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The length weight relationship, age, growth and reproduction of the roach *Rutilus rutilus* (L.) in Lake Volvi

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The length-weight relationship of a sample of 233 roach (*Rutilus rutilus*) can be described by the following equations: $y=0{\cdot}0356x^{3{\cdot}405}$ and $y=0{\cdot}0215x^{3{\cdot}606}$ for males and females respectively. In both equations y equals the body weight in grams and x is the standard length in centimetres. The average condition factor K was 2·01 with a range of 1·71 to 2·26. The roach's span of life was 13 years for both sexes. The growth increment is greater during the first year of life (about 56 mm), decreasing to approximately 17 mm at the end of the sixth year of life and then becoming constant at about 12 mm per year. Roach become sexually mature at age 1+ for males and one year later for females. The mean absolute fecundity was 9294 eggs; with a range from 920 to 32 810. The growth of the gonads is related to the age of the fish. Spawning occurs during the first half of April, at a mean water temperature of 10° C.

I. INTRODUCTION

The present paper reports data on length-weight relationship, age determination, growth and reproduction of the roach, *Rutilus rutilus* (L.) in the lake Volvi. Approximately eliptical in shape, the lake is 22 km long and 3·5 km wide, with an area of about 70 km², its elevation is 37 m above sea level, it is shallow and its greatest depth is 23 m with an average depth of approximately 13·5 m. The water is alkaline (pH= 8·2), but the lake is relatively oligotrophic.

Lake Volvi was selected for this study because the roach is one of the most numerous components of the icthyofauna in this body of water. The average roach catch in the past four years (1973–1977), reached 211 tonnes annually. Other species present in the lake in order of their abundance are: perch *Perca fluviatilis*, bream *Abramis brama*, shad *Alosa alosa*, common carp *Cyprinus carpio*, pike *Esox lucius*, eel *Anguilla anguilla*, wels *Siluris glanis* and bitterling *Rhodeus amarus*.

II. MATERIALS AND METHODS

Samples of roach used in this study were taken from the lake in early March 1978. They were collected randomly using gill nets which had a mesh ranging from 8 to 32 mm. A total of 233 specimens was collected and preserved in 10% formalin solution after opening the abdominal cavity and the length, weight, sex, age, and fecundity estimated in the laboratory.

Total length (T.L.) was measured from the tip of the premaxilla to the tip of the longest caudal fin ray and Standard length (S.L.) was measured from the tip of the premaxilla to the bases of the caudal fin rays, where a groove forms naturally when the tail bends from side to side. These measurements were taken to the nearest millimetre using a conventional fishery

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board. Fish were weighted to the nearest 0·01 g after the surplus liquid was removed with blotting paper. The gonads of each specimen were removed and weighed to the nearest mg (W_g). The stomach content of each fish was removed by opening the stomach and weighed to the nearest mg (W_s). Nominal body weight (W_n) was calculated by subtracting the weight of the gonads and the stomach contents from the total weight: $W_n = W - W_g - W_s$. Sex determination was by visual inspection of the gonads of mature fish and by microscopic examination of sexually immature fish. To determine the age 10 to 15 scales were removed just above the lateral line directly beneath the leading edge of the dorsal fin. They were cleaned and stored in individual envelopes for subsequent examination. Cleaning was effected by soaking the scales for a few minutes in household ammonia to macerate the soft tissues which were then removed by rubbing the scales between thumb and forefinger. An ordinary microprojector was employed for assessing age, by counting the annuli of the scales. Fish with 1, 2, etc. annuli were placed in age 1+, 2+, etc. The determination of the length of the fish corresponding to various annuli was calculated using a nomograph as described by Carlander & Smith (1944). The absolute fecundity was ascertained by removing 3–4 pieces (1–2 g) from various parts of the ovaries of small, medium and large sized fish and the number of eggs per g wet weight calculated. It was then possible to calculate the total number of eggs per ovary since the mean number of eggs g^{-1} and the total weight of each ovary were known. The relative fecundity was calculated by dividing the number of eggs per fish by its total body weight.

The temperature of the lake water was recorded daily at 9.00 a.m. during the study period (March–April).

