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RELATION BETWEEN VISTULA SEA TROUT (*Salmo trutta* L.) EGG SIZE AND SIZE OF FEMALES

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A B S T R A C T. Body length and mass of 2031 Vistula sea trout females, the two diameters of their eggs, and volume of 30 eggs were measured in 1969-1994. The results indicate that one diameter only is sufficient for determining egg size of the species, and that measurement of egg volume may be used instead of egg diameter. Size variability of the Vistula sea trout eggs obtained from one female is small, and egg size depends on the size of the female. The study revealed also that eggs were slightly ellipsoidal, their shape was little variable, and did not depend on the size of females. Vistula sea trout populations in particular years of the study did not vary with respect to egg size.

Key words: MIGRATORY FISH, SEA TROUT, SIZE OF EGGS

INTRODUCTION

Measurements of animals, and in the case of fish also of their eggs, are indispensable for acknowledging their biology, and very helpful for a variety of purposes.

Reliability and comparability of the measurements depend to a large extent on the method applied. Thus, various methods of determining the fish egg size were developed by many authors. Extensive information on this issue in rainbow trout has been reviewed by Bartel (1971a, b). The author concludes that variability of size of the eggs obtained from one female was very small, and the difference between egg diameters (longer and shorter one) was statistically significant. The egg diameters did not correlate with each other, thus it was necessary to calculate the mean value (from the maximum and the minimum egg diameter) of 10 eggs from each female to evaluate the egg size.

There are many data on the factors determining egg size. It is an important issue since egg size affects individual body length and mass, and development of the larvae (Svardson 1949, Dyk et al. 1949, Juszczyk 1951, Sadov 1963, McFadden et al. 1965). Moreover, fry hatched from larger eggs shows almost three fold higher survival than those hatched from smaller ones (Domagała, Trzebiatowski 1987). Still, however, there is no agreement among the authors what factors, and in what degree, affect egg size in particular fish species.

A relationship between egg size and size of females was observed in lake trout (*Salmo trutta m. lacustris* L.) by Sakowicz (1961) and Szczerbowski (1966), in sea trout (*Salmo trutta* L.), but not in the Vistula population, by Farid Pak (1968) and Chełkowski et al. (1985, 1990), and in brown trout (*Salmo trutta m. fario* L.) by Pekarkova (1956). According to Juszczyk (1951), larger females of sea trout from Dunajec River and Rożnowski Reservoir produced usually larger eggs, this, however, was not a rule. On the other hand, Bartel (1971b) and Sklower (1930) did not observe any relationship between egg and female size in rainbow and brown trout. According to these authors, egg size was related to the age of females. Thus, various data suggest that some regularities observed for one species are not always true for another, and variations within one species may also occur.

Relationship between egg and female size in the Vistula sea trout was studied by Bartel and Parlińska (1995), and earlier by Skrochowska (1953). Observations of the latter, however, concerned pond reared fish, and included measurement of eggs from three, four, and five years old F2 females, and from eleven and twelve years old F1 ones. The relationship between egg size and body length and mass of the females was determined from the number of eggs in 10 g samples taken from two 12 years old females of different body length (30.3 cm, and 37 cm) and mass (283.0 g and 535.0 g). The data were not analysed statistically. Thus, despite some data on the relationship between egg size and size of females of various fish species, detailed data for the Vistula sea trout are still lacking.

The aim of the present paper was to assess the variability of size and shape of the Vistula sea trout (*Salmo trutta* L.) eggs, and the relationship between egg size and size of the females. It also seemed interesting whether one diameter measurement would suffice to evaluate egg size, instead of both diameters, and whether calculation of the volume of 30 eggs could replace very troublesome measurements of egg diameters.

MATERIAL AND METHODS

Sexually mature Vistula sea trout (*Salmo trutta* L.) females entering the river to spawn, and their eggs, were used in the study. The eggs were obtained in autumn in Świbno Spawning Station in 1969, 1972-78, 1983, 1985, 1987, and 1990-1994.

