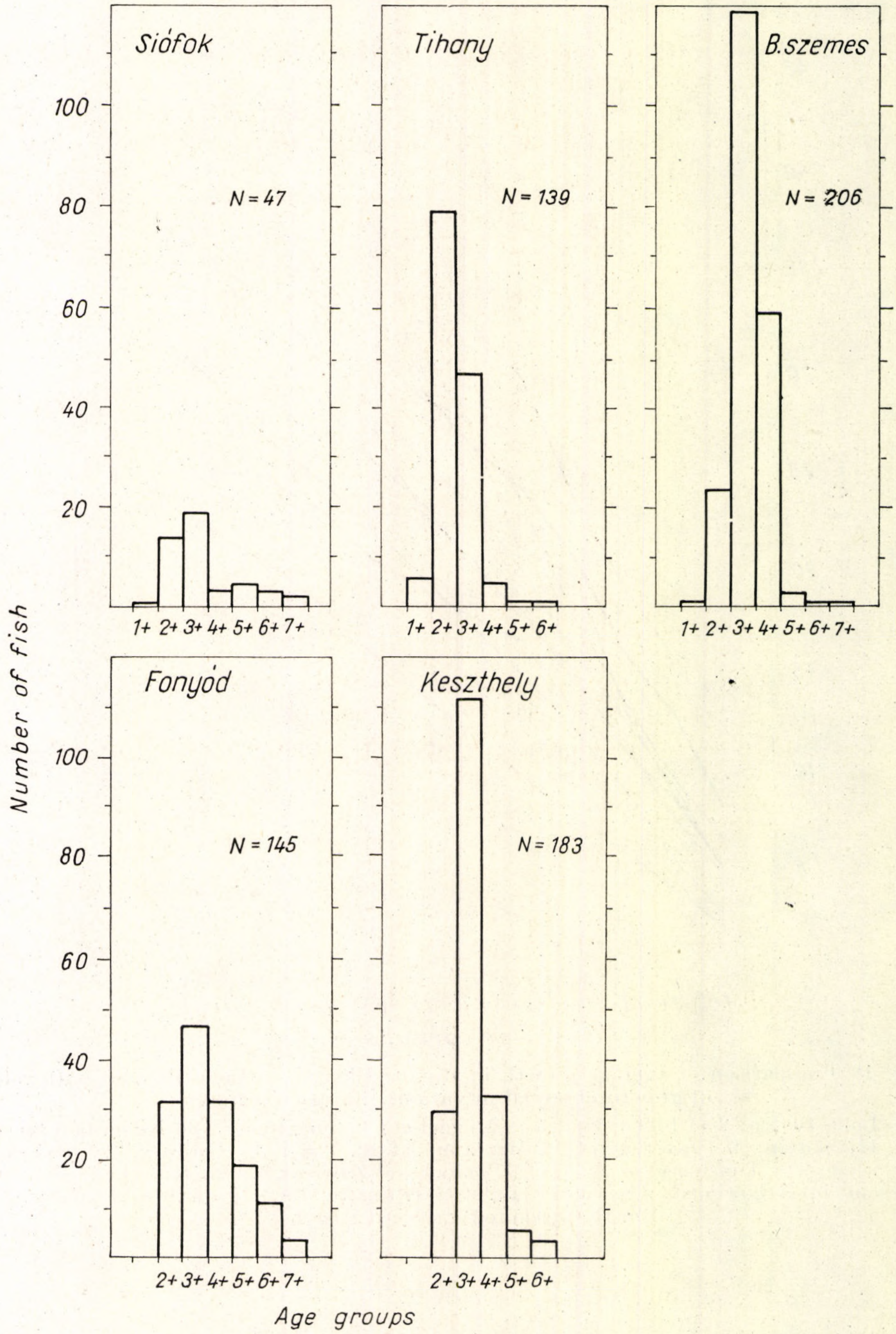


Fig. 19. Age-composition of fish collected at different areas of Lake Balaton

6. *Age-composition*

In 1972, 720 breams were aged on the basis of the number of completed annuli then the age-composition of the stock was studied. From samples collected at five areas of Lake Balaton although the number of individuals was different, it could be observed that the most frequent age-groups in the catches varied between 2+ and 4+. Their local distribution is also different *(Table IV, Fig. 19)*. In the catch from Siófok (47 specimens) the 2+ and 3+ year-old fish dominated, while in that of Tihany (139 specimens) the 2+ year-old ones. The number of individuals in the 3+ age-group was less.