III. RESULTS AND DISCUSSION

LENGTH-WEIGHT RELATIONSHIP

The mathematical relationship between the length and weight for the male and female roach (T.L. = 72 to 230 mm), can be described by the following equations:

$$Y = 0{\cdot}0356X^{3{\cdot}40} \qquad r = 0{\cdot}99$$

$$Y = 0{\cdot}0215X^{3{\cdot}61} \qquad r = 0{\cdot}98$$

or by the logarithmic forms:

$$\log Y = -2{\cdot}448 + 3{\cdot}40 \log X$$

$$\log Y = -2{\cdot}671 + 3{\cdot}61 \log X$$

where X = total length in cm, and Y = body weight in g.

The values of the exponent 3·40 and 3·61 show: females are heavier than males of the same length (> 88 mm) probably because of differences in fatness and gonad development (Le Cren, 1951). Nikolsky (1974) reported that the gonads may form up to 15% of the body weight of a fish, while the weight of the stomach contents may reach to 30% of the body weight. In order to exclude these variables, regressions were calculated using nominal weights. The corresponding equations for male and female roach are:

$$Y = 0{\cdot}0454X^{3{\cdot}27} \qquad r = 0{\cdot}99$$

$$Y = 0{\cdot}0287X^{3{\cdot}45} \qquad r = 0{\cdot}98$$

or by their logarithmic forms:

$$\log Y = -2{\cdot}343 + 3{\cdot}27 \log X$$

$$\log Y = -2{\cdot}541 + 3{\cdot}45 \log X$$

The values of the exponents 3·27 and 3·45 show that the nominal body weight of females is higher than that of males of the same length.

The coefficient of condition K for every fish was calculated using the equation proposed by Hile (1936):

$$K = \frac{W_n \cdot 10^5}{L^3}$$

where W_n = nominal body weight in g, and L = standard length in mm.

This nominal condition factor, since it is not influenced by the weight of the gonads and the stomach content, is more meaningful in measuring environmental suitabilities of a fish species in different localities and evaluating management procedures for the improvement of the ecological conditions of the biotopes. In addition, the absolute condition factor can be used to measure seasonal changes in the robustness of the fish during the year. The grand average coefficient of condition K for female and male roach was 2·05 and 1·95 with a range of 1·76 to 2·31 and of 1·67 to 2·21 respectively. The average condition factor of all 233 specimens was 2·01 with a range of 1·71 to 2·26.

RELATIONSHIP BETWEEN TOTAL LENGTH AND STANDARD LENGTH

Since many papers express the growth of roach using total length, while others use standard length a knowledge of the relationship between the two measurements is of practical value for comparative purposes. The relationship between T.L. and S.L. for small (T.L. < 120 mm), medium (T.L. = 121–180 mm) and large (T.L. > 181 mm) roach can be described by the following equations respectively:

$$Y = -0{\cdot}1386 + 0{\cdot}77\,X \qquad r = 0{\cdot}99$$

$$Y = 0{\cdot}2647 + 0{\cdot}78\,X \qquad r = 0{\cdot}89$$

$$Y = 0{\cdot}0157 + 0{\cdot}81\,X \qquad r = 0{\cdot}97$$

where

Y = standard length in cm and

X = total length in cm.

Clearly the factors relating T.L. to S.L. as shown in Table 1 increase with increase in the size of the fish. This means that the tail tends to be proportionately shorter in the longer fish. Van Osten (1929), Beckman (1943), Hile & Jones (1940) and Carlander & Smith (1945) made the same conclusion with other fish species.

TABLE I. Factors for the conversion of total length (T.L.) and standard length (S.L.) of the lake Volvi *Rutilus rutilus*

Total length (mm)	Number of fish	Conversion factors T.L. to S.L.	Conversion factors S.L. to T.L.
< 120	102	0·77	1·29
121–180	110	0·78	1·28
> 181	21	0·81	1·14

LENGTH-FREQUENCY DISTRIBUTION

The length-frequency distribution of the roach is presented by a histogram in Fig. 1. Examination of the histogram reveals distinctive peaks at 7–8, 11–12, 14–15, 17–18 and 22–23 cm respectively; from these results it may be concluded that the roach (T.L. = 7·0–23·0 cm) can be classified in five age groups according to their total length, these ranging in length from 7–10, 10·1–13, 13·1–16, 16·1–21 and 21·1–23 cm, with a probability of a considerable overlapping at the low frequencies of each age group.

Figure 1, shows the fish of the age group 1 are represented by a low number. This scarcity can be attributed to: (a) the selective action of the gill nets used whose meshes were too large to retain the smaller roach, (b) dispersal of fish according to maturity in different parts of the lake, and (c) high mortality of the young fish born in 1977.