Number of fish analysed in particular years varied from 53 individuals in 1977 to

TABLE I

Characteristics of the Vistula sea trout (*Salmo trutta* L.) females under study

Year	n	Longitudo totalis (cm)				Body weight (kg)			
		range	X	SD	V%	range	X	SD	V%
1969	278	54.5-78.0	65.7	5.5	8.3	1.6-4.4	3.4	1.2	34.6
1972	206	48.0-83.5	64.2	6.8	10.4	1.6-4.5	2.7	0.9	32.2
1973	286	52.5-77.0	65.5	6.9	10.7	1.9-4.7	3.3	1.0	30.8
1974	211	55.0-90.0	66.3	7.1	10.7	1.5-4.7	3.0	0.9	29.8
1975	79	43.5-89.5	66.8	4.9	7.3	1.3-4.4	2.9	0.7	26.0
1976	129	48.5-92.0	69.6	5.5	8.0	1.7-4.6	3.1	0.7	22.9
1977	53	41.5-87.5	61.2	5.6	9.2	1.8-4.5	2.1	0.5	24.9
1978	61	40.0-91.5	65.2	6.6	10.1	1.2-4.5	2.6	1.0	35.7
1983	100	57.0-78.0	70.5	5.6	8.0				
1985	100	54.5-84.5	66.6	5.7	8.6				
1987	100	56.5-83.0	64.1	5.5	8.6				
1990	100	52.5-81.5	71.8	5.7	8.0				
1991	64	57.0-79.0	72.0	6.2	8.6				
1992	80	55.5-82.0	76.0	4.8	6.3				
1893	94	56.5-84.0	72.2	9.8	13.5				
1994	100	52.0-79.5	72.5	5.8	8.0				

n - number, X - average, SD - standard deviation, V - variability coefficient

286 in 1973. Totally 2031 females were studied (Tab. I).

MEASUREMENT OF FISH

The fish were weighed (only in 1969 and in 1973-1978) before and after spawning, with 0.01 kg accuracy, and measured (total length – *longitudo totalis*: from the snout tip to the end of the longest caudal fin ray), with 0.5 cm accuracy.

MEASUREMENT OF EGGS

The eggs were collected during artificial spawning and measured using Zeiss micrometric microscope with 0.01 mm accuracy. The measurements were carried out when egg swelling was complete – after 1 h from the first contact with water (Zotin 1955, 1961, Winnicki, Bartel 1967, Winnicki 1968).

In 1969 and 1972-1978, 10 randomly selected eggs from each female were measured. In each egg two diameters were evaluated: maximum and minimum one, mean diameter was calculated, and the mean values of the two egg diameters for each female.

In 1983, 1985, 1987, and 1990-1994 the procedure was similar, but volume of 30 eggs was also calculated measuring the volume of water forced out by the eggs from a calibrated burette.

Based on the measurements, the following relations were analysed:

1. between maximum and minimum egg diameter
2. between egg diameter and body length of a female
3. between egg diameter and body mass of a female
4. between volume of 30 eggs and average diameter of 1 egg
5. between egg volume and body length of a female.

For the relationships between egg diameter and the independent variables (length and mass of females), mean egg diameter values were used, calculated from 2 diameters of 10 eggs.

6. Ratio of maximum to minimum egg diameter (egg shape) for individual eggs, the mean ratio value, and standard deviation (SD) for each of 191 randomly selected females, divided into 3 groups, based on their body length:

group I	50-60 cm
group II	61-70 cm
group III	71-80 cm.

7. Variability of egg size of individual females (sample of 40 randomly selected individuals of 1969, and 1972-1978; 61, 62, 65, 67, and 70 cm of length). The mean egg diameter was calculated (maximum, minimum and average) for each female, as well as standard deviation (SD) and variability coefficients (V).
8. Differences of egg size among sea trout populations over the study period were analysed statistically.

STATISTICAL ANALYSIS

Correlation coefficient was calculated, according to the formula:

$$r = \frac{cov(x, y)}{s(x)s(y)}$$

where: cov(x,y) – arithmetical mean of the product of deviations of x and y variables from their arithmetical means,

s(x) – standard deviation of x variable

s(y) – standard deviation of y variable.

