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Fish biology

GROWTH RATE OF THE SMOLTS OF THE MIGRATORY MORPHOTYPE OF THE BROWN TROUT (*SALMO TRUTTA* M. *TRUTTA* L., 1758) FROM THE GOWIENICA RIVER

CHARAKTERYSTYKA TEMPA WZROSTU SMOLTÓW TROCI WĘDROWNEJ (*SALMO TRUTTA* M. *TRUTTA* L., 1758) Z RZEKI GOWIENICA

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A total of 277 smolts of the migratory morphotype of the brown trout from the Gowienica River (Pomerania) was examined. The present survey was based on four fishing seasons: 1980, 1982, 1983, and 1984. The aim of this study was to determine the relationship between the body length and the scale radius and to determine the growth rate based on the back reading method.

INTRODUCTION

The present paper constitutes a continuation of the studies on the smolts of the migratory morphotype of the brown trout, *Salmo trutta* m. *trutta* Linnaeus, 1758 from the Gowienica River. The first work in the series (Chełkowski et al. 1984) described the downstream migration of the smolts. The second one (Chełkowski and Chełkowska 1995) provided the biological characteristics, based only on the length and weight. The third paper (Antoszek 1999) dealt with the age and the length and weight in the age groups and in relation to sex.

The aim of the present paper was to determine the relationship between the body length of the smolts of the brown trout and the radius of its scale and to determine the growth rate of the fish in consecutive years of life, based on the back-reading method. This study was based on a total of 277 smolts collected from the Gowienica River during the fishing seasons of: 1980, 1982, 1983, and 1984.

Previously, the growth rate of the smolts of the migratory morphotype of the brown trout migrating down stream to the Baltic Sea from the Pomeranian rivers have been studied by Chełkowski (1978) and Chełkowski and Chełkowska (1982). A number of authors studied the growth rate of the brown trout in the other Polish rivers as well as in the rivers of the other countries based on the readings of the scales of the adult fish (Dahl 1910; Dixon 1930, 1931; Berg 1949; Żarnecki 1963; Sych 1970).

MATERIAL AND METHODS

The Gowienica is a Pomeranian river emptying to the Szczecin Lagoon. It is 53 km long and its drainage area covers 364.9 km^2 (Anonymous 1949). The sampling site was located in the lower stretch of the Gowienica River in the village of Widzieńsko in a distance of 12.6 km from the Szczecin Lagoon where the river empties (Chełkowski and Chełkowska 1995) (Fig. 1).

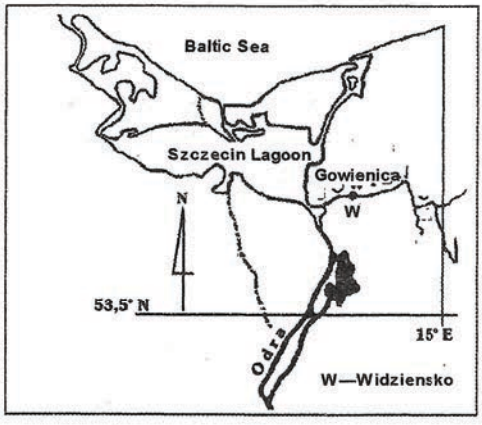

Fig. 1. Location of the Gowienica River in the Odra River estuary

The procedures of the catch, the measurement methods and the sites of the scale sampling were described in the papers of Chełkowski and Chełkowska (1995) and Antoszek (1999). A total of 2 010 smolts of the brown trout was acquired during the five-year period. The length analysis was based on 1 430 smolts (71.1%) out of which a random sample of 287 fish was taken to study the growth rate (Tab. 1). The scales of 10 fish (3.5%), however, were rejected because of undetermined rings or obscure (regenerated) rings. In the season of 1981 no detailed study was conducted because of small number of the fish collected.