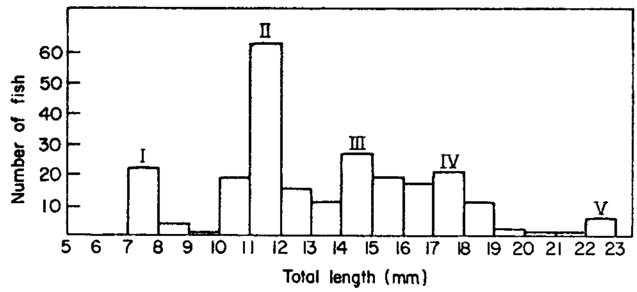

FIG. 1. Length-frequency distribution of the sampled *Rutilus rutilus*.

GROWTH RATES

The growth rates in both sexes at each age class are shown in Table II. Both sexes were combined since no differences were found in growth in length among males and females. The data shown in Table II that the average calculated length of the roach in mm during the successive years of its life is: 56 ± 18–79 ± 29–99 ± 26–116 ± 37–132 ± 20–149 ± 21–162 ± 16–175 ± 24–187 ± 21–199 ± 12–211 ± 11 and 222 ± 12.

The most rapid growth in length occurred during the first year of life (56 mm), thereafter decreasing and reaching 17 mm during the sixth year, after which it remains constant at some 12 mm (Fig. 2). The calculated growth of the roach is compared to the growth of the species in other European countries in Fig. 3. These data provide evidence that in the lake studied: (a) food is not a limiting factor for the growth of the roach, and (b) the roach, because of its good growth, should be considered as an important species in the fishery exploitation and management in the lake.

AGE COMPOSITION AND LENGTH FREQUENCIES

The length-frequency distribution of age of the roach is presented in Table III, which shows that the population of the roach in lake Volvi shows a considerable overlap in age classes for a given length. The overlapping, as showed in Table III, increases with the age. An individual fish of a particular body length may belong to two or four age classes. This is possibly a result of food competition or of inherent differences in the rate of growth of an individual fish. Comparison between the average length of each age as determined by the scale method (Table II), and those found by the length-frequency distribution (Fig. 1), shows that a close correlation exists between the average calculated length of fish of 2+, 4+, 6+, 8+ and 12+ age groups and the

TABLE II. Average calculated total length in millimeters from the Lake Volvi *Rutilus rutilus*, sexes combined (March 1978)

Age	Average T.L. at capture (mm)	Average T.L. at annulus formation												No. fish
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1+	76	66 ± 5[a]												25
2+	113	66 ± 14	107 ± 9											51
3+	123	59 ± 18	91 ± 24	119 ± 13										45
4+	139	57 ± 14	86 ± 21	114 ± 10	134 ± 18									20
5+	151	57 ± 17	82 ± 18	108 ± 17	129 ± 16	147 ± 13								21
6+	160	55 ± 12	80 ± 14	101 ± 16	123 ± 16	142 ± 11	157 ± 15							23
7+	172	55 ± 12	81 ± 15	102 ± 13	122 ± 17	139 ± 14	155 ± 16	168 ± 18						19
8+	181	53 ± 11	75 ± 13	96 ± 12	115 ± 15	132 ± 16	149 ± 5	165 ± 13	178 ± 15					13
9+	193	51 ± 6	71 ± 9	88 ± 10	107 ± 10	123 ± 9	148 ± 8	162 ± 10	178 ± 10	191 ± 11				7
10+	205	50 ± 11	71 ± 15	86 ± 11	104 ± 15	121 ± 17	145 ± 10	161 ± 13	175 ± 14	188 ± 18	203 ± 17			2
11+	218	53 ± 13	66 ± 14	87 ± 6	110 ± 18	128 ± 14	148 ± 15	160 ± 18	175 ± 16	183 ± 22	198 ± 16	212 ± 21		5
12+	226	51 ± 13	63 ± 3	88 ± 5	108 ± 4	126 ± 18	140 ± 23	155 ± 27	170 ± 30	186 ± 28	196 ± 22	210 ± 12	222 ± 12	2
Average calculated total length		56 ± 18	79 ± 29	99 ± 26	116 ± 37	132 ± 20	149 ± 21	162 ± 16	175 ± 24	187 ± 21	199 ± 12	211 ± 11	222 ± 12	

[a] Mean ± $t_{0.05}$ Standard error.

