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Fish biology

THE EFFECT OF THE SIZE OF SEA TROUT (*SALMO TRUTTA* L.) FEMALES FROM POMERANIAN RIVERS ON THE SIZE OF EGGS

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The aim of the work was to assess statistically the effect of length and weight of sea trout females from the rivers Rega, Parsęta, Wieprza and Grabowa on diameter and weight of swollen eggs.

INTRODUCTION

Studies by Chełkowski et al. (1985) revealed statistically significant effect of length, weight and age of sea trout (*Salmo trutta* L.) females from a Pomeranian River Rega on weight of mature eggs and diameter and weight of swollen eggs. Is there a similar relationship between the size of sea trout females grown in the Baltic Sea and entering other Pomeranian rivers: Parsęta, Wieprza and Grabowa, and the size of mature eggs? For comparison, studies on this problem embraced also data from the River Rega collected in the same years and months.

MATERIALS AND METHODS

Studies were made on sea trout migration upstream from the Baltic Sea to the rivers: Rega (fishes caught in Trzebiatów), Parsęta (caught in Rościno), Wieprza (caught in Darłowo) and Grabowa (caught in Jeżyczki) (Fig. 1). The sampling stations were 4 to 53 km distant from the sea. All localities were equiped with traps for catching alive fish (Tab. 1). Water reservoirs used to keep the fish until sexual maturity were available in all

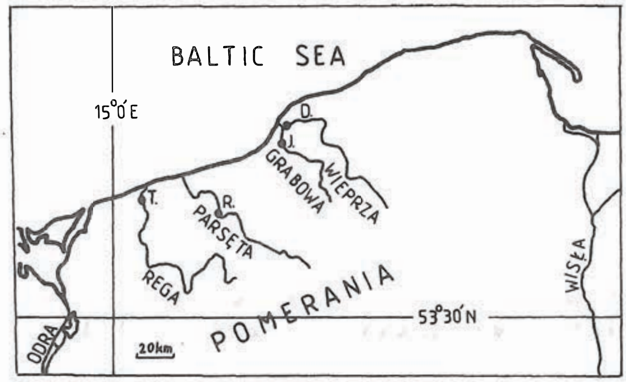

Fig. 1. Catchment areas of the rivers Rega, Parsęta. Grabowa and Wieprza, and sampling stations (T – Trzebiatów, R – Rościno, D – Darłowo, J – Jeżyczki)

Table 1

Number of sea trout females under study

River	Station	Year		Total
		1982	1983	
Rega	Trzebiatów	43	106	149
Parsęta	Rościno	39	34	73
Wieprza	Darłowo	34	39	73
Grabowa	Jeżyczki	39	38	77
Total				372

these localities. Sex products obtained from the fishes are used to enhance sea trout population. Fishes for studies were obtained from these reservoirs. They were collected in 1982 and 1983, in the second and third decade of November, i.e. when sea trout females attained sexual maturity. Studies on females and their eggs were based on the method presented by Chełkowski et al. (1985).

These authors revealed statistically significant effect of length, weight and age of sea trout females on weight of mature eggs, diameter of swollen eggs, and egg weight. Hence, it was concluded that the analyses of the dependence between female size and egg size of sea trout from other Pomeranian rivers may be limited to these features. Consequently, fish age and weight of mature eggs have been omitted, the more so that these two parameters are usually characterized by the highest methodical error. Measurements were made of caudal length (*l. caudalis*) of the females in mm (X_1), female weight after spawning with an occuracy up to 10 g (X_2), diameter of swollen eggs up to 1/100 mm (Y_1) and weight of swollen eggs up to 1/100 mg (Y_2). Females were collected randomly

