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Ichthyology

THE EFFECT OF THE SIZE OF SEA TROUT (*SALMO TRUTTA* L.) FEMALES FROM REGA RIVER UPON THE SIZE OF EGGS

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The aim of work was to assess statistically the effect of body length, weight and age of sea trout (*Salmo trutta* L.) females from Rega River upon average diameter and weight of swollen eggs, and weight of mature eggs.

INTRODUCTION

Usually bigger larvae hatch from larger eggs of the salmonid fishes from the genera *Salmo* and *Oncorhynchus*. Bigger larvae are characterized by higher survival and rate of growth. Consequently, female selection aimed at obtaining fishes producing larger eggs becomes an important breeding measure (Leitritz 1976). Many factors may affect size of eggs of the mentioned fishes, the most important ones being size and age of females. Increasing egg diameter along with increasing size (length and weight) of females was observed for: sea trout (*Salmo trutta* L.) by Juszczyk (1951), brook trout (*Salmo trutta* m. *fario* L.) by Suvorov (1948), lake trout (*Salmo trutta m. lacustris* L.) by Sakowicz

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(1961) and Szczerbowski (1966), Caspian trout (*Salmo trutta caspius* Kesl.) by Farid (1968), rainbow trout (*Salmo gairdneri* Rich.) by Juszczyk (1951).), Suvorov (1948) and Schapercalus (after Backiel 1964), Atlantic salmon (*Salmo salar* L.) by Larsson and Pickova (1978) who quoted also Belding and al. (1932) and Carlin (1951). These observations, however, were contradicted by Bartel (1971a) who found that egg size of rainbow trout (*Salmo gairdneri* Rich.) did not depend on female size (length and weight). Similar observations were made for brook trout (*Salmo trutta m. fario* L.) by Sklower (1930). Larsson and Pickova (1978), Bartel (1971a) and Skrochowska (1953) found that size of eggs depended most of all on fish age. According to Bartel (1971a) in case of reared rainbow trout (*Salmo gairdneri* Rich.) size of eggs can depend also on many other factors, such as type and amount of food, spawning season, fish origin, habitat etc.

There is a general lack of information on the effect of the mentioned factors upon size of mature sea trout (*Salmo trutta* L.) eggs, in this of sea trout from Pomeranian rivers. Hence, a study was undertaken in order to determine statistically the effect of female length, weight and age on average egg diameter and weight of swollen and mature eggs of sea trout from Rega River. On the basis of these data it will be possible to determine the relationships between female length, weight and age, and size of eggs used for reproduction. As a result, it should be possible to work out a simple method for selection

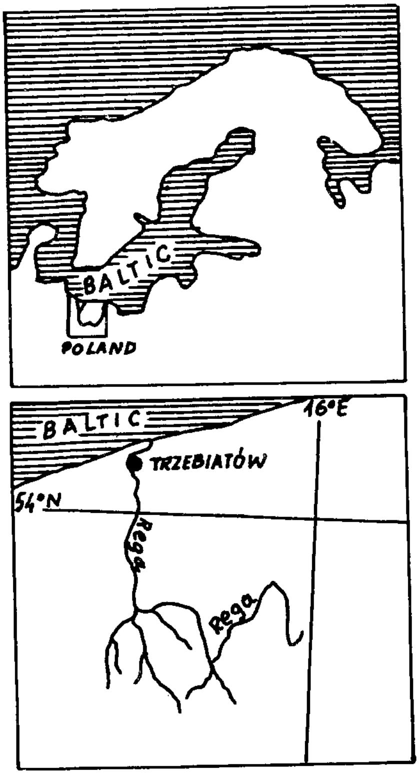

Fig. 1. Location of sea trout sampling station.

of eggs used for production of the stocking material, so as to assure its highest biological value.

Stock of sea trout spawners in the Rega River increased in the past twenty years (1969–1983). The river is situated in Pomerania, and it flows directly to the south-west Baltic (Fig. 1). Increasing density of mature fishes is due to permanent stocking with sea trout hatchlings (Chełkowski 1974). According to Chełkowski (1974) 995 females could be taken for egg stripping in 1968. Demand for eggs of sea trout from the Rega River in the hatcheries is usually much lower, so that it is possible to select the females for further reproduction.

MATERIAL AND METHOD

In autumn each year sea trout spawners which migrate upstream from the Baltic Sea are caught in the Rega River. A trap is set in Trzebiatów, at 16.9 km of the river. Spawners are kept in a water basin untill full sexual maturity. In 1980 only 467 females were taken for artificial reproduction, and in 1981 only 308 females from the whole spawning population in the river. From these 67 specimens (14.3%) were selected randomly in the first year, and 43 (14.0%) in the second year. Fishes were collected in the second and third decade of November, when most females attained sexual maturity. Totally 110 fully mature females were examined in the two years (Table 1). Each female was stripped into a separate bowl. Subsamples of about 100 eggs were then collected, and the eggs were immersed in the serum of a given female. After stripping, length and weight of the female were measured, and scales were collected for age determination. Body length was measured up to 1 mm. Fishes were divided into 1 cm length classes (For instance, 42nd length class contained all individuals 411–420 mm long). Weight of females was recorded up to 10 g. Scales were taken from above the latteral line, between dorsal and fatty fin. The collected eggs were transported to the laboratory in tubes in a thermos with the same water in which the spawners were kept. The sperm collected from a few males was transported in the same way. In the laboratory the materials were placed in a refrigerator, at 6–7°C. Weight of mature eggs was determined about 24 hours after their collection, from two randomly collected samples of n = 30 for each female. Before

Table 1

Preliminary description of the materials

Period of sampling	Number of females	
	caught	analysed
October 1980	467	67
October 1981	308	43
Total	875	110

weighing the eggs were placed on a blotting paper in order to remove the excess of serum. Sea trout sperm was then dropped to the tubes, mixed with the eggs with a glass rod, and placed in a refrigerator following an addition of water. About 5 min. later the eggs were washed with the same water and placed again in the refrigerator to swell. According to Bogucki (1930), Winnicki and Bartel (1967) swelling of salmonid eggs is complete in about 1 hour. Winnicki (1968) stated that in 7–10°C swelling of eggs lasts 1 hour, in lower temperatures it is even longer, whereas the process of hardening of the egg membrane is definitely completed after 24 hours. In our case all further determinations were made 24 hours after the fertilization. Clear eggs were selected. They constituted 94 to 100% in the samples. Average mass of a swollen egg was calculated from two randomly selected subsamples of $n = 30$ for each female. Before weighing the eggs were placed on a blotting paper to remove the adhesive water. In order to determine average diameter of swollen eggs 10 eggs were taken from each female. Since the eggs are ellipsoidal, two measurements were made for each eggs, crossing at a right angle (after Bartel 1971). An average was calculated from these two values (i.e. the biggest and the smallest diameter). These data were used to determine mean egg diameter for a given female. Egg weight was determined using an analytical balance, with an accuracy up to 0.0001 g. Egg diameter was calculated on an outline magnified 17x with a projector. Measurements of the diameter were made up to 0.01 mm. Age of females was determined from scale readings in a passing light (Chełkowski 1974). In case of 8 females the age was not determined due to difficulties in data interpretation, and these females were discarded from the sample. Consequently, 102 sea trout females were analysed (Table 2). The following relationships were determined: female length (X_1) and weight (X_2) and egg diameter after swelling (Y_1), weight of stripped mature egg (Y_2) and egg weight after swelling (Y_3). Relationships between these variables were determined for three age intervals (1+); (2+); (3+ and 4+) of sea life, and for all individuals under study. 4+ females were analysed together with 3+ due to the fact that there were only two specimens in the first age group. Totally 24 dependencies were calculated using the BETA programme. Linear relationships:

$$Y = ax + b$$

were calculated together with non-linear ones:

$Y = ba^*$ (exponential function),

$Y = a \log x + b$ (logarithmic function),

$Y = bx^a$ (power function),

$Y = \frac{a}{x} + b$ (quotient function).

Statistical calculations were performed on EMC-MERA-400 with BETA* programme (Marszałkiewicz 1972, Gren 1978).

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* Calculations were made by B. Gałęziowski, M.Sc., under the supervision of doc dr hab. Z. Woźniak, in the Department of Applied Mathematics and Information of the Agricultural Academy in Szczecin.

Table 2

Number of analysed sea trout females in length classes

Length class (cm)	Year of studies		Total
	1980 indiv.	1981 indiv.	
42	–	1	1
43	–	–	–
44	–	–	–
45	–	–	–
46	–	–	–
47	–	–	–
48	1	–	1
49	1	1	2
50	2	2	4
51	3	1	4
52	4	1	5
53	4	3	7
54	1	1	2
55	5	1	6
56	1	–	1
57	1	2	3
58	6	1	7
59	4	1	5
60	–	–	–
61	1	2	3
62	–	3	3
63	3	1	4
64	3	–	3
65	6	–	6
66	1	2	3
67	3	4	7
68	4	2	6
69	1	3	4
70	3	2	5
71	2	–	2
72	–	–	–
73	–	–	–
74	–	4	4
75	1	1	2
76	–	–	–
77	–	1	1
78	–	–	–
79	1	–	1
Total	62	40	102

Table 3

General data on sea trout females and eggs

Description of the feature	$\bar{X}$	δ	V	Range of variations
Female length (X_1) in cm	61.15	7.856	12.8	42 – 79
Female weight (X_2) in kg	2.12	0.806	31.2	0.69– 5.12
Egg diameter (Y_1) in mm	5.06	0.32	6.3	4.3 – 5.7
Weight of mature eggs (Y_2) in mg	71.23	12.016	16.9	45.8 – 99.2
Weight of swollen eggs (Y_3) in mg	78.67	13.514	17.2	48.9 –111.3

Table 4

Age of sea trout females (in indiv. and %)

Years of life:	in the sea					total
in river	0+	1+	2+	3+	4+	
1		5	5	2	1	13
2		30	43	5	1	79
4		5	5			10
total		40	53	7	2	102
%		39.2	52.0	6.9	1.9	100
%	0.69	37.64	59.82	1.85	–	100

– according to Chełkowski (1974) for females spawning for the first time.