TABLE IV

Age composition of bream stock of Lake Balaton according the specimens collected at different parts of Lake Balaton

	Age-groups							
	1+	2+	3+	4+	5+	6+	7+	Total
Siófok	1	14	19	3	5	3	2	47
Tihany	6	79	47	5	1	1	—	139
Balatonszemes	1	22	119	59	3	1	1	206
Fonyód	—	32	47	32	19	11	4	145
Keszthely	—	30	112	33	6	4	—	183
Total:	8	179	344	132	34	20	7	720

The majority of 206 breams collected near Balatonszemes was 3+ year-old, followed by the 4+ year-old ones. Nearly the same sequence was obtained for the age-composition of 183 fish deriving from Keszthely Bay. At Fonyód the number of individuals in age-groups of 3+ to 7+ gradually decreased. The occurrence of 2+ year-old breams in the catches in considerable quantities was very characteristic for the age-composition of all fish (N = 720) collected at the five different areas of the lake. From the 3+, the dominant group, up to 7+ age-group the number of specimens gradually and significantly decreased *(Fig. 20)*. Older than 7+ year-old fish was not collected. The 1+ and 2+ age-groups amounted to 26 per cent of the sample. 3+ year-old fish occurred in about 48 per cent, and the 4+ year-old ones in 18 per cent. The ratio of 5+ age-group was five per cent, while that of the 6+ was three per cent, and of 7+ was one per cent.

7. *Mortality*

The total number of specimens in the different age-groups was taken as representative ratio for the catches. Instantaneous total mortality coefficient was calculated by the diminishing number of specimens by using their logarithms of natural base *(Fig. 21)*. This calculation refers to the most abundant age-groups from 3+ to 7+. On an average, the instantaneous total mortality coefficient for the entire Lake Balaton proved to be $Z = 0.9677$. Survival rate was assessed to be 38 per cent of which the annual mortality was 62 per cent. In the age-groups these values were different, consequently, the survival rate varied between 26 and 59 per cent, the annual mortality between

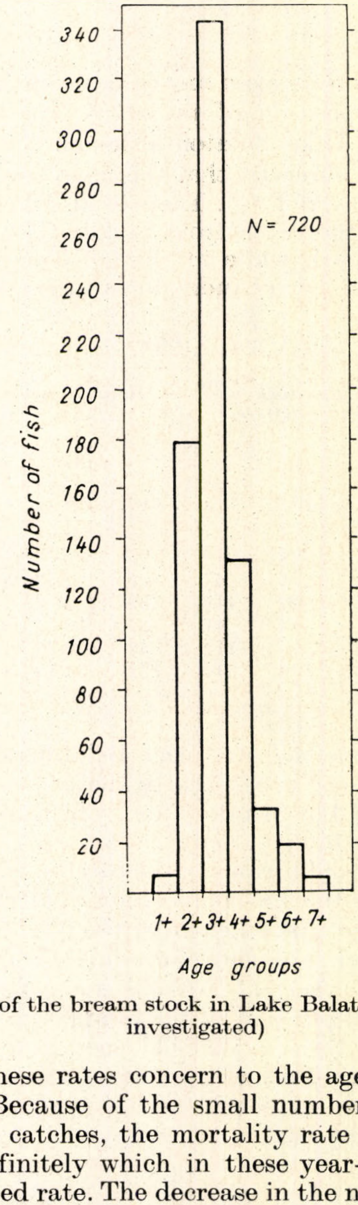


Fig. 20. Age-composition of the bream stock in Lake Balaton (N = total number of fish investigated)

41 and 74 per cent. These rates concern to the age-groups most intensively exploited by fishing. Because of the small number of young fish (0+ and 2+ age-groups) in the catches, the mortality rate for the whole population cannot be assessed definitely which in these year-classes may probably be higher than the estimated rate. The decrease in the number of fish is a decisive result of fishing mortality (and of sport fishing), while the rate of mortality due to natural causes may be relatively small. This, first of all, can be explained by the mass destruction of fish in the spawning period parallel to other external effects, i.e. pollutions, poisons etc.