Table 2

Number of sea trout females in length classes under study

Length class (cm)	Rega			Parsęta			Wieprza			Grabowa			To- tal
	1982	1983	total	1982	1983	total	1982	1983	total	1982	1983	total	
41										1		1	1
42													
43													
44										1		1	1
45	1		1	1		1					1	1	3
46		1	1										1
47				1		1					1	1	2
48		3	3	2		2		2	2	1	1	2	9
49		2	2	1		1		2	2		1	1	6
50	1	2	3	1		1		2	2	1	3	4	10
51		5	5	1		1		3	3	1	1	2	11
52	1	3	4	1		1	1	1	2	1	1	2	9
53	2	2	4	2	1	3	2	1	3	2		2	12
54		3	3	2	1	3	2	1	3	3		3	12
55	1	4	5	1	1	2	1	1	2		2	2	11
56	1	4	5	5		5		2	2		3	3	15
57	2	2	4	1	2	3	2		2	1	1	2	11
58	4	2	6	3		3		2	2	1	1	2	13
59	1	4	5					2	2	1	2	3	10
60	2	5	7	1	2	3	1	1	2		2	2	14
61	3	1	4	1	2	3	3		3	4		4	14
62	1	4	5	2	1	3	3		3	2		2	13
63	1	3	4		3	3	1	2	3	1	2	3	13
64	4	1	5	1	2	3		2	2	4		4	14
65		4	4	2	1	3	2		2	1	2	3	12
66	1	6	7	2	1	3	2		2		3	3	15
67	3	3	8		3	3	6		6	2	1	3	20
68		6	6	2	1	3	2		2	3		3	14
69	3	2	5	2	1	3	2	1	3	1	2	3	14
70	2	5	7	2	1	3	2	1	3	1	1	2	15
71		3	3		1	1		1	1	2		2	7
72	2	3	5		3	3	2	1	3		3	3	14
73	2	4	6		1	1		2	2	2	2	4	13
74	1	3	4	1	2	3		2	2	1	1	2	11
75		2	2		2	2		1	1	1		1	6
76		3	3		1	1							4
77	1	3	4	1		1		1	1				6
78	1	1	2					1	1				3
79		1	1		1	1		3	3				5
80		1	1										1
81	2	1	3					1	1				4
82											1	1	1
83													
84		1	1										1
85													
86													
87													
88													
89													
90													
91		1	1										1
Total	43	106	149	39	34	73	34	39	73	39	38	77	372

in the following numbers: 149 from Rega, 74 from Parsęta, 73 from Wieprza, 77 from Grabowa. Totally 372 fishes were collected (Tab. 1).

Chełkowski et al. (1985) estimated 5 types of regressions. Mathematical analyses of the data revealed that two of these were so similar to the others that they can be omitted. Hence, only three functions were used in this paper i.e.:

linear $y_i = ax_i + b$
power $y_i = bx_i^a$
quotient $y_i = \frac{a}{x_i} + b$

where: y_i the dependent variable,
x_i the independent variable.
a regression coefficient.
b regression constant.

Function fitting to the empirical data was determined using coefficients of determination and correlation. Significance of correlation and regression coefficients was verified with the Student's t test, at significance level of $\alpha = 0.05$ and $\alpha = 0.01$.

Rivers from which sea trout females were obtained were numbered as follows: Rega – I, Parsęta – II, Wieprza – III, Grabowa – IV. Sample of all fish was denotes as Z.

The dependencies under study were denoted:
X_1 with Y_1 as 1
X_1 with Y_2 as 2
X_2 with Y_1 as 3
X_2 with Y_2 as 4

Statistical calculations were performed on EMC-MERA-400 using BETA programme (Marszałkowicz 1972, Greń 1978).

GENERAL CHARACTERISTICS OF THE MATERIAL

Table 3

Length range of mature sea trout females (cm) in Pomeranian rivers

River	Present in the materials	Spawning population	Author
Rega	45–91	36–91	Chełkowski 1974
Parsęta	45–79	34–93	Chełkowski 1969
Wieprza	48–81		
Grabowa	41–91	49–92	Chełkowski 1969

Number of females collected from particular rivers in the length classes is presented in Table 2. This way it was possible to determine length range. It appeared that length ranges of the fishes were similar to the ranges observed for spawning sea trout populations in the rivers (Tab. 3).