Linear regression coefficient was calculated according to the equation:

$$y = a + bx$$

where: a – free parameter of the regression

b – regression coefficient

y – dependent variable (egg diameter or volume)

x – independent variable (total length or body mass of female)

Confidence levels P=0.05 or P=0.01 were assumed (Elandt 1964, Marszałkowicz 1972, Sobczyk 1994).

Calculations were performed using a computer program "Correlation and regression" developed in the Centre of Electronic Computational Techniques at Agricultural Academy in Cracow.

The results are shown in the tables and illustrated in graphs. Significance of differences of egg size among the sea trout populations was tested using one-way ANOVA and Duncan's test.

RESULTS

1. RELATIONSHIP BETWEEN MAXIMUM AND MINIMUM EGG DIAMETER

The correlation between egg diameters was highly significant ($p<0.01$). Correlation coefficient (r) for all year-classes for which the relationship was calculated exceeded 0.9 (Fig. 1).

Relationship between egg diameter and body length (longitudo totalis) of females.

Statistically significant relationships between these parameters were found for all year-classes: at $p<0.01$ for 1969, 1972, 1976, and 1978 year classes, and at $p<0.05$ for 1977.

Correlation coefficients (r) ranged from 0.340 (1977) to 0.626 (1972), and regression coefficient (b) from 0.012 (1977) to 0.030 (1978) (Fig. 2).

2. RELATIONSHIP BETWEEN EGG DIAMETER AND BODY MASS OF FEMALES

In all year-classes (1969, 1972-1978), the relationship was positive and highly significant ($p<0.01$). Correlation coefficients (r) ranged from 0.373 (1975) to 0.667 (1978), and regression coefficients (b) from 0.128 (1975) to 0.244 (1978) (Fig. 3).