8. *Biomass and production*

Initial (B_0) and average biomass ($\bar{B}$) of 3+ to 7+ age-groups were assessed according to the exponential growth by using the number of fish in different age-groups (N_0), their weight (W_0), the mortality (Z) and the

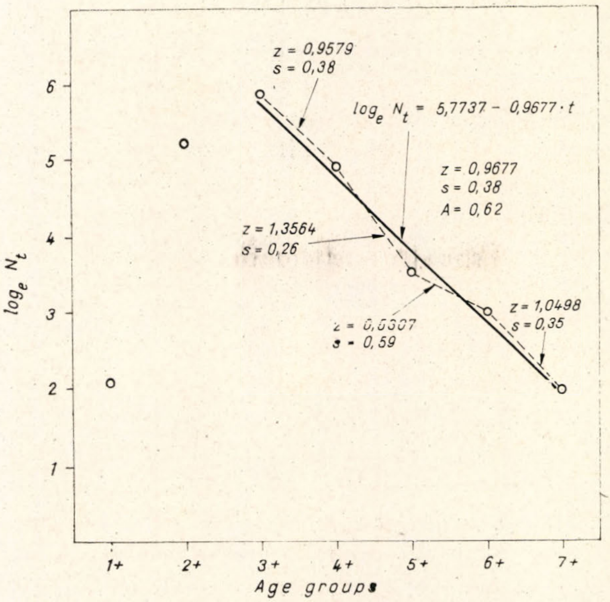


Fig. 21. Instantaneous total mortality coefficient (Z) and rate of survival ($s = e^{-z}$ in per cent) for the age-groups 3+ to 7+ of bream; $A = 1 - s$ = annual mortality in per cent. On the ordinate N_t = logarithms of natural base of individual numbers in different age-groups. On the abscissa the age-groups are represented in an interval of t = 1 year

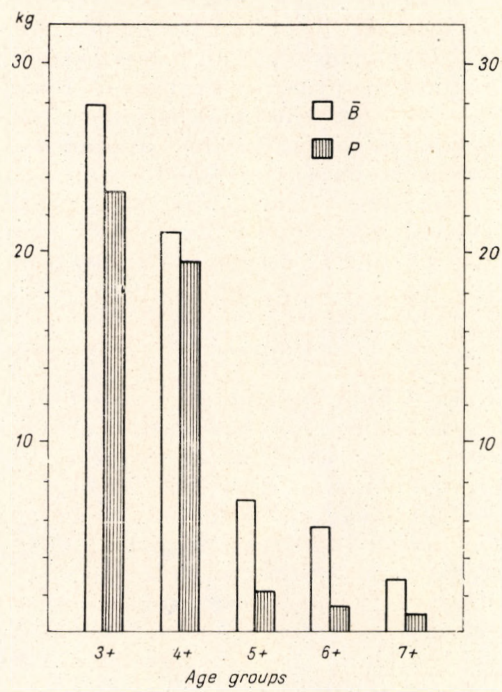


Fig. 22. Average biomass ($\bar{B}$) and its annual production (P) of bream from 3+ to 7+ age-groups most intensively exploited by fishing

TABLE V

Average biomass and its annual production in age-groups 3+—7+ of bream stock in Lake Balaton

Age-group	N_0 (pc)	W_0 (g)	$W_0N_0 = B_0$ (kg)	Z	G	Z—G	$\bar{B}$ (kg)	$\bar{B}G = P$ (kg)	$P/\bar{B} \cdot 100$=A.P. (%)
3+	344	85.3	29.34	0.9677	0.8299	0.1378	27.81	23.08	82.99
4+	132	176.5	23.30	0.9677	0.9243	0.0434	21.04	19.45	92.44
5+	34	287.2	9.76	0.9677	0.2890	0.6787	7.09	2.05	28.91
6+	20	298.3	7.97	0.9677	0.2270	0.7407	5.63	1.28	22.73
7+	7	548.5	3.84	0.9677	0.3198	0.6479	2.83	0.90	31.80
Total:	537		74.11				64.40	46.76	

$$\bar{B} = \frac{W_0 N_0 (1 - e^{-(Z-G)})}{Z - G} \quad \text{if } Z > G \quad \bar{B}G/\bar{B} \cdot 100 = \text{A.P.} = \mathbf{72.61\%}$$

instantaneous coefficients of growth (G) *(Table V, Fig. 22)*. The average biomass was 64.4 kg, while its annual increase was about 46.8 kg. Ratio of increased biomass ($\bar{B}G$) per average biomass ($\bar{B}$) gives the annual net production (P) which proved to be 72.6 per cent for the age-groups considered. Annual net production was the highest in 4+ (92.4 per cent) and in 3+ (83 per cent) year-old fish, but in older groups (5+ to 7+) this rate varied between 23 and 32 per cent.