Table 4 presents age of sea trout females from 4 Pomeranian rivers and years of river and sea life. Comparison with the data presented by Chełkowski (1969) revealed that

Table 4

Number and share trout females in age groups

Vears of life in river	In sea				Total	
	1=	2+	3+	4+	individuales	(%)
Rega						
1 2 3	5 37 11	11 59 13	1 10 2		17 106 26	11.4 71.1 17.5
total	53	83	13		149	
(%)	35.6	55.7	8.7			100.0
Parsęta						
1 2 3	3 15 13	5 28 5	 1 3		8 44 21	11.0 60.3 28.8
total	31	38	4		73	
(%)	42.5	52.0	5.5			100.0
Wieprza						
1 2 3	 19 7	3 31 7	 4 1	 1	3 54 16	4.11 73.97 21.92
total	26	41	5	1	73	
(%)	35.6	56.2	6.8	1.4		100.0
Grabowa						
1 2 3	4 21 7	9 30 5	 1		13 51 13	16.88 66.24 16.88
total	32	44	1		77	
(%)	41.6	57.1	1.3			100.0
Total					372	

percentages of sea and river life were similar for the same rivers. In view of this, it may be concluded that randomly selected females were representative for the spawning populations in the four rivers as regards fish length, age, and frequencies in particular 1 cm classes.

Table 5 presents frequencies of the basic parameters under study and their

Table 5

General characteristics of sea trout females and their eggs

Parameter	River	$\bar{x}$	S	Coefficient of variability (%)
Length (X_1)	Rega (I)	64.0	9.19	14.36
	Parsęta (II)	62.4	8.17	13.09
	Wieprza (III)	62.9	8.79	13.97
	Grabowa (IV)	61.2	8.71	14.23
	awerage (Z)	62.9	8.89	14.13
Weight (X_2)	Rega (I)	2300.7	1063.8	46.24
	Parsęta (II)	2109.7	838.9	39.76
	Wieprza (III)	2319.7	985.9	42.50
	Grabowa (IV)	2057.8	948.0	46.07
	average (Z)	2216.7	990.2	44.67
Swollen egg diameter (Y_1)	Rega (I)	5.225	0.327	6.27
	Parsęta (II)	5.100	0.319	6.26
	Wieprza (III)	5.149	0.285	5.54
	Grabowa (IV)	5.090	0.287	5.66
	average (Z)	5.157	0.315	6.12
Swollen egg weight (Y_2)	Rega (I)	79.363	14.481	18.25
	Parsęta (II)	74.118	13.600	18.35
	Wieprza (III)	73.788	11.258	15.26
	Grabowa (IV)	71.437	11.807	16.53
	average (Z)	75.599	13.578	17.96

coefficients. Analysis of the frequency distribution of these parameters (fish length and weight, egg diameter and weight) showed that we delt with normal or close to normal distributions.

Arithmetical means showed that:

1. Females from the Rega River were characterized by the highest parameters.
2. Females from the Grabowa River were characterized by the lowest parameters.

Differences between the four rivers were not siginificant statistically. Due to the lack of chronological order between egg diameter and fish length, differences in the first parameter could have been taken as non-existant.

Sea trout females did not differ much as to their length, this being confirmed by the lowest coefficient of variability in the whole sample.

Differences in fish weight were also small, but there was strict correlation between female length and weight. Differences of the mean fish lengths in particular rivers were not significant.

Diameters of swollen eggs did not differ, both in particular rivers and for the whole period of studies (V = 6.12%). Egg weight was more differentiated (V = 17.96%) but less than body wieght (V = 44.67%).