3. RELATIONSHIP BETWEEN EGG SIZE AND VOLUME

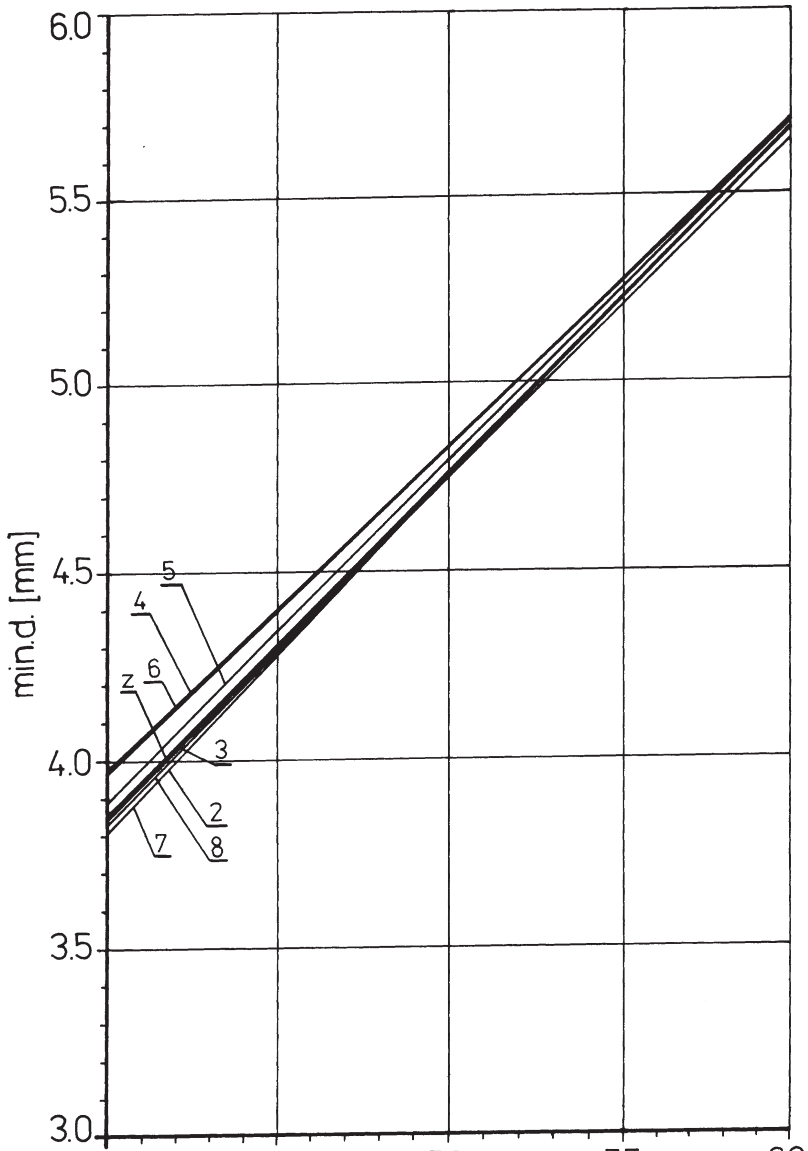

Fig. 1. Relationship between maximum and minimum egg diameter of the Vistula sea trout (*Salmo trutta* L.). 1 - 1969 (y=0.291+0.893x), 2 - 1972 (y=0.142+0.922x), 3 - 1973 (y=0.166+0.92x), 4 - 1974 (y=0.596+ 0.845x), 5 - 1975 (y=0.28+0.902x), 6 - 1976 (y=0.528+0.859x), 7 - 1977 (y=0.052+0.9339x), 8 - 1978 (y=0.058 +0.941x). [min.d. - minimum diameter, max.d. - maximum diameter]

