AUTUMN AND WINTER SHOALS OF FISH IN THE SHORE ZONES OF LAKE BALATON IN 1947—1949.

BY

BÉLA ENTZ

From the Hungarian Biological Research Institute, Tihany, Lake Balaton

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With 10 Figures and 4 Tables in the text.

APPEARANCE OF THE AUTUMN SHOALS

According to numerous observations, fishery data and the information of LISSMANN (1933:86—92), in the autumn in sheltered places along the shores of Lake Balaton, chiefly in bays and among the reed, immense shoals of fish, consisting of many hundred thousands, assemble. I made a study of such gigantic shoals from October 1947, to January 1948 and from November 1948, to January 1949. The investigations were made at Tihany in the Kis-öböl bay, near the Biological Research Institute and in its immediate neighbourhood.

The first large shoals, consisting according to my observations almost exclusively of bleak *(Alburnus lucidus)*, appeared in the middle of October 1947. This was in quiet weather, at about 5—15 m from the shore. They passed in a 5—10 m wide band parallel with the shore. At evening in quiet weather the noise of the masses of little fish in these shoals, jumping out of the water and falling back again, could be heard at a distance of 200 meters from the shore. At the end of October the shoals disappeared and reappeared towards the end of November, but this time in the bay, directly along the shore. The immense shoal remained sluggishly, in one place more or less, and the fish no longer jumped out of the water. It settled down in the midst of a cca 15×15 m patch of reed at the entrance of the Kis-öböl and in the about 80—120 cm deep sheltered water behind it. In this area the water seemed quite black from above owing to the millions of small fish swarming there. The shoal disappeared during storms but in quiet weather reappeared at the same place. The fish stayed in this area, with short interruptions, constantly in large quantities, until the lake froze.

From the end of November 1948, until the middle of December the situation was exactly the same as it had been the previous year.

In spite of its constant presence, the appearance of the shoal slowly but constantly changed, as many fish wandered away from it and other new ones joined it, so that the whole immense mass formed a dynamic rather than a static unit. Between November 20—30 1948, the huge shoal was composed almost exclusively of bleak. Between December 4—12 great numbers of bream had joined it (chiefly *Abramis brama*, *Scardinius erithrophthalmus* and *Leuciscus rutilus)*. But after December 12th, with the disappearance of the other species, the whole again consisted almost exclusively of bleak. By the time it froze, December 14th, the number of bleaks had also greatly diminished and only a few hundred specimens swam about under the ice in small groups in place of the immense autumn shoals. Under the ice at several kms from the shore I observed mighty shoals of bleak but after the ice melted they all dispersed and new ones appeared at spawning time only.

The purpose of the investigations was to get an insight into the life conditions of the great shoals. That is, to ascertain their composition as to species, the sizes and ages of the different species; to make observations on the distribution of the shoals and their structure, and to study the time of their formation, duration, disappearance.

METHODS

The collections were made partly from the shore, partly from a boat. A net of about 40 cm diameter was used for collecting, which on

Fig. 1.