GENERAL CHARACTERISTICS OF THE MATERIAL

Detailed data on length and weight of females and mean diameter and weight of sea trout eggs are presented in Table 3. Females collected during the studies were 42–79 cm long. According to earlier studies (Chełkowski 1974), range of the length of adult sea trout females in the Rega River was 36–91 cm. Hence, lengths of the females under study were within the range most frequently found in the river. Chełkowski (1970) determined range of diameters of swollen eggs of sea trout from Rega River at 4.5–5.45 mm. In this study the values found were 4.3–5.7 mm. Basing on average weight of mature and swollen eggs it was stated that egg weight increased during swelling from 71.23 mg to 78.67 mg, i.e. by 10.5% on the average. Age of sea trout females is presented in Table 4, with consideration given to river and sea life. In calculating the mentioned relationships, only years of sea life were taken into account. The materials consisted of 40 (39.2%) females at the age of 1+, 53 (52.0%) at the age of 2+, 7 (6.9%) at the age of 3+ and 2 (1.9%) at the age of 4+. Percentages of sea trout females in successive years of sea life were similar to the percentages of sea trout females in the Rega River determined from much more numerous materials (n = 4340 specimens) (Chełkowski 1974). From among the females under study, 11 had one and 2 had two spawning rings.

STATISTICAL DETERMINATION OF THE EFFECT OF SEA TROUT FEMALE LENGTH, WEIGHT AND AGE UPON WEIGHT OF MATURE EGGS, AND WEIGHT AND DIAMETER OF SWOLLEN EGGS

Table 5 presents basic statistics of the material, parameters of the best fitting regression functions, and the respective coefficients of correlation, together with critical values of the statistical test of significance.

Analysis of basic statistics (arithmetical mean, variance, standard deviation, variation coefficient) revealed regularities of the distribution, pointing also to proper representativity of the population under study.

Age criterium is noticeably reflected in the differentiation of female length and weight. Differentiation of female length in particular groups was small, as proved by the variation coefficient V_{x1} = 10%. On the other hand, differences between the groups resulted in the variation coefficient of V_{x1} = 12.8%. There was considerable differentiation of female weight in particular age groups; V_{x2} for females at the age 1+ amounted to 31.2%. Variation coefficient decreased with fish weight, but it was 38.1% for the whole sample.

Differentiation of the dependent variables (viz. eggs) was lower, but characterized by similar trends, i.e. egg diameters were less differentiated than egg weights.

It should be noted that all characteristics showed growing trend with the fish age, but

Table 5

Characteristics of the variables and dependencies between the variables for sea trout population in Rega River

	Dependence	for years fo sea life	$\bar{X}$	$\bar{S}x$	Vx (%)	$\bar{Y}$	Sy	Vy (%)	Optimal model of the regression	r	t	a	b
1.	Female length X1 diameter swollen eggs Y_1	1+	54.250	4.543	8.4	4.825	0.309	6.4	$Y = b \cdot x^a$	0.609	4.734 **	− 0.466	0.750
2.	as above	2+	64.887	6.086	9.4	5.175	0.209	4.0	$Y = \frac{a}{x} + b$	0.502	4.141**	−68.672	6.244
3.	as above	3+ i 4+	69.778	4.613	6.6	5.400	0.205	3.8	$Y = \frac{a}{x} + b$	0.864	4.540**	−171.116	7.864
4.	as above	total	61.147	7.856	12.8	5.058	0.320	6.3	$Y = \frac{a}{x} + b$	0.748	11.276**	−109.439	6.878
5.	Female weight X_2 diameter swollen eggs Y_1	1+	1.485	0.464	31.2	4.825	0.309	6.4	$Y = a \cdot \log X + b$	0.636	5.086**	1.615	4.577
6.	as above	2+	2.451	0.714	29.1	5.175	0.209	4.0	$Y = \frac{a}{x} + b$	0.513	4.265**	−0.778	5.521
7.	as above	3+, 4+	2.973	0.487	16.4	5.400	0.205	3.8	$Y = b \cdot X^a$	0.942	7.420**	0.189	4.406
8.	as above	total	2.118	0.806	38.1	5.058	0.320	6.3	$y = \frac{a}{x} + b$	0.759	11.659**	−1.113	5.667
9.	Female length X_1 weight of mature eggs Y_2	1+	54.250	4.543	8.4	62.860	10.965	17.4	$Y = b \cdot X^a$	0.669	5.550**	1.404	0.229
10.	as above	2+	64.887	6.086	9.4	75.189	8.513	11.3	$Y = b \cdot X^a$	0.403	3.148**	0.509	8.954
11.	as above	3+, 4+	69.778	4.613	6.6	85.144	8.827	10.4	$Y = b \cdot X^a$	0.786	3.360**	1.212	0.493
12.	as above	total	61.147	7.856	12.8	71.232	12.016	16.9	$Y = \frac{a}{x} + b$	0.722	10.441**	−3962.337	137.136
13.	Female weight X_2 weight of mature eggs Y_2	1+	1.485	0.464	31.2	62.860	10.965	17.4	$Y = a \cdot \log X + b$	0.648	5.256**	58.468	53.880
14.	as above	2+	2.451	0.714	29.1	75.189	8.513	11.3	$Y = \frac{a}{x} + b$	0.417	3.279**	−25.762	86.638
15.	as above	3+, 4+	2.973	0.487	16.4	85.144	8.827	10.4	$Y = b \cdot a^x$	0.823	3.840**	1.197	49.567
16.	as above	total	2.118	0.806	38.1	71.232	12.016	16.9	$Y = \frac{a}{x} + b$	0.724	10.515**	−39.836	93.050
17.	Female length X_1 weight of swollen eggs Y_3	1+	54.250	4.543	8.4	68.730	11.683	17.0	$Y = b \cdot a^x$	0.683	5.766**	1.026	16.726
18.	as above	2+	64.887	6.086	9.4	83.547	9.392	11.2	$Y = b \cdot X^a$	0.521	4.359**	0.664	5.212
19.	as above	3+, 4+	69.778	4.613	6.6	94.067	11.292	12.0	$Y = b \cdot X^a$	0.873	4.740**	1.618	0.792
20.	as above	total	61.147	7.856	12.9	78.665	13.514	17.2	$Y = \frac{a}{x} + b$	0.773	12.184**	−4769.63	157.996
21.	Female weight X_2 weight of swollen eggs Y_3	1+	1.485	0.464	31.3	68.730	11.683	17.0	$Y = a \cdot \log X + b$	0.680	5.727**	65.350	58.694
22.	as above	2+	2.451	0.714	29.1	83.547	9.392	11.2	$Y = \frac{a}{x} + b$	0.523	4.378**	−35.560	99.368
23.	as above	3+, 4+	2.973	0.487	16.4	94.067	11.292	12.0	$Y = b \cdot a^x$	0.908	5.740**	1.269	45.931
24.	as above	total	2.118	0.806	38.1	78.665	13.514	17.2	$Y = \frac{a}{x} + b$	0.765	11.287**	−47.314	102.578

$\bar{X}$, $\bar{Y}$ – arithmetic means; S – standard deviation; V – coefficient of variability; r – coefficient of correlation; t – test of significance for correlation coefficient; a – coefficient of regression; b – regression constant; * – significant at the level $\alpha = 0.05$; ** – significant at the level $\alpha = 0.01$

differences between the means for 1+ and 2+ were always greater than between 2+ and 3+ and 4+.

The dependencies under study were of similar character both within and between the groups, i.e. they were growing functions but with decreasing increments, i.e. of hyperbolic character. Fitting of the curves to the data is very good, as proved by high coefficients of correlation (r) and t statistics (especially for sum of observations for a given feature).

The effect of female length (X_1) upon diameter of swollen egg (Y_1) is determined by a function (Fig. 2), their distribution being presented in Fig. 3:

$$Y_{1i} = \frac{-109.4}{x_{1i}} + 6.88$$

As results from this function, an increase of female length by 1 cm results in an increase of swollen egg diameter:

– at female length of 42 cm by about 0.06 mm,
– at female length of 78 cm by about 0.02 mm.

The effect of female length (X_1) upon weight of mature eggs (Y_2) was expressed by the equation (Fig. 4):

$$Y_{2i} = \frac{-3962.3}{X_{1i}} + 137.1$$

In this case we deal with almost linear effect in case of females 70 cm long, and then the effect decreases rapidly, so that an increment of female length by 1 cm results in an increase of mature egg weight:

– by about 2.24 mg at female length of 42 cm,
– by about 0.65 mg at female length of 78 cm.