It should be underlined that the dependent variables (parameters/eggs) correlated more strictly with female length than weight, although there was a positive correlation between the variables and these two parameters.

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

Table 6 presents parameters of the three analysed functions: linear, power and quotient, which characterized dependencies between length and weight of sea trout females from four Pomeranian rivers and diameter and weight of swollen eggs.

Analysis of the distribution of the parameters under study and of the respective dependencies for fishes from the rivers Rega, Parsęta, Wieprza and Grabowa revealed that the differences were not significant statistically. In view of this, analyses were made for the whole material (n = 372).

It was found that the power function:

$$y_i = bx_i^a$$

in most cases described most accurately the relationships between the variables under study, and was characterized by the highest correlation coefficients.

The effect of female length (X_1) on egg diameter (Y_1) for the whole material was expressed by the function:

$$y_i = 1.37x_{li}^{0.32}, \quad R = 0.745$$

Table 6

Basic parameters of sea females and the relationships under study

No	River	Dependence	$\bar{x}$	S_x	V_x (%)	$\bar{y}$	S_y	V_y (%)	Regression	R	t	a	b
1.	I	X_1 a Y_1	64.0	9.19	14.36	5.225	0.327	6.27	$y=ax+b$	0.730	12.957	0.026	3.559
									$y=bx^a$	0.738	13.261	0.319	1.385
									$y=\frac{a}{x}+b$	0.733	13.068	–102. 543	6.861
2.	I	X_1 a Y_2	64.0	9.19	14.36	79.363	14.481	18.25	$y=ax+b$	0.745	13.562	1.174	6.197
									$y=bx^a$	0.753	13.890	0.950	1.511
									$y=\frac{a}{x}+b$	0.737	13.225	–4555.106	152.026
3.	I	X_2 a Y_1	2300.7	1063.8	46.24	5.225	0.327	6.27	$y=ax+b$	0.670	10.944	0.0002	4.750
									$y=bx^a$	0.711	12.286	0.098	2.466
									$y=\frac{a}{x}+b$	0.693	11.803	–899.903	5.706
4.	I	X_2 a Y_2	2300.7	1063.8	46.24	79.363	14.481	18.25	$y=ax+b$	0.701	11.933	0.0095	57.394
									$y=bx^a$	0.732	13.057	0.294	8.252
									$y=\frac{a}{x}+b$	0.693	11.664	–39513.3	100.48
5.	II	X_1 a Y_1	62.4	8.17	13.09	5.100	0.319	6.26	$y=ax+b$	0.798	11.193	0.0311	3.153
									$y=bx^a$	0.807	11.531	0.387	1.030
									$y=\frac{a}{x}+b$	0.815	11.867	–117.047	7.010
6.	II	X_1 a Y_2	62.4	8.17	13.09	74.118	13.600	13.35	$y=ax+b$	0.811	11.690	1.350	-10.138
									$y=bx^a$	0.808	11.557	1.185	0.546
									$y=\frac{a}{x}+b$	0.811	11.701	–4967.45	155.16
7.	II	X_2 a Y_1	2109.7	838.9	39.76	5.100	0.319	6.26	$y=ax+b$	0.734	9.128	0.0002	4.510
									$y=bx^a$	0.777	10.432	0.1209	2.036
									$y=\frac{a}{x}+b$	0.781	10.559	–1010.919	5.667
8.	II	X_2 a Y_2	2109.7	838.9	39.76	74.118	13.600	18.35	$y=ax+b$	0.757	9.771	0.012	48.216
									$y=bx^a$	0.772	10.258	0.367	4.497
									$y=\frac{a}{x}+b$	0.752	9.633	–41498.64	97.397
9.	III	X_1 a Y_1	62.9	8.79	13.97	5.149	0.285	5.54	$y=ax+b$	0.748	9.515	0.024	3.619
									$y=bx^a$	0.751	9.597	0.297	1.505
									$y=\frac{a}{x}+b$	0.750	9.554	–93.0007	6.656