TABLE III. Length-frequency distribution of the age classes of the *Rutilus rutilus* from the Lake Volvi (March 1978)

Total length (mm)	Age 0+	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+	11+	12+	Total
221–230												3	2	5
211–220												1		1
201–210											1	1		2
191–200									1	1	2			4
181–190								3	5	4	2			14
171–180							2	5	8	2				17
161–170						3	8	8	1					20
151–160					1	12	11	1						25
141–150				2	12	7	2							23
131–140				7	4	1								12
121–130			2	21	2									23
111–120			35	16										49
101–110			15											15
91–100														—
81– 90		4												4
70– 80		21												21
Average length in mm		76	113	123	139	151	160	172	181	193	205	218	226	
Number of fish		25	52	46	19	23	23	17	15	7	5	5	2	233
Percentage		10·5	21·8	19·2	7·9	9·6	9·6	7·1	6·3	2·9	2·1	2·1	0·9	100·0

peaks formed by the histogram (Fig. 1). However, the 1+, 3+, 5+, 7+, 9+, 10+ and 11+ age groups are not presented as evident peaks by Petersen's method. Therefore, it can be concluded that unless scale analysis is made, no valid conclusions can be drawn regarding the age of the roach from the length frequency distribution. The reason is that the extensive overlap of the frequency distribution of the successive ages which makes the length a relatively poor index of age.

Roach are not particularly long-lived. Their span of life can fluctuate between 7 to 12 years (Muus & Dahlstrom, 1971). In this study, the roach's span of life for both sexes was 13 years. This indicates that the roach in lake Volvi is not subject to a high natural mortality, to which the absence of predators and the low fishing pressure have contributed.

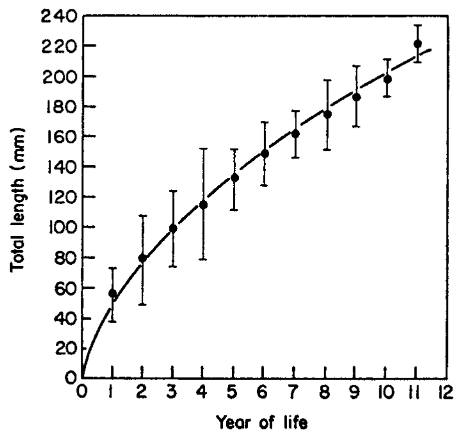

FIG. 2. Growth in length during life-span of *Rutilus rutilus* from lake Volvi. Vertical lines indicate 95% confidence intervals of means.

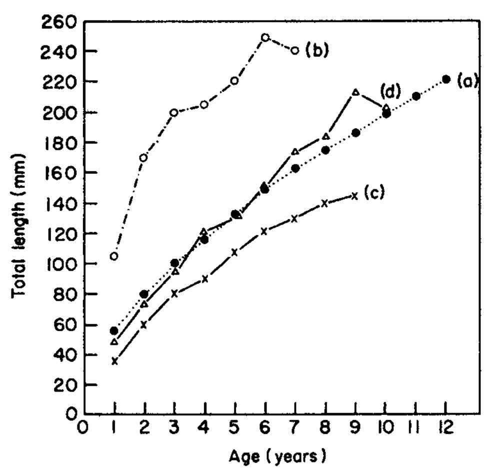

FIG. 3. Growth of *Rutilus rutilus* in lake Volvi compared with growth in other areas. (a) Lake Volvi; (b) Pool Mala and Velka Arazimoua (Czechoslovakia): Frank (1961); (c) Lake Halmsion (Sweden): Kempe (1962); Willow Brook—Elton (England): Cragg-Hine and Jones (1969).

SEX RATIO

Sex data were available for 233 specimens. The distributions of the sexes according to age are presented in Table V. The data suggest an increasing preponderance of females with increasing age of the fish. However, data on the sex ratio was obtained for fish caught in early March—when the roach started moving to the spawning grounds—and may not be descriptive to the true sex ratio of the general population.

Assuming a 1 : 1 sex ratio among males/females at all ages in the population, the data suggest that sexually mature females and young males (< 4+) move earlier than the older males to the spawning grounds.

The low representation of females in age 1+ is because females at this age are not sexually mature, and therefore do not move to the shallow areas of the lake and subsequently were not fully represented in the sample.