The regression between female length (X_1) and weight of swollen eggs (Y_3) is represented by the function (Fig. 5):

$$X_{3i} = \frac{-4769.6}{X_{1i}} + 158.0$$

Shape of this curve is similar to the preceeding one, i.e. it is characterized by decreasing increments. An increase of female length by 1 cm correlates with weight increase of swollen egg:

– by 2.70 mg at female length of 42 cm,
– by 0.78 mg at female length of 78 cm.

The ratio of extreme increments of egg weight (when calculated up to 3 places after the point) is the same, suggesting that it is sufficient to study only one of these parameters in order to draw proper conclusions. This is also proved by the fact that correlation coefficient between weight of mature eggs and weight of swollen eggs is $r = 0.999$, so that the three parameters must be correlated linearly.

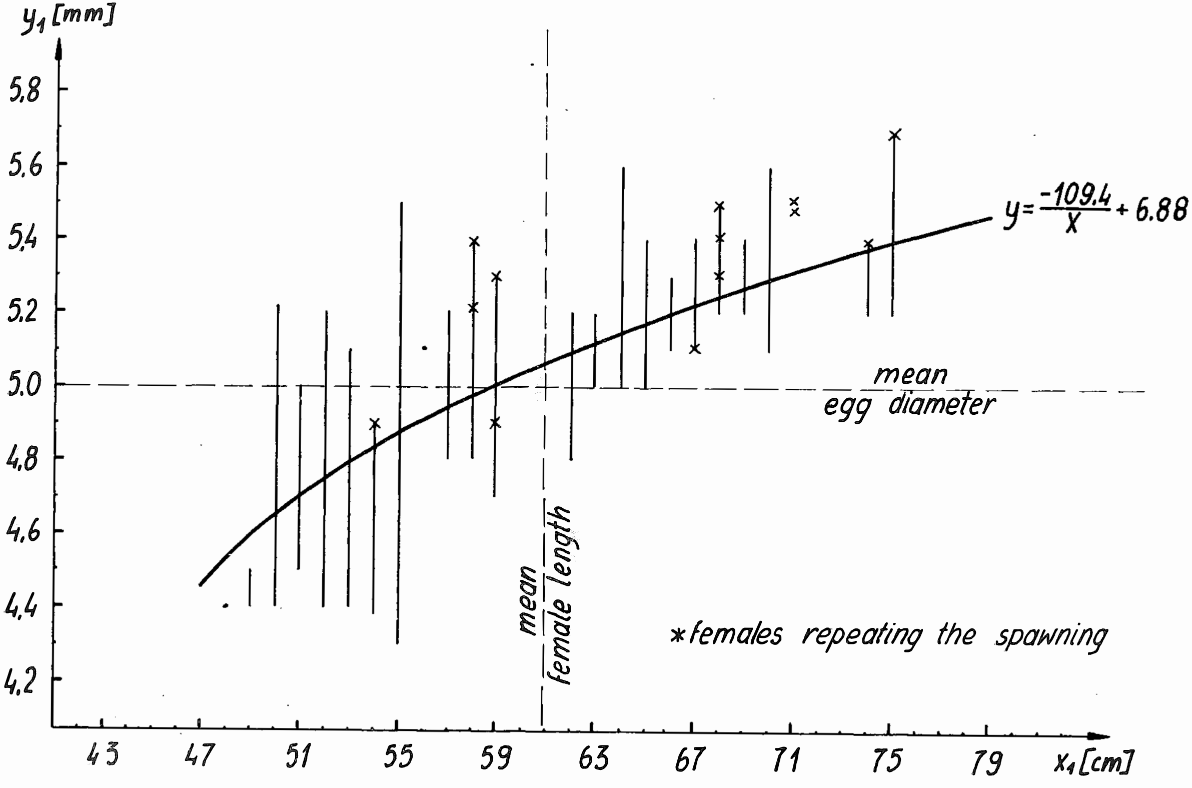

Fig. 2. Distribution of the diameters of swollen eggs (Y_1) (mm) depending on female length (X_1) (cm).

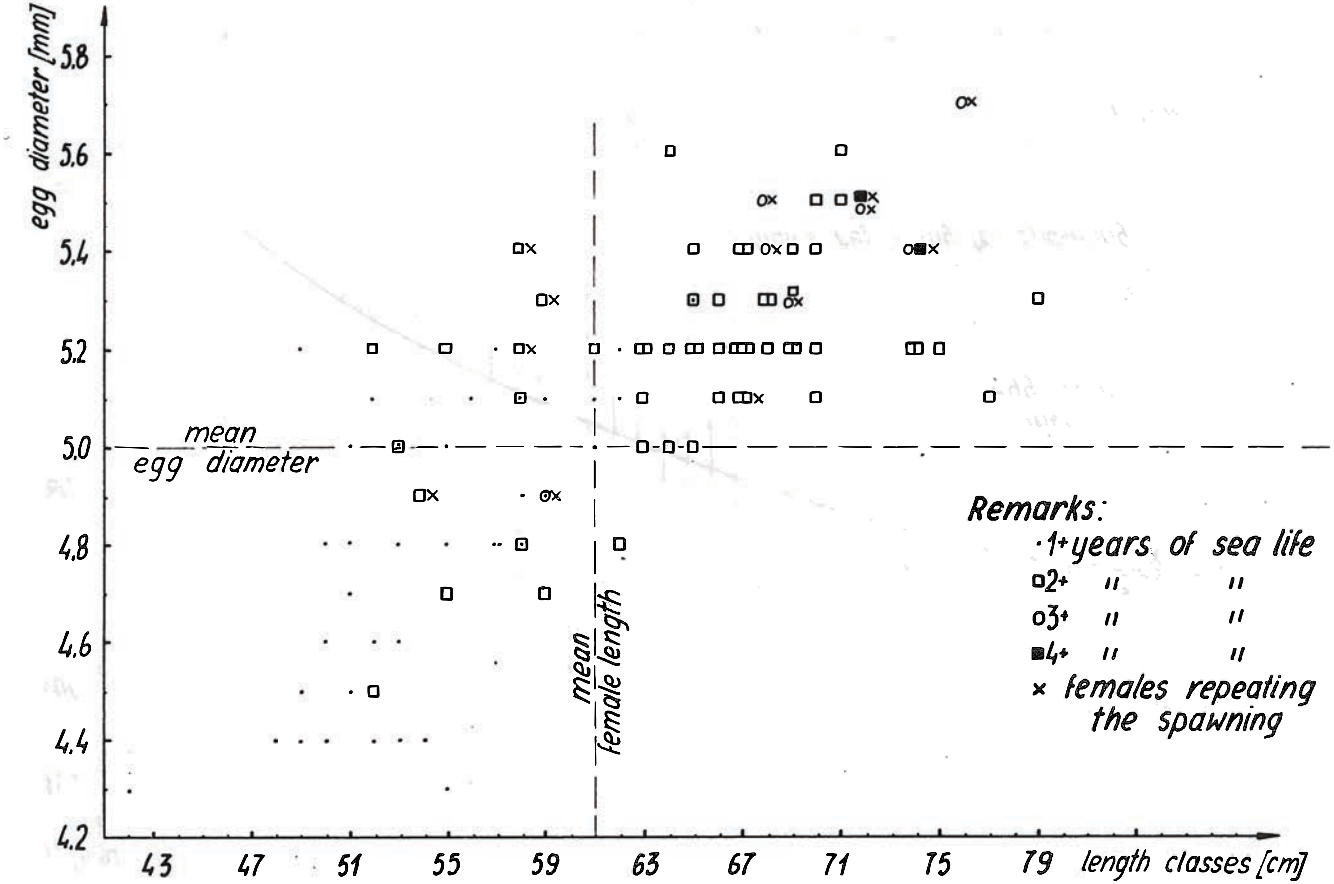

Fig. 3. Distribution of the egg diameters in female length classes, with consideration given to years of sea life.