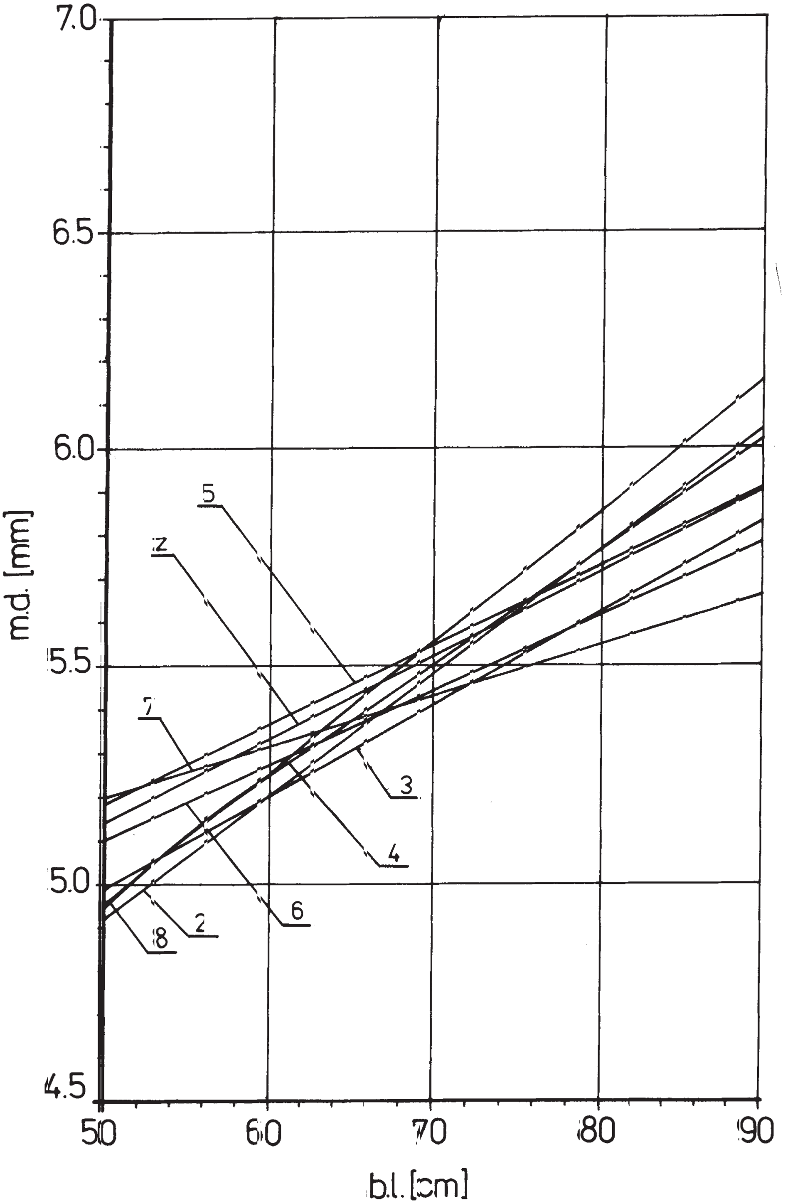

Fig. 2. Relationship between egg diameter and body length of females of Vistula sea trout (*Salmo trutta* L.). 1 - 1969 (y=4.193+0.019x), 2 - 1972 (y=3.5238+0.028x), 3 - 1973 (y=3.942+0.021x), 4 - 1974 (y=3.682+ 0.026x), 5 - 1975 (y=4.286+0.018x), 6 - 1976 (y=4.254+0.017x), 7 - 1977 (y=4.625+0.012x), 8 - 1978 (y=3.45 +0.03x). [b.l. - body length, m.d. - mean diameter of eggs]

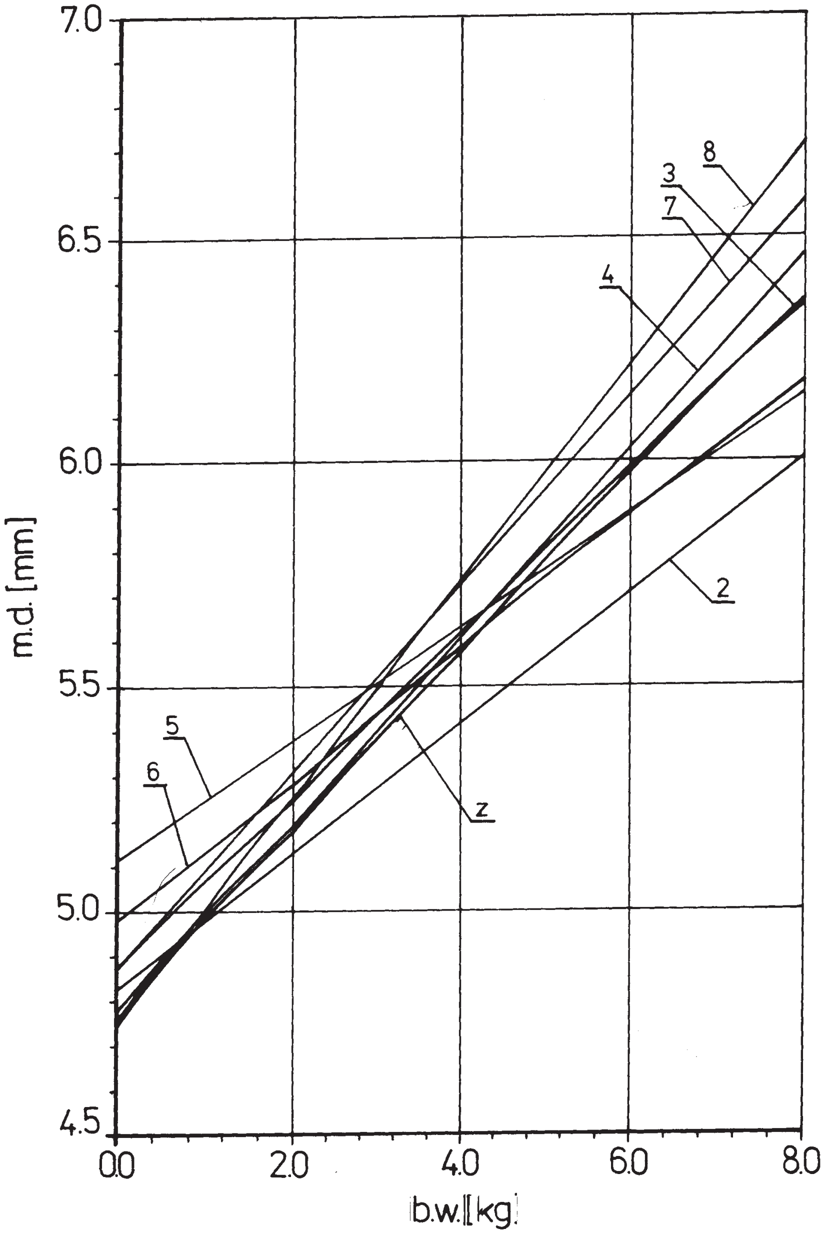

Fig. 3. Relationship between egg diameter and body mass of females of Vistula sea trout (*Salmo trutta* L.).
1 - 1969 (y=4.88+0.184x), 2 - 1972 (y=4.829+0.147x), 3 - 1973 (y=4.783+0.198x), 4 - 1974 (y=4.764+ 0.212x), 5 - 1975 (y=5.12+0.128x), 6 - 1976 (y=4.983+0.149x), 7 - 1977 (y=4.882+0.212x), 8 - 1978 (y=4.76 +0.244x). [b.w. - body weight, m.d. - mean diameter of eggs]