Table 1

Quantitative list of the material studied

Season	Sampling period	No. of fish acquired	No. of fish studied in detail	Growth rate determined (No. of fish)
1980	08.05–01.06	917	56	56
1981	21.03–10.06	110	69	0
1982	29.04–03.06	219	120	111
1983	01.04–31.05	355	61	60
1984	03.05–18.06	409	50	50
Total	21.03–18.06	2010	287	277

The scales of the analyzed smolts were magnified 47 times using a Microprinter Canon 60. The oral radius (S) was measured to the nearest 0.01 mm on the magnified scale images, using a caliper gauge with an electronic display. Following the recommendation of Heese (1992) the relationship between the scale radius (S) and the fish length (L)—essential for selecting the right calculation method in the back-reading scheme—was determined using Microsoft Excel (version 5.0) computer software. The length of the oral radius was given in the real values, obtained by dividing the photocopy-image scale radius by the magnification value (47×). The back readings of the body length of the smolts studied were based on the formula of Rosa Lee modified by Heese (1992).

The normal-distribution tests (K-S and Liliefors) were conducted using Statistica 5.0 computer software (base parameters). These tests, on the confidence level of 0.05, confirmed that all samples—subjected subsequently to the variance analysis for multiple means—had a normal distribution. The variance analysis test (single classification) for multiple means (Greń 1984) were conducted using Statistica 5.0 software (ANOVA/MANOVA) on the confidence level of 0.05). The remaining calculations were performed using Microsoft Excel 5.0 software.

RESULTS

The reason for finding the relationship between the oral radius of the scale (S) and the fish length was a need for devising the optimal method for calculating the growth rate using the back reading method. Out of the analyzed trend lines, the highest correlation coefficient (r) or a measure of reciprocal bonds between the features studied (Greń 1984) was a linear function ($r = 0.787$) expressed as $L = 113.63 \cdot S + 67.8$ (Fig. 2). For comparison, the correlation coefficient for the exponential function was 0.778, while for the power function it amounted to 0.77. These two above-mentioned functions are likely to be rejected not only because of their low coefficient values, but also because of the predicted length of the trout at the moment of scale establishment (67.8 mm). It must be reminded, that Grudniewski (1961) experimentally determined the length of the lake morphotype of the brown trout associated with the establishment of its scales as 30.96–38.27 mm. Taking the above into account the present authors, attempting to determine the L-S relationship, assumed the fish length classes and the classes of the scales after Heese (1992). The values in each class represented the mean values of all lengths recorded in this class. A similar approach characterized the scale radius classes. The size of the length-class was 10 mm, while the size of scale-radius class was 0.05 mm. In the effect the resulting trend line had a relatively high correlation coefficients for exponential function ($r = 0.951$) and for linear function ($r = 0.944$) (Fig. 3). Taking into account less complex calculation method and only slightly lower (by 0.007) correlation coefficient, a linear function following the model of Rosa Lee had been

chosen. This decision was influenced also by the highest correlation coefficient values for a linear function as obtained in a preliminary analysis of the L-S relationship and by the predicted trout length at the moment of scale establishment (a = 36.307 mm) fitting the range of 30.96–38.27 given by Grudniewski (1961).