cd. tabl. 6

No.	River	Dependence	$\bar{X}$	S_x	V_x (%)	$\bar{V}$	S_y	V_y (%)	Regression	R	t	a	b
10	III	X_1 a Y_2	62.9	8.79	13.97	73.788	11.258	15.26	$y=ax+b$	0.762	9.938	0.976	12.335
									$y=bx^a$	0.738	9.221	0.820	2.451
									$y=\frac{a}{x}+b$	0.743	–9.363	–3634.07	132.693
11.	III	X_2 a Y_1	2319.7	985.9	42.50	5.149	0.285	5.54	$y=ax+b$	0.749	9.536	0.0002	4.646
									$y=bx^a$	0.762	9.927	0.0964	2.457
									$y=\frac{a}{x}+b$	0.732	9.061	–872.5	5.60
12.	III	X_2 a Y_2	2319.7	985.9	42.50	73.788	11.258	15.26	$y=ax+b$	0.805	11.430	0.0092	52.467
									$y=bx^a$	0.768	10.103	0.273	9.010
									$y=\frac{a}{x}+b$	0.720	8.746	–33827.4	91.450
13	IV	X_1 a Y_1	61.2	8.71	14.23	5.090	0.287	5.66	$y=ax+b$	0.694	8.351	0.022	3.686
									$y=bx^a$	0.690	8.276	0.270	1.677
									$y=\frac{a}{x}+b$	0.683	8.112	–77.919	6.390
14.	IV	X_1 a Y_2	61.2	8.71	14.23	71.437	11.807	16.53	$y=ax+b$	0.686	8.177	0.930	14.488
									$y=bx^a$	0.686	8.170	0.775	2.926
									$y=\frac{a}{x}+b$	0.665	7.721	–3111.193	123.36
15.	IV	X_2 a Y_1	2057.8	948.0	46.07	5.090	0.287	5.65	$y=ax+b$	0.690	8.255	0.0002	4.658
									$y=bx^a$	0.699	8.468	0.840	2.701
									$y=\frac{a}{x}+b$	0.667	7.754	–617.9	5.466
16.	IV	X_2 a Y_2	2057.8	948.0	46.07	71.437	11.807	16.53	$y=ax+b$	0.710	8.751	0.008	53.219
									$y=bx^a$	0.708	8.698	0.246	11.678
									$y=\frac{a}{x}+b$	0.654	7.500	–24872.7	86.576
17	Z	X_1 a Y_1	62.9	8.89	14.13	5.157	0.315	6.12	$y=ax+b$	0.741	21.237	0.026	3.502
									$y=bx^a$	0.745	21.481	0.320	1.370
									$y=\frac{a}{x}+b$	0.740	21.208	–98.742	6.760
18.	Z.	X_1 a Y_2	62.0	8.89	14.13	75.599	13.578	17.96	$y=ax+b$	0.746	21.621	1.141	3.798
									$y=bx^a$	0.746	21.546	0.947	1.484
									$y=\frac{a}{x}+b$	0.732	20.707	–4201.862	143.779
19.	Z	X_2 a Y_1	2216.7	990.2	44.67	5.157	0.315	6.12	$y=ax+b$	0.698	18.740	0.00022	4.665
									$y=bx^a$	0.728	20.399	0.0992	2.421
									$y=\frac{a}{x}+b$	0.705	19.097	–840.22	5.622
20.	Z	X_2 a Y_2	2216.7	990.7	44.67	75.599	13.578	17.96	$y=ax+b$	0.720	19.963	0.0099	53.711
									$y=bx^a$	0.732	20.688	0.296	7.904
									$y=\frac{a}{x}+b$	0.684	18.110	–35169.2	95.05

R – correlation coefficiens; t – test of significance for correlation coefficient; a – regression coefficient; b – regression constant