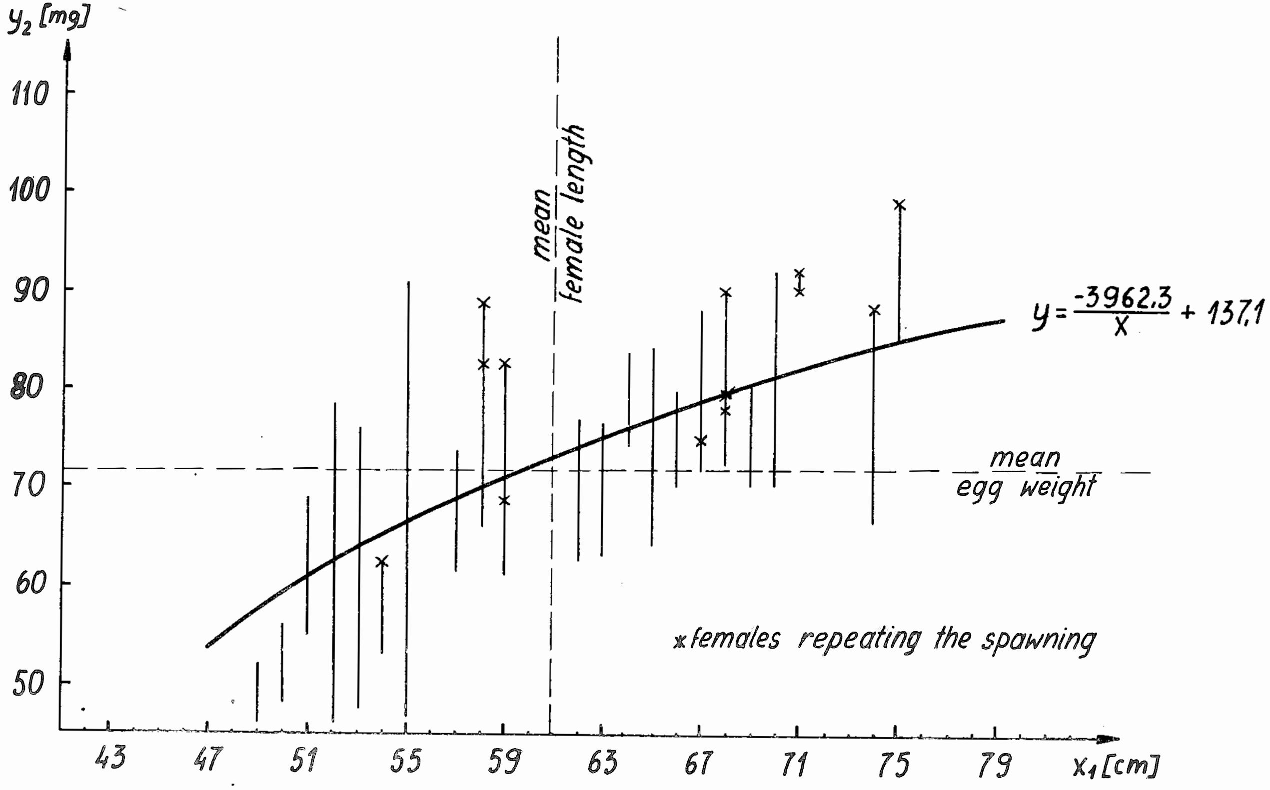

Fig. 4. Distribution of the weight of mature eggs (Y_2) (mg) depending on female length (X_1) (cm).

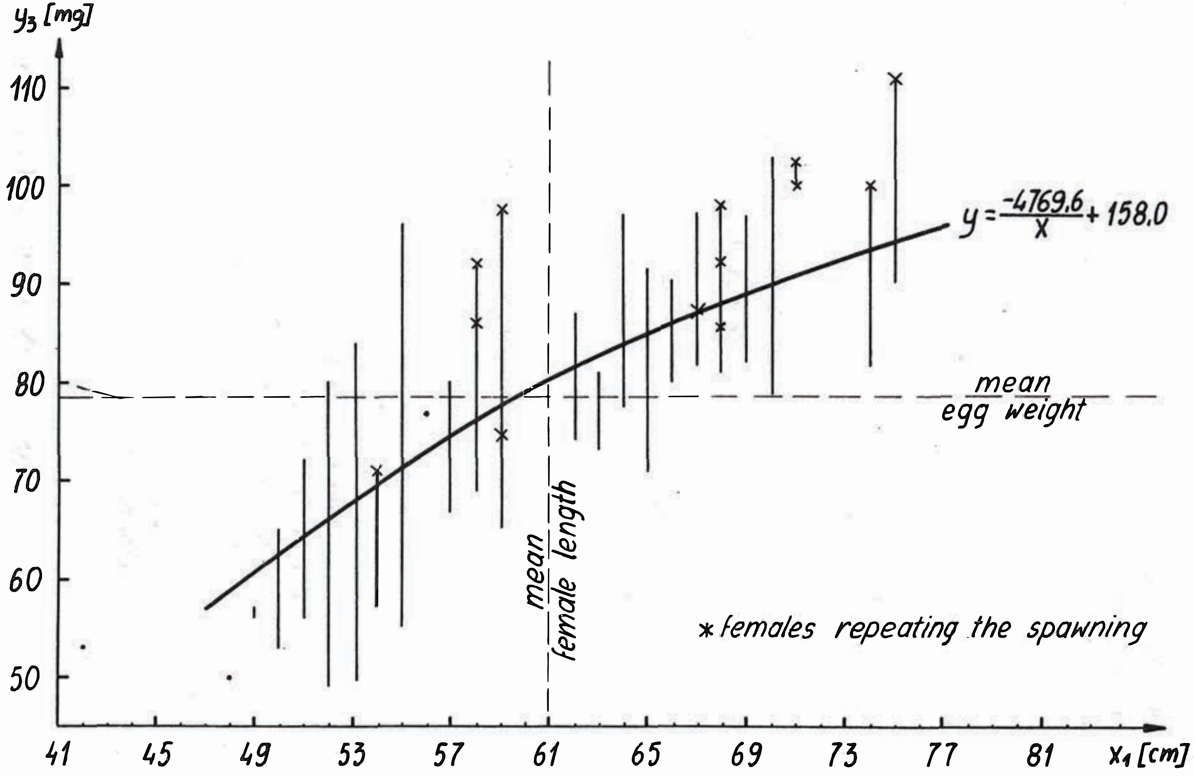

Fig. 5. Distribution of the weight of swollen eggs (Y_3) (mg) depending on female length (X_1) (cm).

As mentioned before, weight of females was more differentiated than their length, and the most differentiated eggs were obtained from the youngest females. Notwithstanding this, correlation between egg diameter and weight on the one side, and weight of fishes on the other was similar, or even more strict than with fish length. The differences were noted only at the fourth place of the correlation coefficients.

Regression of the diameter of swollen eggs (Y_1) on female weight (X_2) is represented by the following function (Fig. 6), and their distribution is presented in Fig. 7:

$$Y_{1i} = \frac{-1.113}{X_{2i}} + 5.67$$

This means that an increase of female weight by 0.1 kg results in an increase of swollen egg diameter:

- by 1.59 mm at female weight of 0.7 kg,
- by 0.03 mm at female weight of 5.3 kg.

An increase of female weight by 1 kg in the weight range from 4.3 to 5.3 kg results in an increase of mean egg diameter by only 0.03 mm. Average diameter of eggs in females weighing 0.7 kg amounted to 4.08 mm, in females weighing 2.1 kg to 5.14 mm, and in those weighing 5.3 kg – to 5.46 mm.

The effect of female weight (X_2) upon weight of mature eggs (Y_2) is reflected by the regression function (Fig. 8):

$$Y_{2i} = \frac{-39.84}{X_{2i}} + 93.05,$$

whereas the effect of female weight (X_2) upon weight of swollen eggs (Y_3) was represented by the equation (Fig. 9):

$$Y_{3i} = \frac{-47.3}{X_{2i}} + 102.58.$$

As results from Figs 8 and 9, both these functions are similar to the previous ones. Hence, an increase of female weight by an arithmetical mean (2.1 kg) significantly affects egg weight, while above this mean the effect is very small.

An increase of female weight by 1 kg results in an increase of the weight of mature and swollen egg respectively by:

- 39.8 mg and 47.3 mg for females of 1 kg,
- 8.07 mg and 9.5 mg for females of 5 kg.

PROBLEM OF FEMALE SELECTION FOR REPRODUCTION

Statistical calculations showed that egg diameter and weight increased along with an increase of female length, weight and age. This fact allows for practical selection of eggs according to their size, and for female selection according to their length, weight or age.