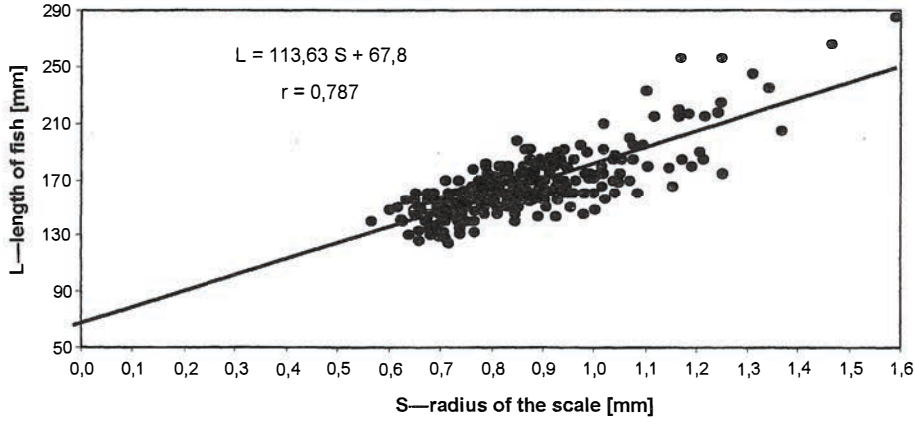

Fig. 2. Relationship between the length of the smolts and the oral radius of the scale

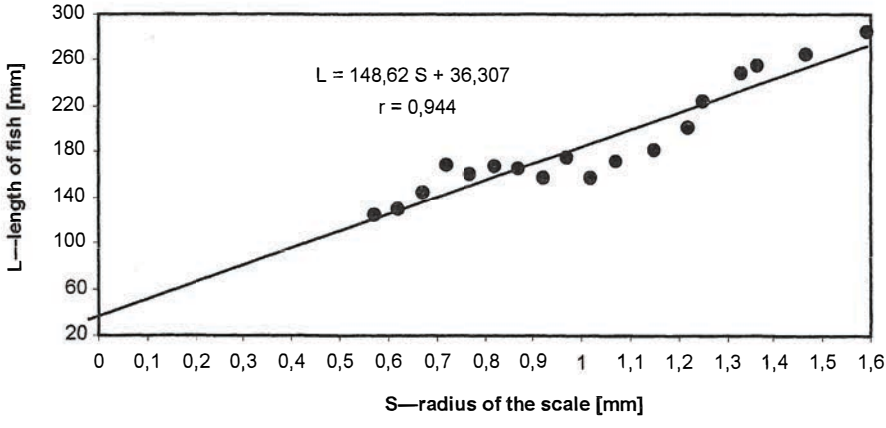

Fig. 3. Relationship between the length of the smolts and the oral radius of the scale (in length classes)

In the age structure analysis, Antoszek (1999) divided trout smolts into four age groups: 1+ with a small edge increment, 1+ with big edge increment, 2+ with small edge increment, and 2+ with big edge increment. Detailed description of the division criteria were

outlined in the above-mentioned work. Using the Rosa Lee formula, the length of smolts in consecutive age-groups was calculated (Tab. 2). The variance analysis tests of the mean length in the first and in the second year of life revealed no significant differences for individual age groups. The mean values of length in the first year of life were: 124 mm for 1+ smolts with "small" edge increment, 110 mm for 1+ smolts with "big" edge increment, 91 mm for 2+ smolts with "small" edge increment, and 100 mm for 2+ smolts with "big" edge increment. In the second year of life the mean length of the smolts was 155 mm in group 2+ with "small" edge increment and 177 mm—in group 2+ with "big" edge increment. The analysis of the smolt length in their second year of life covered only group 2+ and it skipped 1+ group with "big" edge increment. The latter group was assigned to the real age of 2 years because of the lack of fully formed 2-year ring, which in turn would not permit calculation of the length of the fish at the age of 2 years. For the same reason no length was given for the smolts in their third year of life. In both cases there were no complete annual increments observed.

Table 2

Length and length increment of the smolts of the brown trout from the Gowienica River