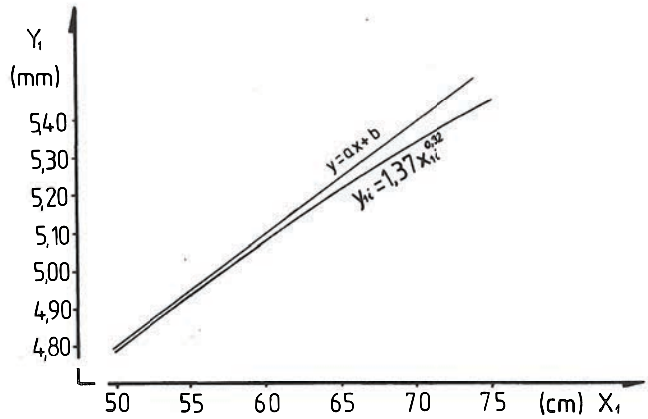

Fig. 2. Dependence of swollen egg diameter (Y_1) on female length (X_1).
Note: Figs 2, 3, 4 and 5 present also straight line regression to expose curvilinearity of the dependence.

High correlation coefficient proves that the regression line fits well the empirical data. Graph of this function is presented in Fig. 2. Parameters of the regression reveal that the function is characterized by decreasing marginal increments. And thus, fish length increase by 1 cm correlates with bigger egg diameter:

– at fish length of 50 cm by about 0.031 mm.

– at fish length of 70 cm by about 0.024 mm.

Similar relationship was found for particular rivers. Marginal increments were higher by about 13% only in river II.

The effect of female length (X_1) on egg weight (Y_2) for the whole material was expressed by a powe function (Fig. 3) very similar to straight line:

$$y_{2i} = 1.484\, x_{1i}^{0.947}, \quad R = 0.746$$

The dependence is very highly significant, similarly as straight line. In view of this, linear function can be used in practice:

$$y_{2i} = 1.141\, x_{1i} + 3.798, \quad R = 0.746$$

Hence, within the length range of $< 50, 80 >$, and increase of female length by 1 cm results in an increase of egg weight by 1.141 mg on the average.

Some differences were found in particular rivers. They were, however, within the limits of standard error.

The effect of body weight (X_2) on diameter of swollen egg (Y_1) for the whole material was expressed best by a power function (Fig. 4):

$$y_{1i} = 2.421\, x_{2i}^{0.099}, \quad R = 0.728$$

The dependence is statistically significant at the level $\alpha = 0.01$. This dependence was non-linear also for particular rivers. Marginal increments decreased with growing fish weight, being:

– at fish weight 1000 g about 0.00044 mm

– at fish weight 3000 g about 0.00017 mm.

Detailed analysis showed that when fish weight increased to over 2.5 kg, there was no further effect on egg diameter, or that this effect was insignificant.

The effect of female weight (X_2) on egg weight (Y_2) was nonlinear. The regression curve for the whole material is presented in Fig. 5. Its mathematical form is:

$$y_{2i} = 7.904\, x_{2i}^{0.295}, \quad R = 0.732$$

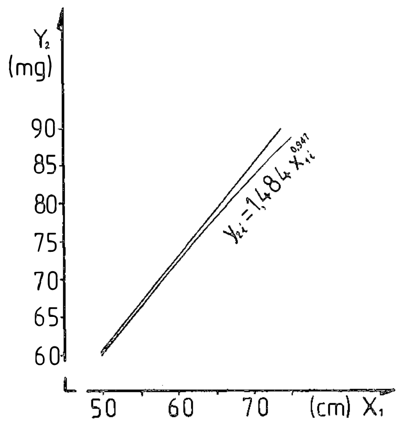

Fig. 3. Dependence of swollen egg weight (Y_2) on female length (X_1)