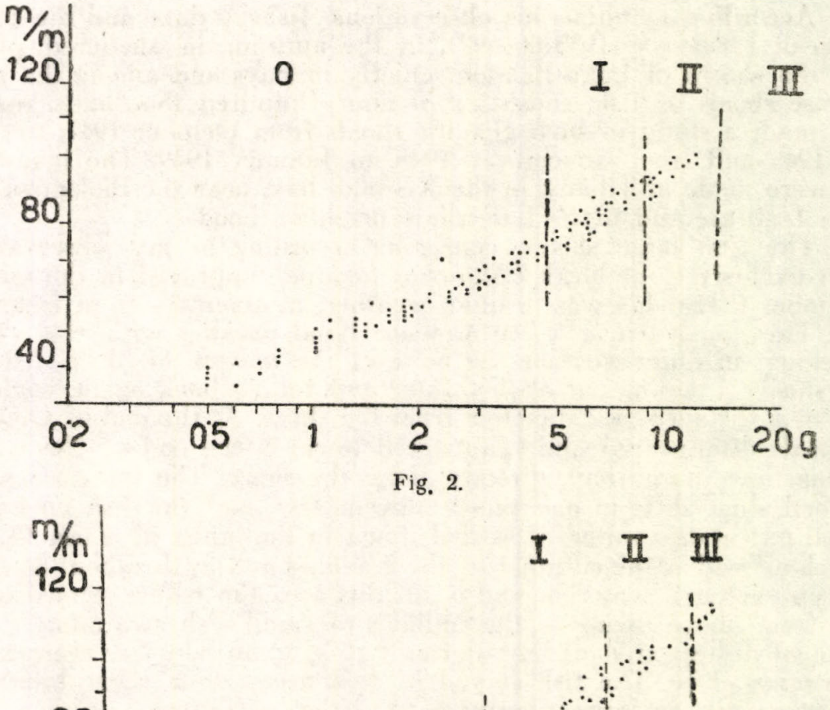
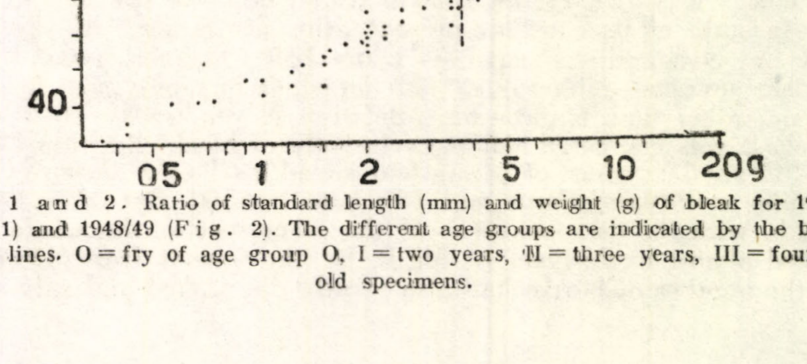


Fig. 2.



Figs. 1 and 2. Ratio of standard length (mm) and weight (g) of bleak for 1947/48 (Fig. 1) and 1948/49 (Fig. 2). The different age groups are indicated by the broken vertical lines. O = fry of age group O, I = two years, II = three years, III = four-year old specimens.

Fig. 3.

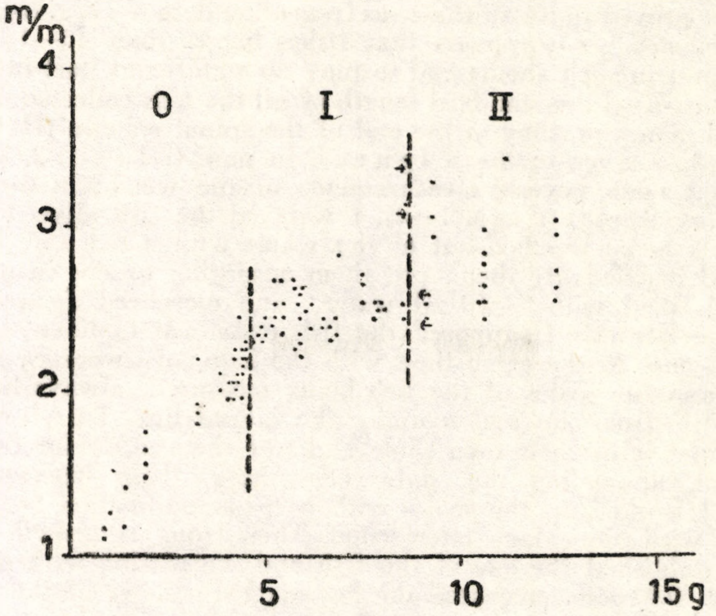
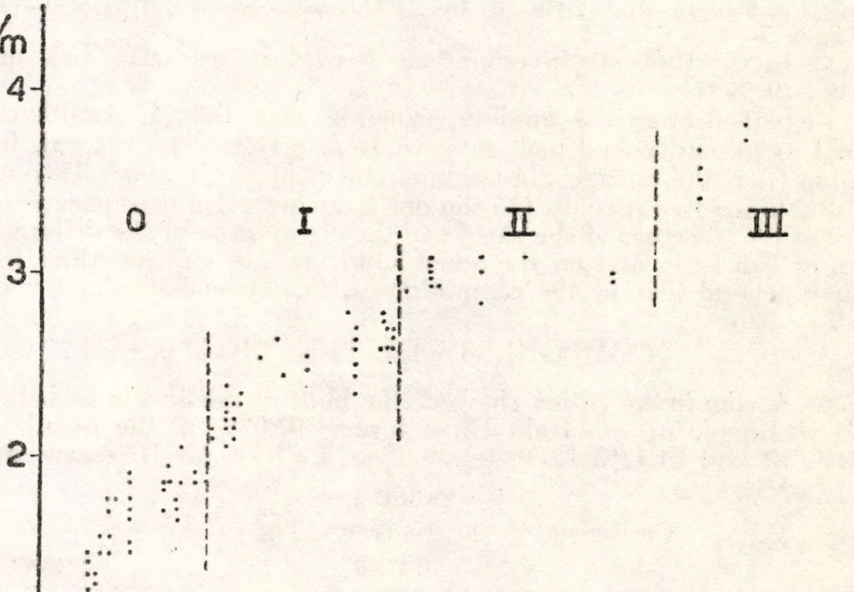