From the initial biomass (B_0 = 74.1 kg) 62 per cent is eliminated while 38 per cent survived. The biomass of dead fish is balanced by the growth in weight and by the natural recruitment. Increase of average biomass ($\bar{B}G$) or the production is P = 46.7 kg. This mass is annually reproduced and can recover the sum of yield and mortality, which appears as a loss of the system, consequently, the average biomass is increased by three-fourth. The estimated 72.6 per cent production of bream being the greatest population in Lake Balaton is relatively high and with respect of presently irrespective production of younger age-groups (0+ to 2+) may be about 100 per cent, even more.

Discussion

Bream population of Lake Balaton is consisted of *Abramis brama* L. in 98—99 per cent (Pénzes, 1966; 1968) and according to the fishery statistics, the majority of annual catches consisted of bream in 70—80 per cent (Biró and Elek, 1970). Treated statistics show that the quantity of bream caught in Lake Balaton generally decreased from 1952 to 1964, and then increased after the mass destruction of fish occurred in 1965 (*Fig. 3*, lines B and C). According to earlier data the bream population in Lake Balaton had been large and did not stunt in growth as compared to other bream populations inhabiting different Hungarian waters (Ribiánszky and Woynárovich, 1962; Pénzes, 1966; 1968). The above-mentioned decrease in catch of bream was a natural result of increased stocking of pike-perch (*Stizostedion lucioperca* (L.)), carp (*Cyprinus carpio* L.), sheat-fish (*Silurus glanis* L.), asp (*Aspius*

aspius L.), pike (*Esox lucius* L.), and that of the disappearance of natural spawning grounds (TÖLG, 1961). Maintenance of the stock on the present level is possible with the construction of about 10 000 artificial juniper spawning-nests every year.

For the selectivity of nets used in Lake Balaton it is characteristic that the abundance of length-groups of bream ranging from 12 to 20 cm are suddenly increasing. Age-groups of 1+ and 2+ represent 26 per cent of the catch, however, the majority is 3+ and 4+ year-old and 20—30 cm long. Length-distribution is regionally different, i.e. from the north-eastern basin to the direction of Keszthely Bay, the larger fish dominate *(Figs 4* and *6)*.

Compared to the growth in length, the length–weight relationship reflects an intensive weight increase *(Fig. 7)*. Growth of the caudal radii of scales was found to be linear *(Fig. 8)* and its intercept with the abscissa was 0.8 cm, which gives the length measurable in time of scale formation. It is somewhat smaller than that found by OLIVA (1950) for the inundation area of River Elbe as 1.2 cm. POUPE (1971) observed it 1.2 cm for Danube, 2.0 cm for Lipno Reservoir, and 2.0 cm for Rybinsk Reservoir, besides these, 2.1 cm for Slapy Water Reservoir (POUPE, 1973). Complete scale formation in Lake Balaton was observed about 4 cm. In the age-groups at different areas of the lake the measured average distances from the focus of scales to the annuli were more or less different *(Fig. 9)*. Measurements back-calculated from scales showed the average growth to be relatively straightened, and among the different areas a deviation may be observed to the advantage of Keszthely Bay. This fact is evidently connected with the food-supply and the different degrees of eutrophication of Lake Balaton. WUNDER (1930) described food-competition and nannism of bream in Lake Balaton due to its dense population. According to PÉNZES (1966, 1968) the bream stock in Lake Balaton does not stunt in their growth as compared to other populations of Hungarian waters. From fishery statistics for 1950—71 and from our results it may be established that the bream population did not respond to the mass fish destruction (1965) and their growth became more rapid comparing with the previous years. Its reason can partly be the effect of increased exploitation by fishing which heavily influenced the population dynamics and that of fast eutrophication. Consequently, the food-supply for fish in Keszthely Bay (mostly the larvae of *Chironomus* ex gr. *plumosus*) became more important comparing with other parts of the lake (BIRÓ, 1974c).