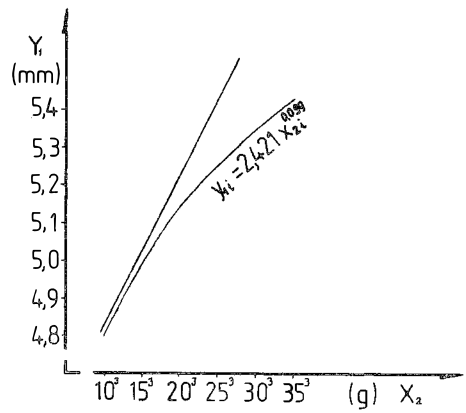

Fig. 4. Dependence of swollen egg diameter (Y_1) on female weight (X_2)

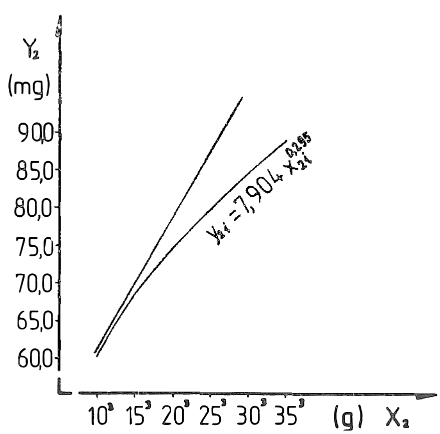

Fig. 5. Dependence of swollen egg weight (Y_2 on female weight (X_2).

In river IV this dependence was best described by a linear function. The differences, however, were very small, so power functions were used in all cases. Average fish weight in river IV was the highest, amounting to 2.3 kg. As mentione earlier, an increase of fish weight to over 2.5 kg did not affect egg diameter and, thus, also egg weight.

The dependence between female weight and egg weight was very highly significant. Egg weight increased with fish weight, but marginal increments decreased reaching:

about 0.018 mg at female weight 1000 g
about 0.008 mg at female weight 3000 g

CONCLUSIONS

1. It was found that weight and length of sea trout females from the rivers Rega, Parsęta, Wieprza and Grabowa correlated positively with diatemer and weight of swollen eggs.

2. The dependencies between these parameters were non-linear. Power function ($y_i = bx_i^a$) appeared to give the best fit.

3. Variability of the diameter and weight of swollen sea trout eggs in the four Pomeranian rivers was explained better by female length than weight. Fish length appeared to be a sufficient criterium for selecting the females producing eggs of desired size.

4. Analysis of correlation and regression based on the materials from the four rivers, in this from the Rega River for the period 1982–1983, confirmed earlier conslusion of Chełkowski et al. (1985) that female length and weight significantly affected weight and diameter of swollen sea trout eggs. This conclusion was formerly based only on the materials from the Rega River collected in 1980 and 1981.

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WPŁYW WIELKOŚCI SAMIC TROCI (*Salmo trutta* L.)
RZEK POMORSKICH NA WIELKOŚĆ JAJ

STRESZCZENIE

Przedmiotem pracy było statystyczne określenie wpływu długości i masy samic troci z Regi, Parsęty, Wieprzy i Grabowej na średnicę i masę jaja napęczniałego. Materiał do badań został pobrany w II i III dekadzie listopada 1982 i 1983 r. od w pełni dojrzałych 372 ryb, w zakresie długości 41–91 cm. Jak wynika z opracowanych materiałów, wzrost długości i masy samic troci z czterech wymienionych rzek jest dodatnio skorelowany z wzrostem średnicy i masy jaja napęczniałego. Kształt zależności badanych cech ma charakter nieliniowy, a najlepiej opisującą tę zależność okazała się funkcja potęgowa ($y_i = bx_i^a$). Z analizy dwóch cech, długości i masy samic troci z czterech rzek pomorskich, cechą lepiej opisującą zmienność średnicy i masy jaja napęczniałego okazuje się długość. Stanowi ona dostateczne kryterium selekcji samic zapewniające otrzymanie jaj o wymaganych parametrach.

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