Fig. 4.



Figs. 3 and 4. Ratio of weight (g) of bleak and horizontal diameter (mm) of scales. The age groups are indicated as in Figures 1 and 2. The specimens marked with arrows do not belong to the group where they appear, but to the next one. All data are averages calculated from several scales. Figure 3 is for 1947/48, Figure 4 for 1948/49.

account of its size was not good for catching fish larger than 25—30 cm. Yet it proved quite suitable, as from other data — e. g. fishing with finemeshed nets — it appears that fishes bigger than 15—16 cm are rarely found in such shoals and so play no significant part in them.

I measured the standard length of all the fish collected, i. e. from the closed mouth-opening to the end of the spinal column (HUGH, 1942). This length is given in the Figures, in mm. (Figs. 1, 2, 5—9). Besides this I made several measurements of the weight in each group, arranged by length. (Figs. 1—2). I weighed the fish alive. I took the individuals to be weighed out of the water with a net and, after the water had trickled off them, put them according to size in a measuring vessel filled with 5—50 ml water, and measured them according to volume. For this I supposed the fish examined to have a specific weight of one. At the same time with the help of tweezers I took a sample from the scales of the fish being measured, always behind the pectoral fin, from the region under the lateral line. I pasted the scales on paper with their own slime and put them aside for further investigation, appending the data concerning them (species, length, weight). I worked up the scales with a 20×magnification by transillumination with binocular microscope. Then from its growth rings (annuli) I established the age of the fish and, measuring with an exactitude of ± 0.02 mm, measured the horizontal diameter of the scale and the growth of previous years as shown by the rings. From the latter data the size of the fish in the preceding years can be calculated (Figs. 3—4).

In the 1947—48 investigations I worked up 4834 fish and in 1948—49 5093.

In collecting the guiding principle was that I considered the shoal as an entity and took samples from different parts of it, for example from the outside, the middle, and near the bottom. This seemed desirable for two reasons. On the one hand we get a more complete picture of the structure of the shoal and the distribution of the different species of fish in it, and on the other hand because we can thus form a fairly general idea of the composition of the whole shoal.

COMPONENTS OF THE SHOALS

As the investigation showed, the bulk of the shoals in both periods was made up of bleak. These formed 97.07% of the population in 1947—48 and 61.47% in 1948—49 (See Table I). It seems that in