Evaluating the growth in length by generations *(Fig. 11)* several changes of fish dimensions in different age-groups were observed. These could have parasitological aspects mainly in younger age-groups besides the different temperature and feeding conditions, registered in past years (PÉNZES, 1968). MOLNÁR et al. (1968) published important data on this. They established that 4.19 per cent of 3—5 summer-old breams are invaded by Ligula plerocercoids. BRYLIŃSKI (1970) demonstrated that the weight of Ligula plerocercoids can reach 26 per cent of the fish weight in the abdominal cavity of 3—5 year-old breams. Mortality due to strong Ligula invasion may even surpass 50 per cent, whereas in non-invaded areas mortality was about 17 per cent. He observed the greatest mortality attributed to *Ligulosis* during spring time. In Lake Balaton, observations were carried out on the probable relationship between the *Ligula* invasion and the growth of fish, but these could not be estimated definitely since the number of investigated fish was small.

Parameters of growth described by the Bertalanffy's model are different according to the rate of growth, and there is a difference between materials collected along the southern and northern shorelines. Consequently, great variances may be in the food-supply of northern and southern shorelines, and in their eutrophication and/or pollution. Furthermore the inhomogeneity of the stock can mainly be explained by feeding relations. Food-supply and the relative density of the stock can be assessed from the rate of growth with respect to data on catch statistics.

The overwhelming majority of younger 2+ to 4+ age-groups is characteristic of the age-composition. According to Pénzes (1966) the majority of breams caught from Lake Balaton are 3—5 summer-old. His material contained 2+ age-group in 12 per cent, 3+ in 30 per cent, 4+ in 29 per cent, 5+ in 24 per cent, 6+ in four per cent and 7 + in one per cent. Our experiences show changed ratios, i.e. the ratio of fish in 2+ age-group doubled (25 per cent), while in 3+ year-old ones increased from 30 to 48 per cent, however, in 4+ age-group diminished from 29 to 18 per cent, in 5+ decreased from 24 to five per cent. From these changes it is evident that the exploitation by fishing of younger, most productive 2+ to 4+ age-groups became more intensive (overfished). This method of stock regulation results that the ratio of older age-groups decreases and the most fertile part of the population diminishes. In this case, because of the very high larval mortality (Woynárovich, 1958) the population cannot compensate for a long time the harvested part of the stock by recruitment. It is supported by the circumstances observed along certain shore sections of the lake in 1973. An enormous quantity of eggs laid down was totally destructed before hatching because the eggs were covered by deposit and mud. Mortality of bream population of Lake Balaton was assessed from 3+ to 7+ age-groups which was fairly high (62 per cent) and it is balanced by the natural recruitment. Total mortality of bream in the northern Caspian Sea for two periods were found by Lukasov (1961) to be $Z = 0.55$ and 0.80. According to his calculations the parameters of Bertalanffy's model were as $L_\infty =$ $= 42$ cm, the rate of growth (slope) $K = 0.233$ and $t_0 = 0.62$ year. Balon 1963) calculated the total annual mortality for 256 specimens over 4+ age-group and he found it to be 65 per cent. Tiurin (1962) recorded the mortality of 2—11 year-old breams of Lake Ilmen to be 40 per cent. 62 per cent annual mortality in Lake Balaton can be adapted well to this line. Rate of survival and relative number of recruits in moderately fished populations may sometimes be higher. Variations in growth of bream and resulting changes in average age have equally influenced recruitment (Backiel and Zawisza, 1968).

Our calculations on the average biomass and its annual production rate of the bream stock of Lake Balaton are accounted as first publication. These data relating to undoubtedly most dense fish species of the lake recover a missing link in the estimation of nekton production. In this line the participation and energy-transformation of pike-perch (*Stizostedion lucioperca* (L.)) being the most significant predator of the lake already known in details (Biró, 1974a, b). From this point of view, the determination of some basic parameters of the bream population needs further investigations.

Summary

Investigations were carried out on length-distribution, age-composition and growth of breams collected at five different areas of Lake Balaton (720 specimens in 1972 and 1403 specimens in 1973). It has been established that:

1. Regression of the total caudal radii of scales on the standard length is linear.

2. On the basis of back-calculated standard lengths from the annuli of scales the growth of bream is fearly rapid. Average values indicate a straightened growth, although in several age-groups considerable variations are observable. Exponential growth in standard length could be represented well by Bertalanffy's model. Breams of Lake Balaton did not stunt in growth compared with other bream populations inhabiting different Hungarian waters. It is considered even in European relations to be a fast growing population. According to earlier data referring to the bream stock of Lake Balaton the fast growth is an evident result of the eutrophication and of the quantitative increase of zoobenthos in the open waters, chiefly in Keszthely Bay.