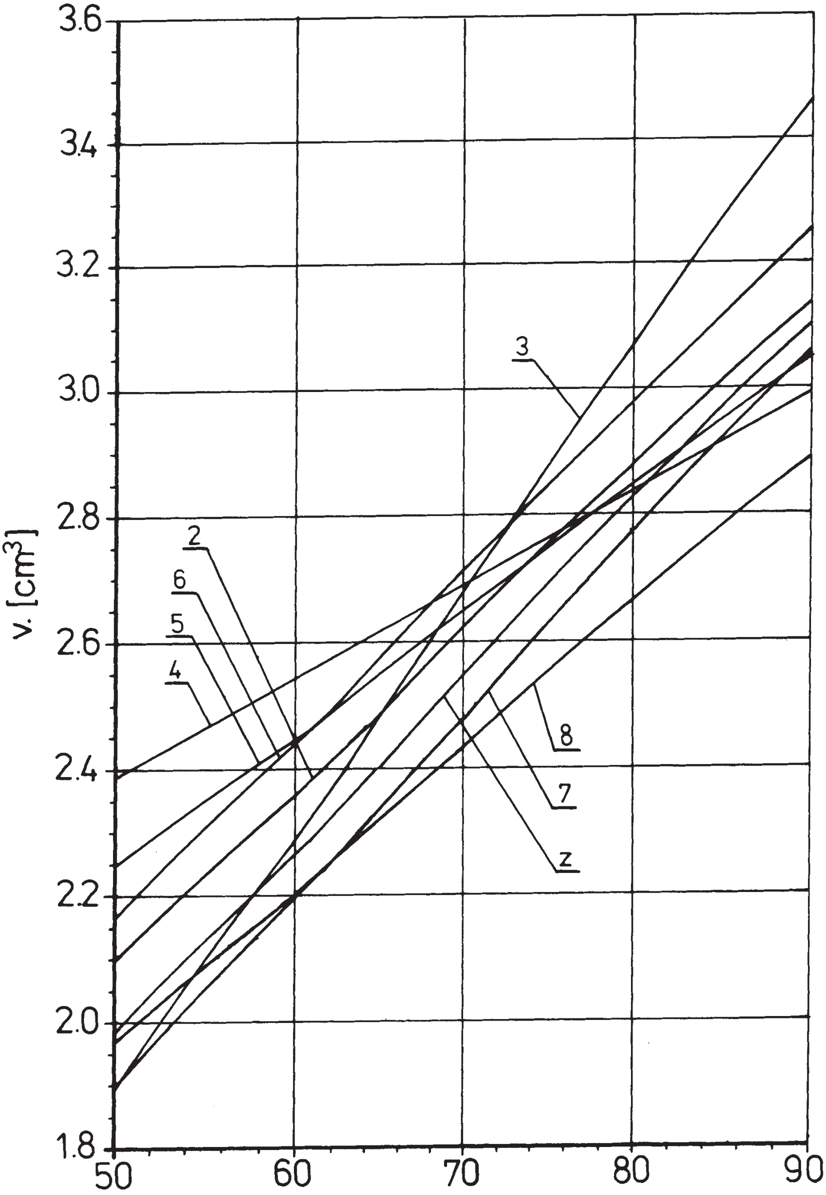

Fig. 4. Relationship between the volume of 30 eggs and body length of females of Vistula sea trout (*Salmo trutta* L.). 1 - 1983 (y=0.587+0.028x), 2 - 1985 (y=0.8+0.026x), 3 - 1987 (y=0.052+0.039x), 4 - 1990 (y=1.64+ 0.015x), 5 - 1991 (y=1.249+0.02x), 6 - 1992 (y=0.819+0.027x), 7 - 1993 (y=0.452+0.029x), 8 - 1978 (y=0824 +0.023x). [b.l. - body length, v. - volume of 30 eggs]

For all year-classes for which the egg volume was calculated (1983, 1985, 1987, 1990-1994), highly significant positive correlation between volume of 30 eggs and the mean egg diameter was found. Correlation coefficient (r) exceeded 0.8.