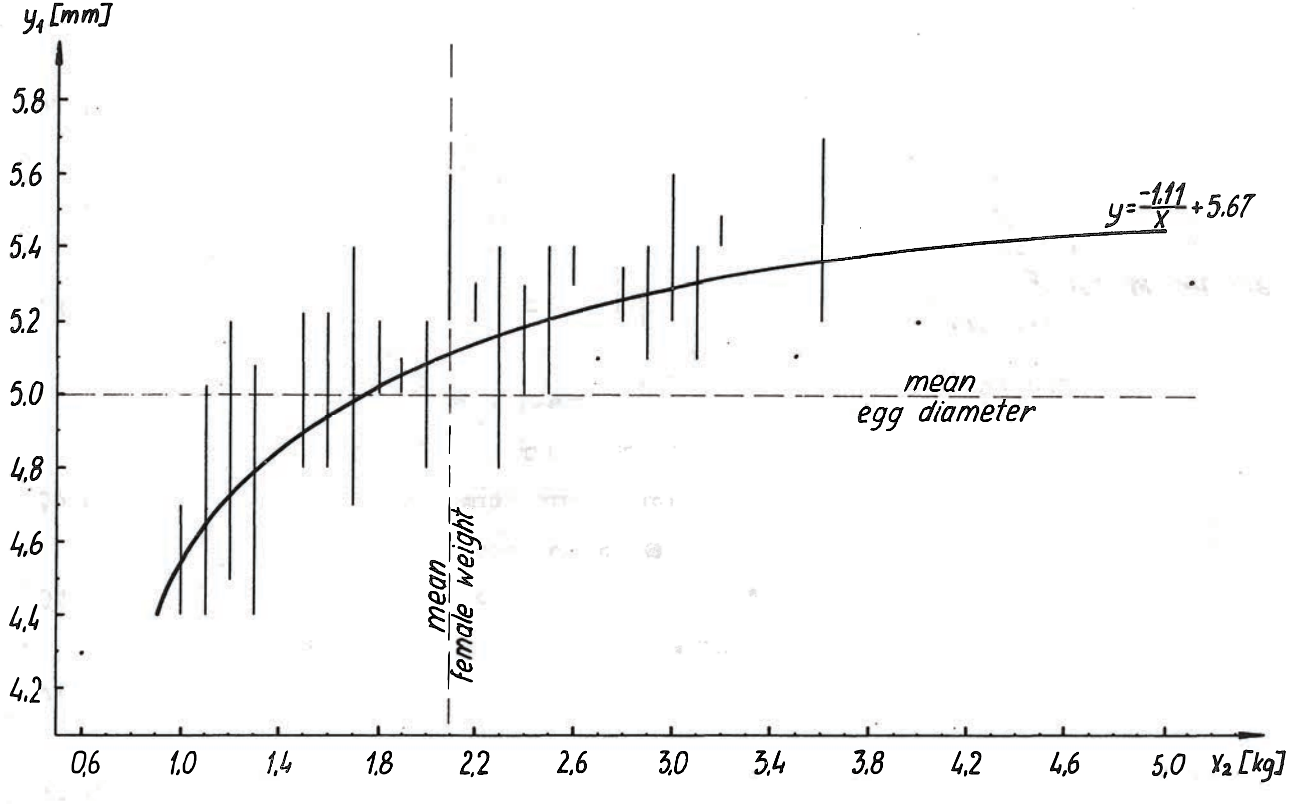

Fig. 6. Distribution of the diameters of swollen eggs (Y_1) (mm) depending on female weight (Y_2) (kg).

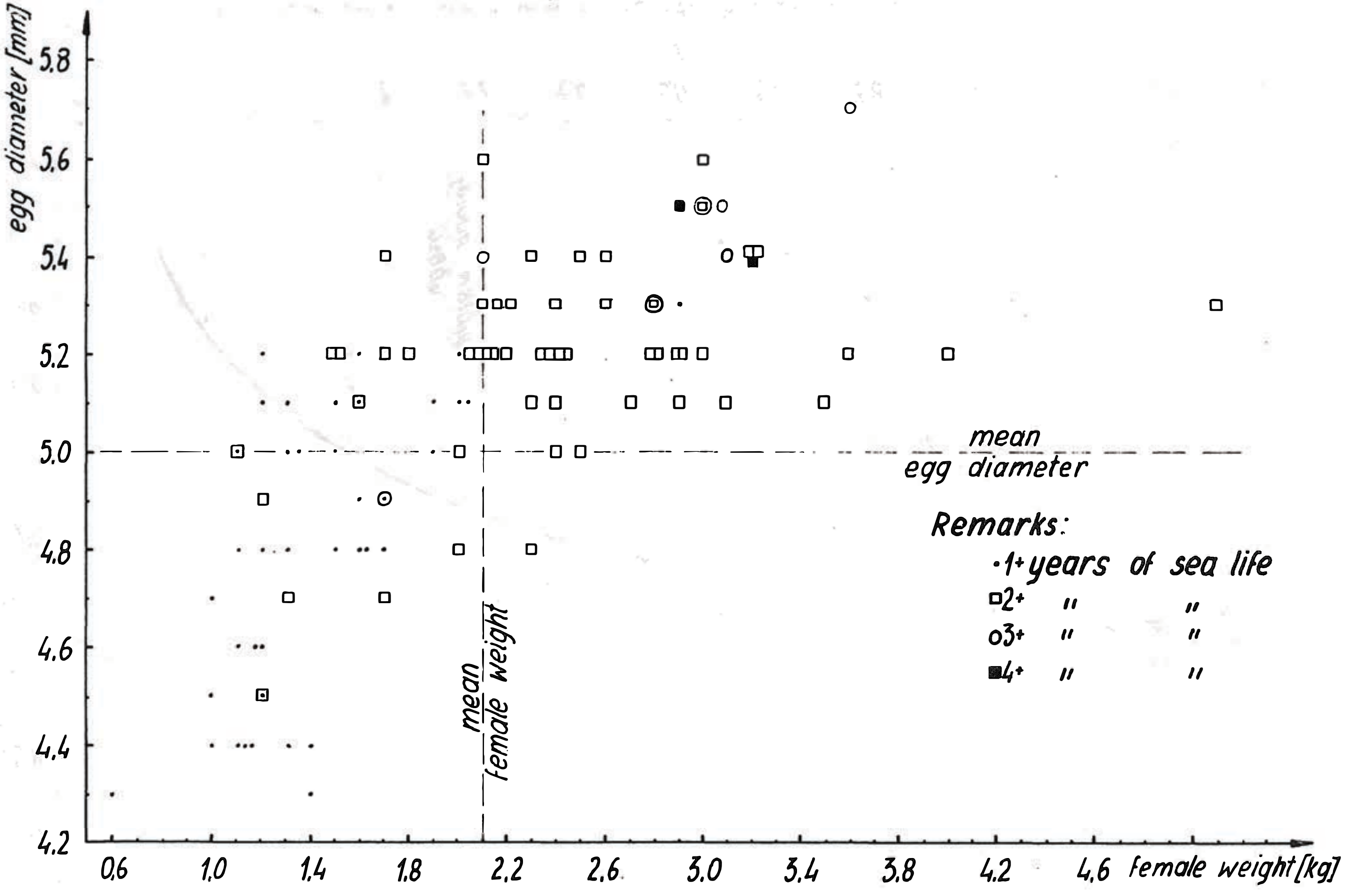

Fig. 7. Distribution of the egg diameters in female weight classes, with consideration given to years of sea life.

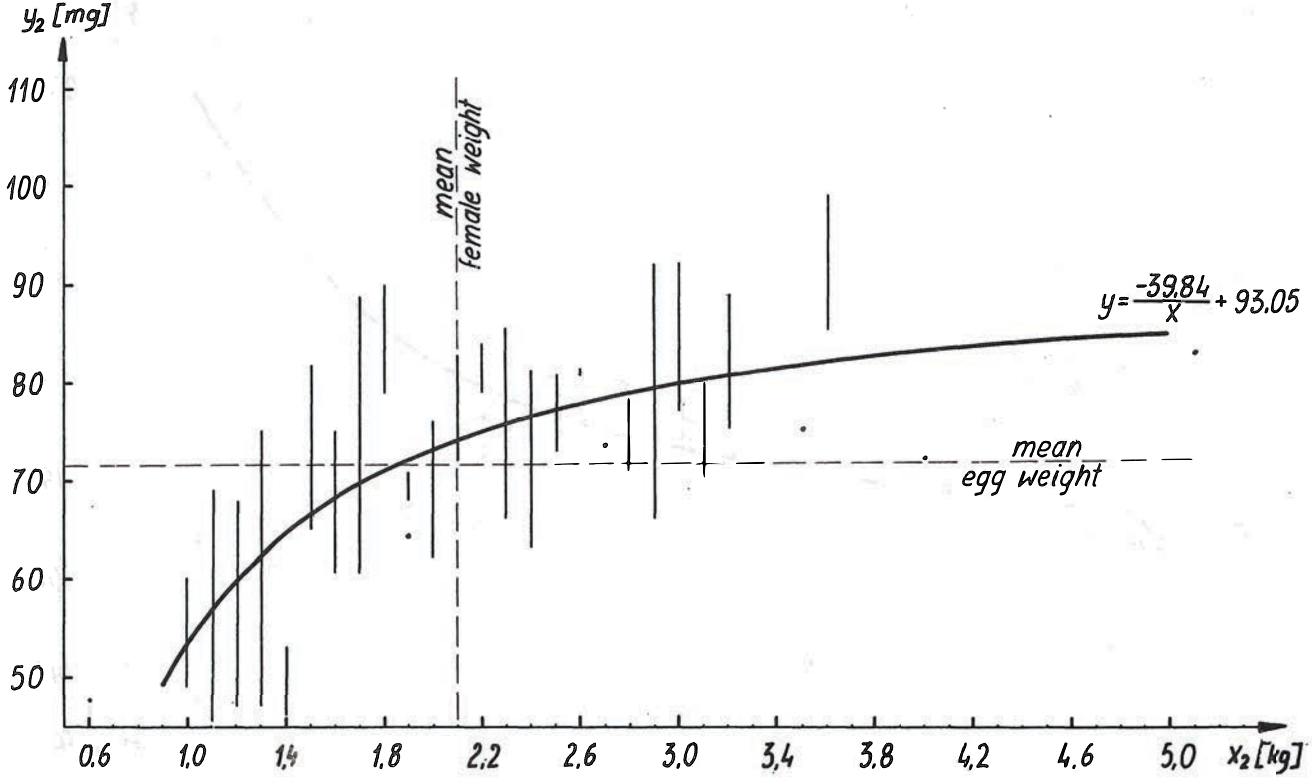

Fig. 8. Distribution of the weight of mature eggs (Y_2) (mg) depending on female weight (X_2) (kg).