3. Considering the data of earlier years, the ratios of breams of different age caught in Lake Balaton are shifted to the advantage of the youngers, i.e. 2+ age-group is doubled and it already consists of 1/4 of the annual catch (25 per cent). 3+ age-group dominates, and from 3+ to 7+ year-old ones the instantaneous total mortality coefficient proved to be $Z = 0.9677$. Average annual mortality was 62 per cent and the survival rate was 38 per cent. The sudden increase of 2+ age-group in the catches from the north-eastern basin was on account of the overfishing the population here.

4. Average biomass ($\bar{B}$) according to the exponential growth was assessed and its annual production for the most intensively exploited 3+ to 7+ age-groups was derived as 72.6 per cent.

REFERENCES

Backiel T., J. Zawisza (1968): Synopsis of biological data of bream *Abramis brama* (Linnaeus, 1759). — *FAO Fisheries Synopsis* No. 36.

Balon E. (1963): Altersstruktur der Populationen und Wachsgesetzmässigkeiten der Donaubrachsen *(Abramis brama, Abramis sapa, Abramis ballerus)*. — *Sborn. vys. Sk. chem.-technol. Praze* **7**, 459—542.

Bertalanffy L. (1938): A quantitative theory of organic growth. — *Hum. Biol.* **10,** 181—243.

Bertalanffy L. (1957): Quantitative laws in metabolism and growth. — *Q. Rev. Biol.* **32,** 217—231.

Beverton R. J. H., S. J. Holt (1957): On the dynamics of exploited fish populations. — *Fishery Invest. London* **19,** p. 533.

Biró P., L. Elek (1970): A Balaton halászata és az utóbbi évek ichthyológiai problémái. — *Állattani Közlemények* **57,** 39—49.

Biró P. (1974a): Observations on the fish production of Lake Balaton. — *Symposium on "Limnology of Shallow Waters", Tihany,* 3—8. *September,* 1973.

Biró P. (1974b): Food consumption, production and energy transformation of pike-perch (*Stizostedion lucioperca* (L)) stock in Lake Balaton. — "*First European Congress of Ichthyology*", *Sarajevo, Yugoslavia,* 21—29. *September,* 1973.

Biró P. (1974c): Observations on the food of eel (*Anguilla anguilla* L.) in Lake Balaton. — *Annal. Biol. Tihany* **41,** 133—152.

Brylinski E. (1970): Wplyw Ligulozy na smiertelnosc zarazonej populacji leszcza *(Ligulosis* and mortality in invaded bream population). — *Roczn. Nauk Roln.* **92**-H-**2,** 35—59.

CHAPMAN D. W. (1968): Production, pp. 182—196. In: RICKER W. E. (Ed.) Methods for assessment of fish production in fresh waters. — *IBP Handbook No.* **3**, *Blackwell Sci. Publ. Oxford.*

FRASER C. McL. (1916): Growth of the spring salmon. — *Trans. Pacif. Fish. Soc. Seattle,* for 1915, 29—39.

LUKASOV N. V. (1961): Лукашов, В. Н.: Динамика численности эксплуатируемых стад воблы, леща и судака Северного Каспия. — *Тр. Совещ. Ихтиол. Комиссии, АН СССР* **13,** 445—453.

MOLNÁR K., L. BÉKÉSI, GY. HÁMORI (1968): Untersuchungen über die Ligula-Infektion der Ungarischen Fischfauna. — *Annal. Biol. Tihany* **35,** 145—154.

OLIVA O. (1950): The growth of the bream (*Abramis brama* [L.]) in the inundation area of the River Elbe in Bohemia. — *Acta Univ. Carol.-Biol.* 1950 (**2**), 169—196.

PÉNZES B. (1966): Adatok a balatoni dévérkeszeg (*Abramis brama* L.) növekedéséhez. — *Annal. Biol. Tihany* **33**, 173—176.

PÉNZES B. (1968): Magyarországi dévérkeszeg-populációk összehasonlító növekedésvizsgálata. — *Állattani Közlem.* **55**, 87—96.

POUPE J. (1971): The growth of the bream (*Abramis brama* [L.]) in selected localities of central and eastern Europe (Pisces, Cyprinidae). — *Vestnik Cs. spol. zool.* **35,** 297—310.