4. RELATIONSHIP BETWEEN EGG VOLUME AND BODY LENGTH OF FEMALES

Correlation between volume of 30 eggs and body length of females was positive and highly significant ($p<0.01$) in all year-classes (see above). Correlation coefficients (r) ranged from 0.376 (1992) to 0.688 (1993), and regression coefficients (b) from 0.015 (1990) to 0.039 (1987) (Fig. 4).

5. EGG SHAPE

Maximum egg diameter was equal to 103.04-109.02% of the minimum egg diameter. Ratio of maximum to minimum egg diameter was not related to body length of the females (Tab. II). Correlation coefficient (r) for this ratio and body length of the females was not significant.

6. SIZE VARIABILITY OF EGGS FROM ONE FEMALE

TABLE 2

Shape of the eggs of the Vistula sea trout (*Salmo trutta* L.) – maximum diameter length in fish of various length classes expressed as percent of the minimum diameter

Females		
length (cm)	n	d1/d2 (%)
50 - 60	54	103,1 - 109,0
61 - 70	78	103,0 - 108,6
71 - 80	59	103,2 - 108,8
Total	191	103,0- 109,0

Size of eggs of one female varied very little. The mean length of maximum diameter calculated for all females (n=40) ranged from 5.296 mm to 5.780 mm, with variability coefficient (V) ranging from 1.96% to 7.14%. The results for the other diameters were similar:

minimum (5.041-5.476 mm, V: 1.44%-6.08%),

mean (5.168-5.628 mm, V: 1.65%-6.49%).

Variability coefficients (V) were not related to body length of the females for either of the diameters (Tab. III).

TABLE 3

Range of average length of egg diameters, standard deviations, and variability coefficients for the sample of the Vistula sea trout (*Salmo trutta* L.)

Females		Diameter of eggs (mm)								
length (cm)	n	X	SD	V(%)	X	SD	V(%)	X	SD	V(%)
61	8	5,3 - 5,5	1,2 - 0,3	3,1 - 5,3	5,0 - 5,3	0,1 - 0,2	1,7 - 5,0	5,2 - 5,4	0,1 - 0,3	2,3 - 5,0
62	8	5,3 - 5,6	0,1 - 0,2	2,0 - 5,2	5,0 - 5,3	0,1 - 0,3	1,4 - 6,0	5,2 - 5,4	0,1 - 0,3	1,7 - 5,0
65	8	5,4 - 5,6	0,2 - 0,3	2,7 - 5,3	5,1 - 5,3	0,2 - 0,3	3,1 - 5,3	5,3 - 5,4	0,2 - 0,3	2,8 - 5,3
67	8	5,3 - 5,6	0,2 - 0,4	3,2 - 7,1	5,1 - 5,4	0,2 - 0,3	3,3 - 6,1	5,2 - 5,6	0,2 - 0,4	3,2 - 6,5
70	8	5,6 - 5,8	0,1 - 0,3	3,3 - 5,2	5,3 - 5,5	0,1 - 0,3	1,6 - 5,2	5,4 - 5,6	0,1 - 0,3	1,8 - 5,1

7. NO STATISTICALLY SIGNIFICANT DIFFERENCES IN EGG SIZE WERE FOUND AMONG THE VISTULA SEA TROUT POPULATIONS IN ALL YEARS OF THE STUDY

DISCUSSION

Statistically significant correlation between maximum and minimum egg diameter indicates that in the Vistula sea trout it is sufficient to measure one diameter only (minimum or maximum one) to get a reliable evaluation of the egg size.

Analysis of the material collected in the eighties revealed that egg volume of the Vistula sea trout was significantly related (with correlation coefficient over 0.8) to both egg diameters. Thus, measurement of the volume of 30 eggs may replace measurements of egg diameter.