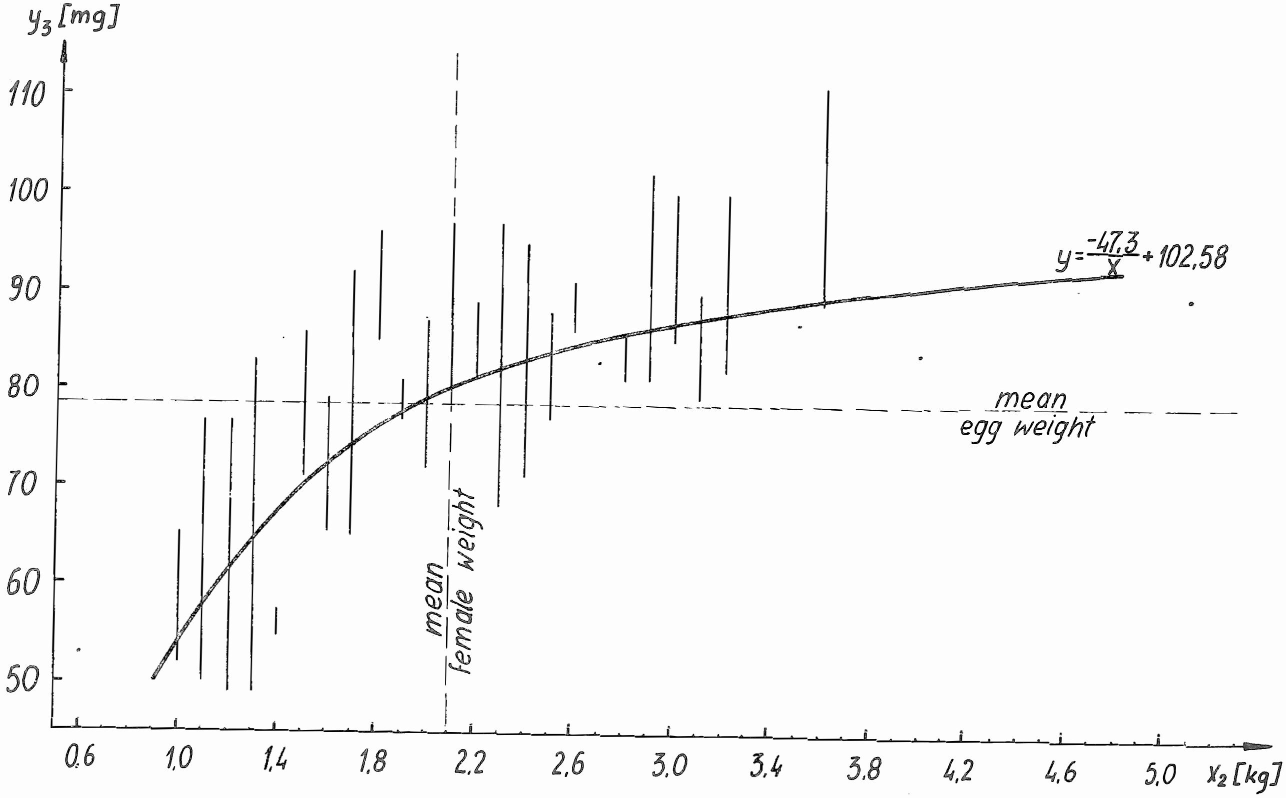

Fig. 9. Distribution of the weight of swollen eggs (Y_3) (mg) depending on female weight (X_2) (kg).

As mentioned before, large eggs of sea trout represent a more valuable reproductive material.

From a practical point of view it seems advisable to introduce two groups of egg sizes: standard I (large eggs), and standard II (small eggs). This way it is possible to take mean values of the variables under study as the division line (Tables 3 and 6).

Table 6

Adopted standard values for sea trout females and eggs

Description of the feature	Standard	
	I	II
Female length in mm	⩾ 610	⩽ 609
Female weight in kg	⩾ 2.1	⩽ 2.0
years of life in the sea	2+, 3+, 4+	1+
egg diameter in mm	⩾ 5	⩽ 4.9
weight of mature eggs in mg	⩾ 71.2	⩽ 71.1
weight of swollen eggs in mg	⩾ 78.7	⩽ 78.6

PROBLEMS OF FEMALE SELECTION ON THE BASIS OF LENGTH

From a theoretical point of view, females ⩾ 610 mm of length (*l. caudalis*) should produce eggs in the I standard, while females ⩽ 609 mm – in the II standard. This, however, does not illustrate egg sizes in particular length classes of the fishes. In order to solve this problem, egg diameters and weights in particular length classes of the females were presented in graphs (Figs 2, 4 and 5). Additionally, mean egg diameter was presented in Fig. 2 and mean diameter of swollen egg – in Fig. 5. Moreover, mean female length was presented in each of these graphs. As results from these data, in the group of females longer than the average there were:

a. 98.1% of females with mean egg diameter in the I standard, i.e. with eggs ⩾ 5 mm, and 1.9% of females with eggs in the II standard, ⩽ 4.9 mm (Table 7).

b. 83.3% of females with average egg weight in the I standard, i.e. with eggs ⩾ 71.2 mg, and 16.7% of females with eggs in the II standard, ⩽ 71.1 mg.

c. 90.7% of females with average weight of swollen eggs in the I standard, i.e. with eggs ⩾ 78.7 mg, and 9.3% of females with eggs in the II standard, ⩽ 78.6 mg.

Similarly, it can be stated that in the group of females smaller than the mean length (⩽ 609 mm) there were:

a. 60.4% of females with average egg diameter in the II standard, and 39.6% of females with egg diameter in the I standard.

b. 75.0% of females with weight of mature eggs in the II standard, and 25.0% of females with egg weight in the I standard.

Table 7

Share of sea trout females in length classes and egg standards

Female length in mm	n	egg standart			
		I		II	
		indiv.	%	indiv.	%
a. depending on egg diameter					
⩽609	48	19	39.6	29	60.4
⩾610	54	53	98.1	1	1.9
b. depending on weight of mature egg					
⩽609	48	12	25.0	36	75.0
⩾600	54	45	83.3	9	16.7
c. depending on weight of swollen egg					
⩽609	48	10	20.8	38	79.2
⩾610	54	49	90.7	5	9.3

c. 79.2% of females with weight of swollen eggs in the II standard, and 20.8% of females with eggs in the I standard.

Moreover, distribution of females was determined for successive years of sea life, in length classes, with consideration given to egg size. Egg size in this case was represented

Table 8

Share of sea trout females in years of sea life and length classes

Length class (mm)	⩾610		⩽609	
years of life in the sea	indiv.	%	indiv.	%
1+	5	12.5	35	87.5
2+	41	77.4	12	22.6
3+	6	85.7	1	14.3
4+	2	100.0		
Total	54	52.8	48	47.1

only by the egg diameter (Fig. 3). This figure presents also mean value of egg diameter, and mean female length.

Analysis of these materials revealed some interesting matters. One of them is the share of females in the length classes and groups above and below the mean length, in particular years of the sea life. It appeared that age group 1+ was predominated by females smaller than the mean length (87.5%), while those longer than the mean were much less numerous (12.5%). Structure of the 2+ age group was quite different. In this group there were 77.4% of females larger than the mean, and 22.6 % of females smaller than the mean length. In the age group 3+ 85.7% were represented by females above the mean length, and 14.3% by females below this length. In the age group 4+ there was only one female larger than the mean length (Table 8).

Share of sea trout females in particular length classes during sea life was also interesting. Group of females longer than the mean length was represented mostly by the age group 2+ (75.9%). In the group of smaller females there were mostly fishes in the age group 1+. Percentages of females from the other age groups were also characteristic (Table 9).

Table 9

Share of sea trout females in length classes and years of sea life

Length class (mm) years of life in the sea	⩾610	⩽609
1+	9.3	72.9
2+	75.9	25.0
3+	11.1	2.1
4+	3.7	
Total	100.0	100.0

Generally, in the length class below the average, there were 1+ to 3+ females, with a noticeable predomination of 1+ fishes. In the length class above the average, the 2+ fishes predominated.

Special attention should be given to data which took into account also the female distribution in relation to the average diameter of swollen eggs. It appeared that in the length class ⩾610 mm, there was only one female at the age of 2+ which was classified as belonging to the II standard with respect to egg diameter. The other females in this length class (n = 53) represented the I standard with respect to the diameter of swollen eggs. In the length class ⩽609 mm most females (n = 29) had average diameter of swollen eggs in the II standard, and only 19 females were classified as belonging to the I standard (Table 10). Numbers of eggs produced by females above and below the average are still to be determined. There were no sufficient materials to study this problem extensively. However, it can be stated that females longer than the mean length supplied more eggs

Table 10

Occurence of sea trout in years of sea life depending
on length and diameter of swollen eggs
(indiv.)

Length class (mm)	≥610		≤609	
egg standard	I	II	I	II
	egg diameter in mm			
years of life in the sea	≥5	≤4.9	≥5	≤4.9
1+	5		12	23
2+	40	1	7	5
3+	6			1
4+	2			

than those smaller than the mean length. This results from higher fecundity of bigger sea trout females compared to smaller ones.

The calculations showed that in the length class ≥ 610 mm there were 52.9% females, and in the lenght class ≤ 609 mm – 47.1% (Table 8).

PROBLEMS OF FEMALE SELECTION BASED ON THE FISH WEIGHT AFTER STRIPPING

Female weight represents another factor which can be taken advantage of for fish selection for reproduction. It was assumed that females I-standard 2.1 kg produce eggs in the I standard, and females ≤ 2.0 kg – eggs in the II standard. Distribution of egg size in the adopted weight classes is presented in Figs 6, 8 and 9. From the data presented in Table 11 it can be concluded that in the weight class above the mean there would be:

a. 98.0% of females with egg size in the I standard, and 2% of females with egg size in the II standard.

b. 81.6% of females with weight of mature eggs in the I standard, and 18.4% of females with weight of mature eggs in the II standard.

c. 93.9% of females with weight of swollen eggs in the I standard, and 6.1% of females with weight of swollen eggs in the II standard.