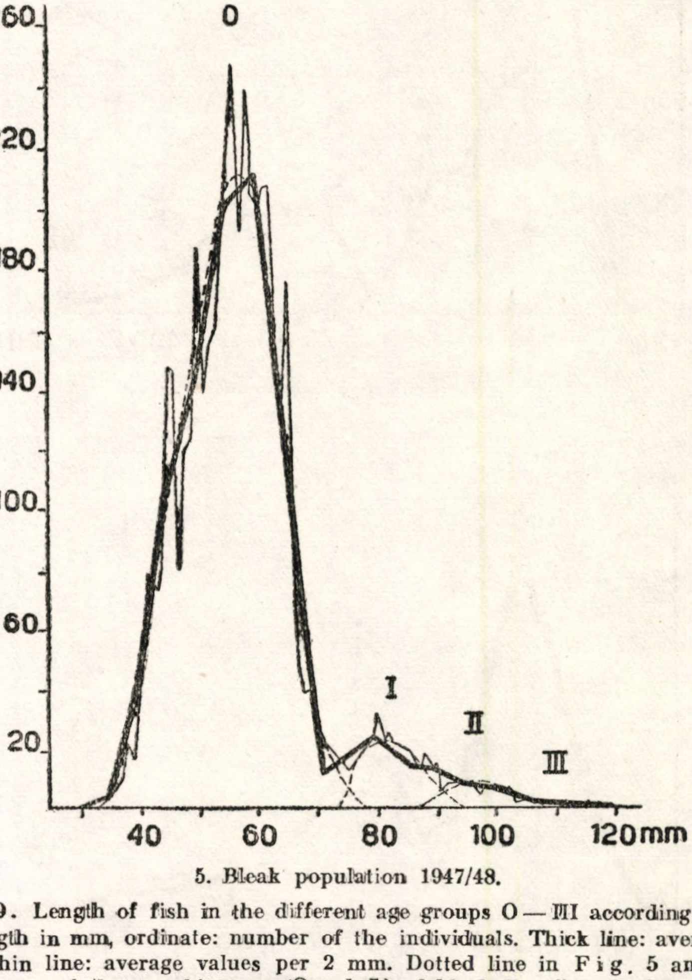
TABLE I.

Components of the shoals, according to species.

	1947/48		1948/49	
		%		%
Bleak	4680	97·07	3131	61·47
Bream	33	0·70	1578	30·98
Roach and rudd	101	2·09	178	3·50
Pope (Acerina)	2	0·04	203	3·99
Rhodeus	2	0·04	—	—
Aspius	3	0·06	2	0·04
Perch	—	—	1	0·02
Total	4834	100·00	5093	100·00

1947—48 the rôle of the other species was quite subordinate to the predominating majority of bleak. The roach *(Scardinius erithrophthalmus* and *Leuciscus rutilus)* predominated in the minority species (101 specimens=2.09%) while at the same period there were only a few specimens of bream *(Abramis brama).* Of other species there occurred only sporadic *Acerina cernua, Rhodeus amarus, Blicca björkna* and *Aspius rapax.* The shoals had a relatively more varied composition in 1948—49. Besides the bleak there were bream in considerable numbers *(Abramis brama* among them now and then *Blicca björkna),* with about 1570 specimens (31%), roaches *(Scardinius erithrophthalmus* and *Leuciscus rutilus)* 178 specimens=3.5%, and *Acerina cernua,* 203 specimens=4%. It was interesting to note that in both seasons there was a remarkable lack of predaceous fishes. Among almost 10,000 fish there were only 5 young *Aspius rapax* of the first growing season (age group O) and one perch *(Perca fluviatilis)* to represent the predaceous.

Fig. 5—9.