Variability of size of the eggs collected from one sea trout female was small, similar as in rainbow trout (Bartel 1971b). Also variability of trout egg size in various years of the study was similar, and the differences among populations were not significant.

The shape of swollen eggs was ellipsoidal, similarly as in many other fish, also salmonids, (Schaperclaus 1940, Skrochowska 1953, Kraj & Włoszczyński 1957, Goryczko 1960, Winnicki & Bartel 1967, Hardy 1967, Bartel 1971a). Ratio of maximum to minimum diameter (maximum diameter was equal to 103.04%-109.02% of the minimum one), and the relationship between them indicate that shape of the Vistula sea trout eggs is highly stable. No globular or flattened eggs were observed. Thus, shape of these eggs is less variable than in rainbow trout (Bartel 1971a). It is also not related to fish size, contrary to the brook trout (*Salvelinus fontinalis* M.) eggs (Dlaboga 1996).

In all year-classes, egg size (diameters and volume) was related to the size of females (body length and mass). Age of females, however, was not analysed in the present study. Regression coefficients show that with the increase of fish body length by 1 cm, volume of 30 eggs increased on the average by 0.017 cm^3, and their diameter – by 0.025 mm. With the increase of body mass by 1 kg, egg diameter increased by 0.18 mm. This confirms the results by Skrochowska (1953), and Bartel & Parlińska (1995). Similar results were obtained also for sea trout populations of different Pomeranian rivers (Chełkowski et al. 1985, 1990, Bartel, Parlińska 1995), and for lake trout (Sakowicz 1961, Szczerbowski 1967). Thus, it may be assumed that egg size is related to the size of females in all migratory populations of the species *Salmo trutta* L.

CONCLUSIONS

1. Measurement of one diameter only is sufficient to evaluate the Vistula sea trout egg size. Diameter measurements may also be replaced by the evaluation of egg volume.
2. Variability of size of the Vistula sea trout eggs obtained from one female, and from various females of one population, was small. Variability coefficient did not exceed 7.14%.
3. Sea trout eggs obtained from the females harvested in particular years did not differ in size.
4. Sea trout egg shape is ellipsoidal, slightly variable, and does not depend on the fish size.
5. Statistically highly significant positive relationship between body length and mass of females, and size of their eggs (diameter and volume), was found in the Vistula sea trout.

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STRESZCZENIE

ZALEŻNOŚĆ ROZMIARÓW IKRY TROCI WIŚLANEJ (*Salmo trutta* L.) OD WIELKOŚCI SAMIC

Na podstawie pomiarów (długość i masa ciała) 2031 samic troci wiślanej oraz pomiarów 2 średnic (maksymalnej i minimalnej) otrzymanej od nich ikry zbadano następujące zależności: 1 - pomiędzy obu średnicami ikry, 2 - średnicą ikry a długością ciała samicy (longitudo totalis), 3 - średnicą ikry a masą ciała samicy, 4 - średnicą ikry a jej objętością, 5 - objętością ikry a długością ciała samicy. Prócz tego zbadano stosunek średnicy maksymalnej do minimalnej, zmienność rozmiarów ikry poszczególnych samic oraz porównano rozmiary ikry samic wycieranych w poszczególnych latach badań.

Materiał do badań zebrano w bazie tarlakowej w Świbnie w latach 1969,1972-1978 oraz 1983,1985,1987,1990-1994.

Wyniki badań pozwalają na wysunięcie następujących wniosków: 1 - dla określenia wielkości ikry troci wiślanej wystarczy pomiar jednej średnicy a pomiarami objętości ikry można zastąpić pomiary jej średnic, 2 - zmienność rozmiarów ikry troci wiślanej pozyskanej od jednej samicy jest mała (współczynnik zmienności nie przekracza 7,14%), 3 - kształt ikry troci wiślanej jest elipsoidalny, odznacza się małą zmiennością i nie zależy od wielkości ryby, 4 - u troci wiślanej występuje statystycznie wysoko istotna zależność pomiędzy długością samicy i jej masą a rozmiarami ikry, 5 - trocie wiślane z poszczególnych lat produkują ikrę nie różniącą się pomiędzy sobą rozmiarami.

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