As regards the group of females with weight below the average, there would be:

a. 54.7% of females with egg diameter in the II standard, and 45.3% females with egg diameter in the I standard.

b. 77.4% of females with weight of mature eggs in the II standard, and 22.6% of females with weight of mature eggs in the I standard.

Table 11

Share of sea trout females in weight classes and egg standards

Female weight	n	egg standard			
		I		II	
		indiv.	%	indiv.	%
a. depending on egg diameter					
⩽2.0 kg	53	24	45.3	29	54.7
⩾2.1 kg	49	48	98.0	1	2.0
b. depending on weight of mature egg					
⩽2.0 kg	53	12	22.6	41	77.4
⩾2.1 kg	49	40	81.6	9	18.4
c. depending on weight of swollen egg					
⩽2.0 kg	53	12	22.6	41	77.4
⩾2.1 kg	49	46	93.9	3	6.1

c. 77.4% of females with weight of swollen eggs in the II standard, and 22.6% of females with weight of swollen eggs in the I standard.

Distribution of sea trout females in weight classes, with consideration given to age and egg diameter, is presented in Fig. 7. Data presented in Tables 12, 13 and 14 suggest that share of females in particular years of the sea life within the two fish weight classes, and within the two egg standards, was very similar as in the case of female distribution according to the length.

Final calculations revealed that in the weight class ≥ 2.1. kg there were 48.0%, and in the weight class ≤ 2.0 kg – 52.0% of females (Table 12).

PROBLEMS OF FEMALE SELECTION BASED ON AGE

Analysis of the fish age related to the sea life appeared to be another factor allowing for pracitical selection of the females producing larger eggs. Distribution of females in sea life age classes, related to the classes of mean egg size and weight of mature and swollen eggs, is presented in Tables 15, 16 and 17. Materials summarized in Table 18 suggest that all females at the age of 4+ of the sea life produced eggs in the I standard. In the other age classes, the eggs produced belonged to both standards. In the age group 3+ 85.7% of the females produced eggs in the I standard, and 14.3% of females – in the II standard. At the age of 2+ most females produced eggs in the I standard, an at the age of 1+ – in the II standard.

Distribution of females in the egg standards was as follows:

in the age group 2+ eggs of the I standard were obtained from:
88.7% of females as regards egg diameter,
66.0% of females as regards weight of mature eggs,
79.2% of females as regards weight of swollen eggs;
while eggs in the II standard were obtained from:
11.3% of females as regards egg diameter,
34.0% of females as regards weight of mature eggs,
20.8% of females as regards weight of swollen eggs;
in the age group 1+ eggs of the I standard were obtained from:
42.5% of females as regards egg diameter,
25.0% of females as regards weight of mature eggs,
22.5% of females as regards weight of swollen eggs,
and in the II standard from:
57.5% of females as regards egg diameter,
75.0% of females as regards weight of mature eggs,
77.5% of females as regards weight of swollen eggs.

In view of these data it seems that females at the age of 4+, 3+ and 2+ should be used for reproduction. This group of females supplies eggs mostly in the I standard. When the

Table 12

Share of sea trout females in years of sea life and weight classes

Weight class in kg	≥ 2.1		≤ 2.0	
Years of life in the sea	indiv.	%	indiv.	%
1+	1	2.5	39	97.5
2+	40	75.5	13	24.5
3+	6	85.7	1	14.3
4+	2	100.0		
Total:	49	48.0	53	52.0

Table 13

Share of sea trout females in weight classes
and years of sea life

Weight class in kg	≥ 2.1		≤ 2.0	
Years of life in the sea	indiv.	%	indiv.	%
1+	1	2.0	39	73.6
2+	40	81.6	13	24.5
3+	6	12.3	1	1.9
4+	2	4.1		
Total:	49	100.0	53	100.0

Table 14

Occurence of sea trout females in years of sea life
depending on weight and diameter of swollen eggs
(indiv.)

Weight class in kg	≥ 2.1		≤ 2.0	
egg standard	I	II	I	II
	egg diameter in mm			
years of life in the sea	≥5.0	≤4.9	≥5.0	≤4.9
1+	1		16	23
2+	39	1	8	5
3+	6			1
4+	2			

Table 15

Occurence of sea trout females in years of sea life
and diameter of swollen eggs (indiv.)

egg diameter in mm	years of life in the sea				Commentes
	1+	2+	3+	4+	
4.3	2				
4.4	6				
4.5	2	1			
4.6	3				
4.7	1	2			
4.8	7	2			
4.9	2	1	1		mean diameter of swollen egg
5.0	5	4			
5.1	7	7	1		
5.2	3	20	1		
5.3	1	7			
5.4		8	2	1	
5.5	1	1	1	1	
5.6					
5.7			1		
Total:	40	53	7	2	

Table 16

Occurence of sea trout females in years of sea life
and weight classes of mature eggs (indiv.)

Weight class in kg	years of life in the sea				Commentes
	1+	2+	3+	4+	
45 – 49	8	1			
50 – 54	3				
55 – 59	5	1			
60 – 64	3	5			
65 – 69	11	5	1		
70 – 74	5	12			mean weight of mature egg
75 – 79	3	13	3		
80 – 84	1	11			
85 – 89		4	1		
90 – 94	1	1	1	2	
95 –100					
Total:	40	53	7	2	

Table 17

Occurence of sea trout females in years of sea life
and weight classes of swollen eggs (indiv.).

Weight class in mg	years of life in the sea				Commentes
	1+	2+	3+	4+	
45 – 49	1	1			
50 – 54	4				
55 – 59	6				
60 – 64	4				
65 – 69	7	3	1		
70 – 74	5	4			mean weight of
75 – 79	6	4			swollen egg
80 – 84	4	17			
85 – 89	2	13	2		
90 – 94		4	1		
95 – 99	1	6	2		
100 –104		1		2	
105 –109					
110–115			1		
Total:	40	53	7	2	

females were divided into two age groups: 1+ females, and separately 2+, 3+ and 4+, it appeared that in case of older females there were:

a. 88.7% of females with egg diameter in the I standard,
   11.3% of females with egg diameter in the II standard.
b. 69.4% of females with egg weight in the I standard,
   30.6% of females with egg weight in the II standard.
c. 80.6% of females with weight of swollen eggs in the I standard,
   19.4% of females with weight of swollen eggs in the II standard.

On the other hand, in the group of 1+ females there were:

a. 62.5% of females with egg diameter in the II standard,
   42.5% of females with egg diameter in the I standard.
b. 75.0% of females with egg weight in the II standard,
   25.0% of females with egg weight in the I standard.
c. 77.5% of females with weight of swollen eggs in the II stanard,
   22.5% of females with weight of swollen eggs in the I standard.

General percentage of females in the I egg standard (2+, 3+ and 4+ females) was 60.8%, and in the II egg standard – 39.2%.

It was also found that females in the same length class repeating spawning, possessed eggs of larger diameter and heavier than females spawning for the first time at the same or older age.

Table 18

Share of sea trout females in years of sea life and egg standards

Years of life in the sea	egg standard			
	I		II	
	indiv.	%	indiv.	%
a. depending on egg diameter				
1+	17	42.5	23	57.5
2+	47	88.7	6	11.3
3+	6	85.7	1	14.3
4+	2	100.0		
b. depending on weight of mature egg				
1+	10	25.0	30	75.0
2+	35	66.0	18	34.0
3+	6	85.7	1	14.3
4+	2	100.0		
c. depending on weight of swollen egg				
1+	9	22.5	31	77.5
2+	42	79.2	11	20.8
3+	6	85.7	1	14.3
4+	2	100.0		

Table 19

Share of sea trout females in age groups and egg standards

Years of life in the sea	egg standard			
	I		II	
	indiv.	%	indiv.	%
a. depending on egg diameter				
1+	17	42.5	23	62.5
2+, 3+, 4+	55	88.7	7	11.3
b. depending on weight of mature egg				
1+	10	25.0	30	75.0
2+, 3+, 4+	43	69.4	19	30.6
c. depending on weight of swollen egg				
1+	9	22.5	31	77.5
2+, 3+, 4+	50	80.6	12	19.4

CONCLUSIONS

The results showed statistically significant effect of length, weight and age of the sea trout females on weight and diameter of swollen eggs, and weight of mature eggs. Basing on the above statement, selection of larger eggs for reproduction can be made selecting the females according to their length, weight, or else – life span in the sea.

For practical purposes, sea trout eggs were divided into two size groups:

I standard – „large“ eggs, and II standard – „small" eggs.

Eggs in the I standard are produced by females $\geqslant$ 610 mm long (*l. caudalis*) or weighing $\geqslant$ 2.1 kg after stripping, or at the age of 2+, 3+ and 4+ years of sea life. Eggs in the II standard are produced by females $\leqslant$ 609 mm long, weighing $\leqslant$ 2.0 kg after stripping, or at the age of 1+ (sea life). Percentages of females in these length, weight and age classes in relation to egg size suggest that reproduction should be based on eggs in the I standard.