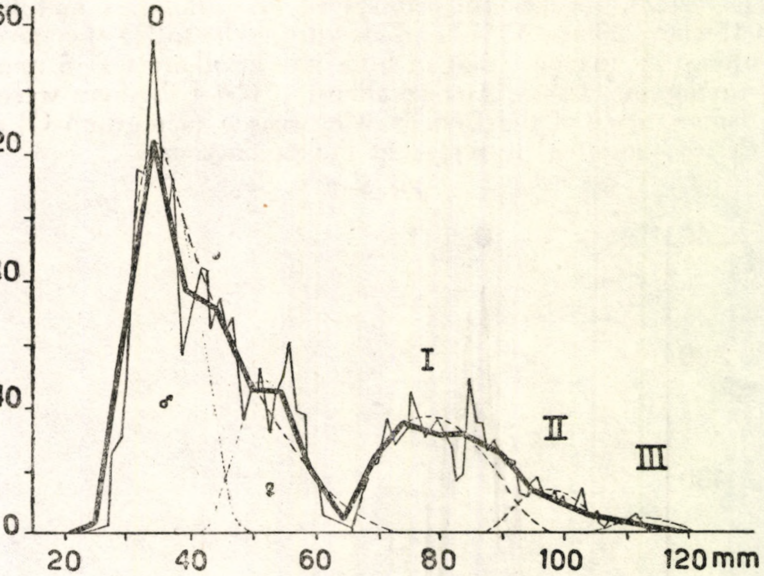


5. Bleak population 1947/48.

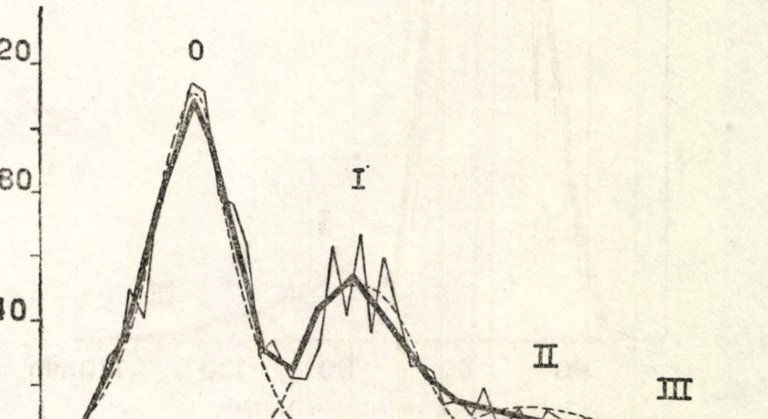
Figs. 5—9. Length of fish in the different age groups O — III according to species. Abscissa: length in mm, ordinate: number of the individuals. Thick line: average values per 5 mm; thin line: average values per 2 mm. Dotted line in Fig. 5 and 6 is the distribution curve of the two biotypes (♀ and ♂) of bleak. For figs. 6—9 see p. 88—89.

If we investigate the age of the fishes in these populations, we find the following: Among the bleak, more than 94% of the inviduals were fry of one summer (age group O), there were only 5,5% of second year specimens (=age group I), and the still older comprised scarcely 0.3%. Conversely in 1948—49 more than a fourth of the bleaks were of age group I and there were even 10% of those still older.

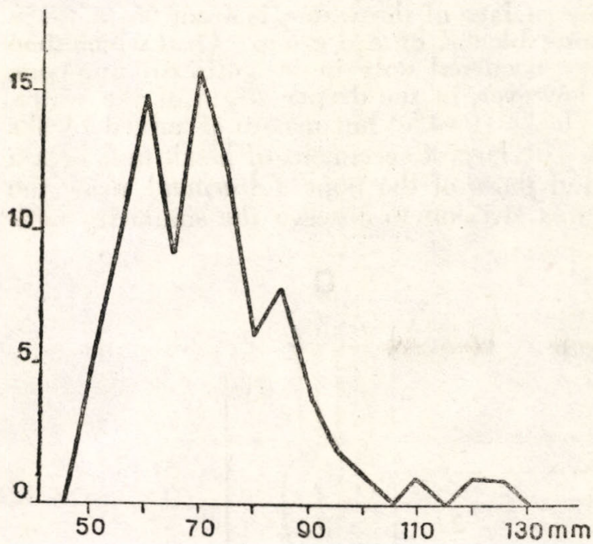
A similar phenomenon was to be seen in the bream. In 1947—48 scarcely 1.5% of the bream were in their second year, all the others



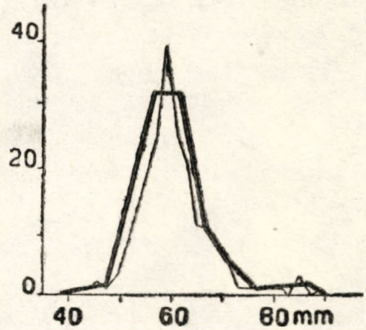
6. Bleak population 1948/49.