POUPE J. (1973): Contribution of the growth of the bream, *Abramis brama* (Linnaeus, 1758) (Osteichthyes, Cyprinidae) in the Slapy Water Reservoir, between 1957 and and 1965. — *Vestnik Cs. spol. zool.* **37**, 104—109.

RIBIÁNSZKY M., E. WOYNÁROVICH (1962): Hal, halászat, halgazdaság. — *Mezőgazd. Kiadó, Budapest.*

RICKER W. E. (1958): Handbook of computation for biological statistics of fish populations. — *Bull. Fish. Res. Bd. Canada* **119**, p. 300.

RICKER W. E., R. E. FOERSTER (1948): Computation of fish production. — *Bull. Bingham Oceanogr. Coll.* **11**, 173—211.

TESCH F. W. (1968): Age and growth, pp. 91—120. *In:* RICKER W. E. *(Ed.) Methods for assessment of fish production in fresh waters.* — *IBP Handbook No.* **3**, *Blackwell Sci. Publ. Oxford.*

TIURIN P. V. (1962): Тюрин, П. В.: Фактор естественной смертности рыб и его значение при регулировании рыболовства. — *Вопросы Ихтиологии* **2,** 403—427.

TÖLG I. (1961): Über die Ursache des Nahrungsmangels des Balaton-Zanders (*Lucioperca lucioperca* L.) und Begründung des Nahrungsersatzplanes. — *Annal. Biol. Tihany* **28,** 179—195.

WALFORD L. A. (1946): A new graphic method of describing the growth of animals. — *Biol. Bull.* **90**, 141—147.

WOYNÁROVICH E. (1958): A balatoni keszegkérdés . . . — *Halászat* **5,** 58.

WUNDER W. (1930): Bau und Funktion der Netzhaut beim Zander (*Lucioperca sandra* CUV. et VAL.) und einiger anderen im Balatonsee häufigen Fischarten. — *Annal. Biol. Tihany* **3**, 322—334.

A DÉVÉRKESZEG (*ABRAMIS BRAMA* L.) NÖVEKEDÉSÉNEK ÉS POPULÁCIÓSTRUKTÚRÁJÁNAK VIZSGÁLATA A BALATON KÜLÖNBÖZŐ VIZTERÜLETEIN, A MORTALITÁS ÉS PRODUKCIÓ BECSLÉSE

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Összefoglalás

Vizsgáltuk a Balaton 5 különböző vízterületéről származó dévérkeszegek méret- és kormegoszlását (1972-ben 720 db-ot, 1973-ban 1403 db-ot), scalimetrikus mérések alapján növekedésüket. Megállapítható volt, hogy:

1. A pikkelyek teljes kaudális rádiusza és a törzshossz regressziója gyakorlatilag lineáris.

2. A pikkely-évgyűrűkből visszaszámított törzshosszak alapján a dévérkeszeg növekedése kielégítően gyorsnak tartható. Az átlagértékek kiegyenlített növekedést jeleznek, bár korcsoportonként jelentősebb mérethatárok figyelhetők meg. A törzshossz exponenciális növekedésének üteme BERTALANFFY-féle modellel pontosan leírható.

A növekedés nem marad el egyéb hazai vizekben megfigyelt növekedéstől, de a balatoni európai viszonylatban is gyorsan növő egyedek populációjának számít. A korábbi balatoni dévérállományra vonatkozó adatokhoz képest gyorsabb növekedés nyilvánvaló következménye az eutrofizálódásnak és a nyíltvízi zoobenthos mennyiségi növekedésének (elsősorban a Keszthelyi-öbölben).

3. A korábbi évek adataihoz képest a kifogott keszegek korcsoportonkénti aránya a fiatalabbak javára tolódott el, a 2+ korcsoport mennyiségileg megduplázódott és már az évenkénti fogások 1/4-ét alkotja (25%). Dominál a 3+ korcsoport, ettől kezdve 7+ koruakig a teljes mortalitás pillanatnyi együtthatója $Z = 0{,}9677$-nek adódott. Innét az éves mortalitás aránya átlagosan 62%, a túlélési ráta pedig 38%. Az ÉK-i medencében a 2+ korcsoport ugrásszerű növekedése a fogásokban, az itteni állományrész fölülhalászottságára utal.

4. Az exponenciális növekedésnek megfelelően becsülve az átlagos biomasszát ($\bar{B}$), annak éves produkciója (P) 72,6%-nak adódott a halászatilag legnagyobb mértékben kihasznált 3+ — 7+ korcsoportokra.