TABLE IV. Fecundity of *Rutilus rutilus* in relation to total length (March 1978)

Total length (mm)	Number of fish	Mean body weight (g)	Absolute fecundity	Relative fecundity
101–110	6	11·71 ± 0·61[a]	1057 ± 165	90
111–120	35	14·60 ± 2·38	1473 ± 603	100
121–130	11	18·11 ± 2·95	1725 ± 622	95
131–140	7	26·05 ± 8·51	3092 ± 702	118
141–150	14	36·82 ± 8·27	4951 ± 1619	134
151–160	12	41·60 ± 6·01	5580 ± 2115	134
161–170	19	54·77 ± 10·40	8317 ± 3607	151
171–180	16	63·22 ± 12·03	10 361 ± 4250	164
181–190	11	82·87 ± 16·7	13 005 ± 5253	156
191–200	1	98·11	14 240	145
211–220	1	143·80	20 780	145
221·230	5	156·44 ± 20·4	26 949 ± 9720	172

[a] = Mean ± $t_{0 \cdot 05}$ Standard error

TABLE V. Number of male and female *Rutilus rutilus* in each age group in the Lake Agios Vasilios (March 1978)

Age	Males	Females	Ratio M : F
1+	20	5	1 : 0·25
2+	24	27	1 : 1·13
3+	22	23	1 : 1·04
4+	9	11	1 :1·22
5+	13	8	1 : 0·61
6+	3	20	1 : 6·69
7+	1	18	1 : 19
8+	1	12	1 : 11·5
9+	2	5	1 : 1·82
10+	1	1	1 : 1
11+	1	4	1 : 4
12+	—	2	0 : 1
Total	97	136	1 : 1·38

REPRODUCTION

The roach is the first fish to spawn in lake Volvi, which occurs during the first half of April after the water reaches a temperature of 10° C; this is the normal pattern (Berg, 1968). The female roach matures at age 2+ while the male roach reaches sexual maturity a year earlier.

From the 140 mature female roach (T.L. = 106 to 230 mm), the average absolute fecundity was 9294 and ranged from 920 to 32 810 eggs. The smallest mature female was 106 mm long and weighed 11·7 g. Its ovaries weighed 0·868 g (7·35% of the body weight 0·868 g (7·35% of the body weight), and its absolute fecundity was 920 eggs, (relative fecundity 78 eggs/g). The smallest sexually mature male measured 74 mm and weighed 3·78 g. The weight of its testes was 0·138 g (3·65% of the body weight). The highest absolute fecundity of 32 810 eggs was in a twelve year-old female of T.L. = 223 mm and body weight 167·06 g (relative fecundity 196 eggs/g). The absolute and relative fecundity shown in Table IV suggests that both factors increase with the length of the fish.

The absolute growth of the gonads during the life span of the male and female roach is presented in Table VI. The data show that the weight of the gonads increases with age. The data also reveal that gonads after age 4+ show a marked difference in pattern of growth between sexes, the ovaries being considerably heavier than testes in fish of the same age.

The relative increase in gonad weight during the life span of both sexes reveal a marked difference among males and females. The ovaries increase in mass relative to somatic weight up to age 7+, after which they remain constant at about 15%. The mean value for the ovarian weight was equal to 13·49% of the body weight. The weight of the testes relative to body weight showed rapid increase until the age 2+, after which it remained constant at 10%. The data for old males were distorted by the small number of old fish in the sample. The mean value for the weight of the testes was equal to 8·32% of body weight.

TABLE VI. Absolute and relative growth of the gonads of *Rutilus rutilus* during the life span (March 1978)

	Females				Males			
Age	Number of fish	Mean body-weight (g)	Mean gonad-weight (g)	Relative gonad-weight (%)	Number of fish	Mean body-weight (g)	Mean gonad-weight (g)	Relative gonad-weight (%)
1+	5	2·93	—	—	20	4·23	0·14	3·3
2+	27	13·59	1·23	9·03	24	13·27	1·29	9·7
3+	23	19·30	1·89	9·80	22	17·75	1·79	10·1
4+	11	24·86	2·88	11·60	9	31·70	3·42	10·8
5+	8	39·98	5·11	12·79	13	39·12	4·19	10·7
6+	20	48·74	6·89	14·14	3	44·80	5·56	12·4
7+	18	63·85	9·82	15·38	1	55·15	5·81	10·4
8+	12	71·92	10·11	14·06	1	64·22	7·11	11·07
9+	5	77·24	11·26	14·57	2	75·97	6·91	9·09
10+	1	101·35	15·10	14·89	1	95·40	7·70	8·07
11+	4	151·52	25·25	16·67	1	145·07	6·05	4·17
12+	2	157·13	24·45	15·56	—	—	—	—

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