7. Abramis brama population 1948/49.



8. Scardinius erithrophthalmus and Leuciscus rutilus population 1948/49.



9. Acerina cernua population 1948/49.

were young fry of age group O. In 1948—49, on the other hand, nearly half of the specimens examined were more than a year old, in their 2—4 year (=age groups. I. and II.) (Table II).

TABLE II.

Distribution of bleak according to age groups O—III.

	1947/48		1948/49	
		%		%
0	4408	94·2	2016	64
I	258	5·5	814	26
II	14	0·3	246	8
III	—	—	55	2
Total	4680	100·0	3131	100

It is interesting to compare in the December 1948 collections the data for the surface and lower depths of the shoal respectively with those for its interior. It can be seen in Table III that the top of the shoals,

TABLE III.

Distribution of bleak and breams in the shoal according to age groups O—IV and size.

		Alburnus lucidus				Abramis brama			
	Date	0	I	II	III	0	I	II	III
Surface of large shoal	XII. 3	138	1	—	—	—	—	—	—
	8	851	1	—	—	—	—	—	—
	14	470	12	—	—	3	—	—	—
Interior of large shoal	XII-4	12	55	14	—	39	162	35	—
	5	17	183	61	14	232	100	13	2
		3	174	61	14	59	53	—	—
Length, mm		25—68	69—91	89—105	106-	40—85	75—110	100—130	130-

at about 20—40 cm below the surface of the water, is from 96 to 100% composed of 32—60 mm young bleaks, of age group O, at which time there were no bream, or they occurred only in insignificant numbers. In the middle of the shoal, however, in the deeper strata of the water, there were very few young bleaks (1—4%) but masses of mixed bleaks and bream several years old. The largest specimens of bleak and bream occurred near the bottom, and those of the pope *(Acerinae)* near the shore (see Figure 10). It was striking to observe the similarity with

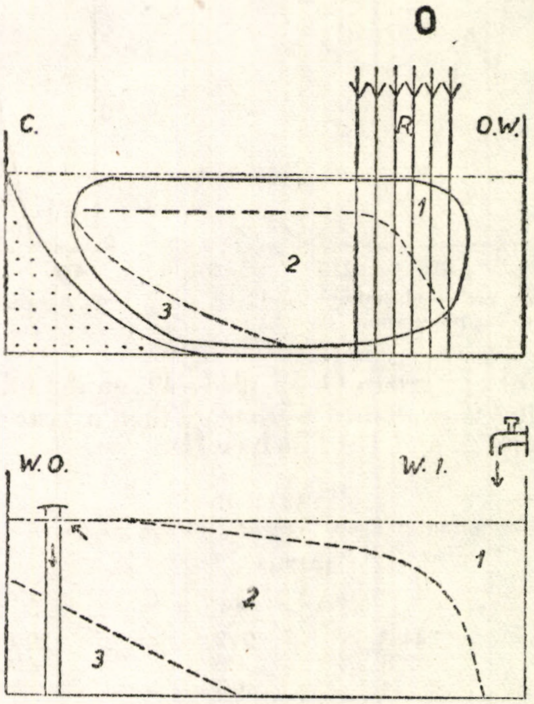


Fig. 10. Disposition of the fish in the bleak population investigated in the Kis-öböl (upper graph) and in the aquarium (lower graph). O W = open water; C = shore; R = reed; W I = water inflow, W O = water outflow, 1 = 1 year bleak, 2 = 1—4 year old roaches (Abramis brama, Leuciscus rutilus, Scardinius erithrophthalmus, etc.)

which the fish arranged themselves within the shoal, both in natural and under experimental aquarium conditions. Thus on December 10th I put into a 50 l aquarium 400 young bleaks, 200 bleaks of two years or more, 100 breams of one and two years, and 30 Acerinae. After a few hours the fish took up the positions shown in Figure 1. The levels of the 1 year old bleaks formed a spheroid surface towards the light and the inflowing water, the older ones mixed with the bream were in the middle, and the Acerinae in the darkest part farthest from the water inflow. This was not a transitory situation, but was maintained for several weeks.