Analysis of the materials showed that the lowest percentage of females used for reproduction is the one based on weight (48.0%), higher – based on length (52.9%), and the highest (60.8%) – on age. The most selective method of classifying the females for reproduction is the determination of weight. However, in practice this method can lead to errors, resulting – for instance – from different degree of female stripping. On the other hand, selection of females based on age determination is the least selective and most labour-consuming method, so that is should not be used in practical breeding. Consequently, it seems that the most practical and feasible method of selecting the females for reproduction is the one based on fish length. The analysis of correlation revealed that:

– length of sea trout females can be used as a criterium for their selection,

– values of the dependent variables increase more rapidly along with an increase of female length and weight in case of younger fishes. At female length and weight close to the mean level this increase is insignificant, while in case of larger fishes it does not change any more,

– determination of an optimal range of female length and weight necessitates further studies and new statistical methods,

– limitation of the studies to one of the three dependent features discussed in this paper still allows for proper conclusions, while selection of the most appropriate egg feature to be used should be based on the possibilities of its easy measuring.

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WPŁYW WIELKOŚCI SAMIC TROCI (*Salmo trutta* L.) RZEKI REGI NA WIELKOŚĆ JAJ

STRESZCZENIE

Z większych jaj ryb łososiowatych z rodzaju Salmo i Oncorhynchus wykluwa się większy wylęg, a większy wylęg ma większą szansę przeżycia i wykazuje szybszy wzrost. Stąd selekcja samic na wielkość dojrzałych jaj staje się ważnym zabiegiem hodowlanym. Tymczasem odczuwamy brak szerszych informacji co do wpływu wielkości samic troci na wielkość jaj. To skłoniło autorów do podjęcia pracy, której celem było statystyczne określanie wpływu długości, masy i wieku samic troci pomorskiej rzeki Regi na średnicę i masę jaja napęczniałego i masę jaja dojrzałego. Badania oparto o analizę 110 sztuk dojrzałych samic w przedziale długości 42–79 cm. Badano zależność: długość (X_1) i masę samic (X_2) oraz średnicę jaja napęcznienia (Y_1), masę jaja dojrzałego wyciśniętego z jamy brzusznej (Y_2) i masę jaja po napęcznieniu (Y_3). Zależności między wyżej wymienionymi zmiennymi badano w trzech przedziałach wieku (1+); (2+) i (3+ i 4+) lat życia morskiego oraz dla ogólnej liczby osobników analizowanych. Ogółem badano 24 zależności. Oprócz modelu prostoliniowego

$Y = ax + b$ badano również modele nie liniowe: $Y = ba^x$; $Y = a \log x + b$; $Y = bx^a$; $Y = \frac{a}{x} + b$.

Przeprowadzone badania wykazały statystycznie istotny wpływ długości, masy oraz wieku badanych samic troci na masę i średnicę jaja napęczniałego oraz masę jaja dojrzałego.
Opierając się na powyższym stwierdzeniu, wyboru dużych jaj do reprodukcji można dokonać poprzez selekcję samic na długość, masę lub na podstawie określenia lat życia morskiego.
Dla praktyki hodowlanej wprowadzono podział jaj troci na dwie grupy wielkościowe: I-szy standard – „duże" jaja i II-gi standard – „małe" jaja.
Pierwszy standard dostarczą samice ⩾ 610 mm długości (*l. caudalis*) lub o masie ⩾ 2,1 kg po wytarciu lub w wieku 2+, 3+ i 4+ lat życia morskiego, a drugi standard dostarczą samice ⩽ 609 mm długości lub o masie ⩽ 2,0 kg po wytarciu lub w wieku 1+ lat życia morskiego. Udział samic w przyjętych klasach długości i masy oraz przyjętych grupach wieku i wielkości jaj jakie wystąpią w ich obrębie, uzasadniają celowość przeznczenia do reprodukcji jaj I standardu.
Jak z przedstawionych materiałów wynika, do reprodukcji przeznacza się najmniej samic na podstawie analizy masy (48,0%) więcej na podstawie długości (52,9%) a najwięcej na podstawie analizy wieku (60,8%). Stąd najbardziej selektywną metodą klasyfikacji samic do reprodukcji okazał się podział na podstawie określenia masy. Wydaje się jednak, że metoda ta obarczona może być w praktyce dużym błędem, wynikającym np. z różnego stopnia wytarcia samic.
Ze względu na to, że wybór samic do reprodukcji na podstawie analizy wieku okazał się metodą najmniej selektywną a ponadto stanowi on metodę najbardziej pracochłonną, stąd wydaje się, że w praktyce hodowlanej powinien być pominięty.
Najbardziej więc praktyczną metodą wyboru samic do reprodukcji okazała się metoda pomiaru długości ryb.
Przeprowadzona analiza korelacji pozwala na stwierdzenie, że:

- długość samic uznać można jako kryterium w pełni wystarczające do selekcji samic,
- wartości badanych cech zależnych rosną szybciej przy wzroście długości i masy samic mniejszych, natomiast w górę od wartości zbliżonych do średnich ulegają niewielkim przyrostom, a po przekroczeniu pewnego poziomu długości i masy w zasadzie nie podlegają zmianom,
- ustalenie optymalnego przedziału długości i masy samic wymaga dodatkowych badań i nowych metod statystycznych,

– ograniczenie badań cech zależnych od jednej z trzech cech badanych pozwala na wyciągnięcie prawidłowych wniosków, a wybór cechy może być podyktowany łatwością pomiaru.

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ВЛИЯНИЕ ВЕЛИЧИНЫ САМОК КУМЖИ (SALMO TRUTTA L.) ОБИТАЮЩЕЙ В РЕКЕ РЕГЕ НА РАЗМЕР ЯИЦ

Резюме

Из больших яиц лососевых рыб вида(Salmo и Oncorhynchus' вылупливаются большие личинки, а больщие личинки имеют больше шансов выжить и кроме этого быстрее растут. Поэтому селекция самок по критерию размеров зрелых яиц становится очень важным мероприятием при разведении рыб. В то же время ощущается нехватка более широкой информации относительно влияния величины самок кумжи на размеры яиц. Это побудило авторов разработать статистическое определение влияния длины, массы и возраста самок кумжи поморской реки Реги на диаметр и массу зрелого овулировавшего яйца из полости тела, а также на диаметр и массу после его набухания. Исследования основывались на анализе 110 особей зрелых самок длиной 42-79 см. Исследовали зависимость между длиной (X_1), массой самок (X_2) и диаметром набухшего яйца (Y_1), массой зрелого овулировавшего яйца, выдавленного из брюшной полости (Y_2) и массой набухшего яйуа (Y_3). Зависимости

между вышеуказанными переменными исследовали в трёх возрастных группах (1+); (2+); (3+ и 4+) морского периода жизни, а также для общего количества анализированных особей. В общей сложности исследовали 24 зависимости. Кроме модели прямой зависимости $У = ax + b$ исследовали также нелинейные модели: $Y=ba^x$; $Y=a \log x+b$; $Y=bx^a$; $Y= \frac{a}{x} + b$.

Проведённые исследования показали статистически существенное влияние длины, а также возраста подопытных самок кумжи на массу и диаметр набухшего яйца, и массу зрелого овулировавшего яйца.

Опираясь на вышеуказанное утверждение, выбор больших яиц для репродукции можно произвести путём селекции самок по длине, массе или на основе определения количества лет морской жизни. Для рыбоводческой практики яйца кумжи разделили по величине на две группы:

1-й стандарт - „большие яйца"
11-й стандарт - „малые яйца".

Первый стандарт получают от самок длиной (l.caudalis) $\geqslant$ 610 мм, массой $\geqslant$ 2,1 кг после нереста или в возрасте 2х, 3х, и 4х лет морской жизни. Второй стандарт получают от самок длиной $\leqslant$ 609 мм или массой $\leqslant$ 2,0 кг после нереста или в возрасте 1+ лет морской жизни. Для самок в принятых пределах длины и массы, а также в принятых возрастных группах и величине яиц, принятых в пределах этих групп, обосновывают целесообразность предназначения для репродукции яиц 1-го стандарта.

Из представленных материалов видно, что для репродукции направляется самое малое количество самок, отобранных по массе (48,0%), больше по длине (52,9%) и самое большое количество по возрасту (60,8%). Отсюда видно, что наиболее селективным методом классификации самок для репродукции оказался выбор на основе определения массы. Кажется, однако, что этот метод может на практике иметь большую погрешность, которая может вытекать, например, из различной степени отнерещивания самок.

Ввиду того, что отборт самок для репродукции по возрасту оказался самым малоселективным, кроме того, самым трудоёмким методом, то в рыбоводческой практике он не рекомендуется.

Наиболее практичным методом отбора самок для репродукции оказался метод определения длины рыб.

Проведённый анализ корреляции позволяет утверждать, что:

длину самок можно считать критерием вполне пригодным для селекции самок;

- значения исследуемых характеристик растут быстрее при росте длины и массы самок с меньшей длиной. У самок с длиной близкой к средней прирост исследуемых признаков небольшой. После достижения некоторого уровня длины и масса по существу не изменяются;

- определение оптимального диапазона длины и массы самок требует дополнительных исследований и применения новых статистических методов;

- ограничение исследований до одной характеристики из трёх позволяет сделать правильные выводы, а выбор этой характеристики может быть продиктован простотой замера.

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