Summing up the data on bleak populations in the different collections and grouping them according to year, we get Figures 1—9 and Tables I—IV.

Figures 1—6 and Table IV show that in the average the

TABLE IV.

Relation between age (Groups O—III), diameter of scale, weight and length of bleak. The last column gives the length of the individuals occurring in greatest numbers.

	Scale, diam, in mm		Weight, in gs.		Length, in mm		Maximum in length, in mm	
	1947/48	1948/49	1947 48	1948/49	1947/48	1948/49	1947/48	1948/49
0	1-2·2	0·9-2·1	0·6-4·4	0·3-3·8	31-77	25-71	56	36
I	2·2-2·8	2·1-2·7	4·4-9·0	3·9-8·1	75-95	69-96	80	76
II	2·4-3·4	2·8-3·1	8·5-12·3	8·3-13	89-102	88-106	98	98
III	—	3·4-3·9	22	15·0-18	115	106-116	112	112

bleaks were more developed and larger in 1947—48 (Fig. 5.) than in 1948—49 (Fig. 6). It furthermore appears that the bleaks of age group O are quite distinct in respect to dimensions from those of age group. I. The boundary between age groups I. and II. was not so distinct and because of the small numbers of the data the difference between age groups II and III could only be approximated.

Investigating the 1948—49 *Abramis* population (see Figure 7) we find a similar distinction as to size among those of different years. Here too, those of one year are in the majority as compared with the older ones. In the same way the young fry of one year also dominate among the roach (see Figure 8) and the Acerinae (see Figure 9).

The few young predaceous *Aspius rapax* occurring sporadically were without exception fry of age group O.

Among all the fish occurring in these immense populations, without respect to species, the young fry of age group O, 3—7 cm in length, dominated. The number of fish of age group I was significantly smaller and the number of those older still decreased still more according to age. There were scarcely more than 250 (2.5%) specimens of three years or more among the nearly 10,000 fish examined.

The length of the *Abramis* and *Acerina* populations gives typical distribution curves (Figs. 7, 9). Thus, for 1948—49 in *Abramis brama* of O years M=64 mm,* D=64.5 mm, σ=13.7 and S=0.03, i. e. the distribution was almost completely symmetrical. In *Acerina cernua* of O years M=60.06, D=60 mm, σ=6.1 and S=0.1, that is, here too the situation is quite similar.

In the bleak population, especially in the O group, the course of the curves is highly asymmetric. In 1947—48 M=55.05, D=58, σ=15.47, and S=0.1584. In 1948—49 M=41, D=35, σ=8.36 and S=0.807. As we know, one of the causes of asymmetry is that the population is not uniform but covers two or more biotypes. According to LISSMANN there is a distinct difference in size between males and females of the same age (LISSMANN, 1933). Taking this and the data of different separate collections into consideration, we can distinguish two biotypes in Figures 5 and 6, which probably express distribution according to sex. The curves of these biotypes are entirely symmetrical and of a structure simi-

* In the data M = means value, D = place of greatest density, σ = standard deviation, μ = standard error, and S = index of symmetry, which is positive if the curve is asymmetric on the right side and negative if asymmetric on the left side (WEBER 1948:86).

lar to the general distribution curves. If we accept the distribution of the sexes according to such biotypes, we get the following values:

	M ♂ mm	σ	M ♀ mm	σ
1947—48	44.4	3.48	57.5	12.2
1948—49	35.5	4.15	53	11.6

A significative difference can be established between the two biotypes in the years above. In 1947—48 $\mu=0.565$ and M ♀—M ♂=13.1, In 1948—49 $\mu=0.7146$ and at that time M♀—M♂=17.5; i. e. the difference in both cases is a statistically significant difference. The separate data for the ♂ ♂ and ♀ ♀ biotypes during the two years was similar, that is, the σ values stood close to one another — only in the first year the whole population was somewhat more developed on the average than in the second year, probably on account of more favourable conditions. From the standpoint of size, besides the great difference apparent between the two years, i. e., the evident difference in development, much can be explained by difference in the distribution of sexes. Naturally in order to clear up the question completely more investigations on population and anatomy are necessary.

It is an interesting question how these shoals of fish come about. In other words, what are the causes which, on the one hand, lead to the formation of the immense autumn shoals and, on the other hand, what determines their choice of grouping places. Fundamentally we can distinguish internal and external factors among the causes. The internal causes, which are very important, from many standpoints of decisive significance (e. g. effects of different hormones, etc.) I did not consider during these studies. Among the external conditions I investigated first the temperature and the effect of wave action, which LISSMANN (l. c. p. 87) cites as decisive factors. According to my measurements, the protection of the bay is not as important from the standpoint of temperature as LISSMANN says, if we consider that in the autumn all the water of the Balaton cools off almost uniformly from surface to bottom (ENTZ, 1949, in the press).

Protection against the strong wave action undoubtedly plays an important part, all the more so because the fish, massed together in the shoals are very inactive; they usually float sluggishly, almost motionless in one place in the water. According to observation, at times when violent waves broke into the bay, the shoal disappeared and only formed in the old place when the water was quiet again.

It is perhaps worthy of notice that the shoals formed and drew near to the shore at the time when the transparency of the water was greatly increased, in the autumn. It is also possible that the small fry in the more transparent water escaped to the neighbourhood of the shore and sought for safety from predatory fish by uniting in shoals. Apparently confirming this hypothesis is the fact that second-year or older predaceous fish do not occur at all in these immense shoals. This again calls attention to the possibility that the absence of the larger predaceous fish may be due to some immediate cause. In order to clear up this problem I began some investigations of the conditions reigning in the interior of the shoals.

First and foremost the immense density of the shoals was remarkable. It was typical, for example, that when the shoal was disturbed and trying to escape, it often became so crowded that quantities of small fish were thrust completely out of the water, on to the backs of the others, and wriggled there in the air as if they were on dry land. Owing to this great density the absorbed oxygen content of the water. which at 10—15 m from the shoal was ± 100%, dropped to 80—50 or even 31% in the middle of the shoal (December, 1948). In pH value too some bias towards the acidic occurred from the open water to the interior of the shoal, but it scarcely amounted to 0.02—0.05 pH unit and therefore was probably quite without significance. This assembling of the fish in a small place, over a long period is made possible, as we know, by many factors. For example, they feed scarcely or not at all; because of the low temperature and their almost complete immobility their metabolism is probably very low, etc.

The average annual variations in size and the distribution of sexes within the shoals, the effect exercised by outside conditions on the formation and maintenance of the shoals, as well as the occurrence of similar large shoals in other parts of the Balaton, will form the subjects of further investigations.

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ОСЕННИЕ И ЗИМНИЕ СТАИ РЫБ В БЕРЕГОВЫХ ПОЯСАХ ОЗЕРА БАЛАТОНАВ 1947—1949 ГГ

Автор: БЕЛА ЭНЦ

РЕЗЮМЕ

1. Во время осеннего исследования береговых стай рыб, я обследовал 10 000 рыб возрастом от 1 года до 5-ти лет (возрастные группы от 0—IV) на основании стандартной длины, веса и образца чешуи.

2. Чешуи, приклеенные собственной слизью к бумаге, я откладывал для обследования, совместно с относящимися к ним данными.

3. На поверхности и краях громадные стаи рыб состоят из однолетних уклеек, в середине или внутри из 2—4 летних уклеек и 1—4 летних лещей; а на дне вблизи берега преобладают окуни. (Acerina)

4. Применением действия света и тока воды, мы получили такое-же распределение в аквариуме.

5. Рыбы образуют хорошо отличающиеся по возрастам популяции. У уклеек встречаются каждый год два биотипа, что вероятно следует отнести к их половому диморфизму: меньший ♂ и больший ♀.

6. Длина и вес тела, диаметр чешуи и возраст пропорциональны и рыбу о жно отличать по возрасту на основании любого из этих данных.

7. Примечательными чертами являются большая густота громадных стай, почти полное отсутствие хищных рыб среди них и слабое насыщение кислородом внутри отдельных стай.