Age	Season	Edge increment	n	Length [mm]				Length increment [mm]			
				1	+	2	+	1	+	2	+
1+	1980	dk ≤ 44	31	117	142			117	25		
	1982	dk ≤ 43	34	131	155			131	24		
	1983	dk ≤ 44	30	123	147			123	24		
	1984	dk ≤ 36	13	129	156			129	27		
	Total	dk ≤ 44	108	124	149			124	25		
1+	1980	dk ≥ 63	13	105	162			105	57		
	1982	dk ≥ 57	21	111	165			111	54		
	1983	dk ≥ 65	25	108	168			108	60		
	1984	dk ≥ 61	10	119	177			119	58		
	Total	dk ≥ 57	69	110	168			110	58		
2+	1980	dk ≤ 39	8	94	—	155	175	94	—	61	20
	1982	dk ≤ 34	56	90	—	155	175	90	—	65	20
	1983	dk ≤ 38	5	92	—	155	180	92	—	63	25
	1984	dk ≤ 36	18	94	—	157	177	94	—	63	20
	Total	dk ≤ 39	87	91	—	155	175	91	—	64	20
2+	1980	dk ≥ 67	4	85	—	158	221	85	—	73	63
	1984	dk ≥ 61	9	107	—	180	244	107	—	73	64
	Total	dk ≥ 61	13	100	—	173	237	100	—	73	64
Grand total $\bar{x}$			277	109	—	158	—	109	—	65	—

The mean length of the smolts calculated for the entire study period in their first year of riverine life was 109 mm, while in the second year—158 mm. In the third year only approximated value of 237 mm can be given. (Tab. 2).

The highest annual increments amounting to 109 mm were reached by the smolts in their first year of life. In the second year the increment was considerably smaller and it was only 65 mm.

DISCUSSION

The higher growth rate of the smolts in their first year of life determined in the present study, compared to the cited authors (Tab. 3) was an effect of using different methods. The other authors used the Dahl Lea formula while the present study was based on the Rosa Lee method and it also considered the length of fish at the time of scale establishment. However, the growth rate in the second year of life in the present study assumed similar values as presented by the other authors.

Table 3

Growth rate of smolts from the Pomeranian rivers according to different authors

Age and edge increment	n	Length [mm]*		Author
		1	2	
1+ "small" dk	8	115		Chełkowski (1978)
	142	102		Chełkowski and Chełkowska (1982)
	108	124		Present study
1+ "big" dk	56	84		Chełkowski (1978)
	35	78		Chełkowski and Chełkowska (1982)
	69	110		Present study
2+ "small" dk	74	77	177	Chełkowski (1978)
	67	73	141	Chełkowski and Chełkowska (1982)
	87	91	155	Present study
2+ "big" dk	22	81	171	Chełkowski (1978)
	4	70	127	Chełkowski and Chełkowska (1982)
	13	100	173	Present study
Total	170	82	174	Chełkowski (1978)
	250	90	140	Chełkowski and Chełkowska (1982)
	277	109	158	Present study

* in age groups

Compared to the results of the other authors, the present survey, does not give data on the growth rate of three-year-old smolts (3+). Consequently the full year length cannot be calculated. In the present study there were only 2+ smolts with big edge increment treated as three-year-olds.

The final results of the present study on the growth rate demonstrated that the smolts in their first year of life attained the length of 109 mm, while in the second—158 mm. These results in the consecutive years of life are similar to the results of Chełkowski and Chełkowska (1982), which were 90 and 140 mm respectively, but they differ from the results of Chełkowski (1978)—82 and 174 mm respectively. As for the length increment—according to the present study, the smolts in their first year of life reached 109 mm, while 49 mm in the second year. It is clearly visible that they had better increment in their first year than they had in the second. Similar results were obtained by Chełkowski and Chełkowska (1982). According to their data the smolts reached 90-mm increment in the first year, while only 50 mm in the second year. On the other hand Chełkowski (1978) studying the smolts from the Rega River, revealed that in the first year they grew 82 mm, while in the second year—92 mm. This means that the length increment in the second year was bigger than it was in the first year.

The presently determined growth rate of the fish in the consecutive years of life does not differ from the growth rate of the brown trout smolts determined by the other authors, based on the scales collected from the adult fish in the other Polish rivers. Considerable differences, however, in the growth rate in consecutive years of life are visible compared to the smolts form Norwegian rivers and from the northern Russia, representing different climatic zone (Tab. 4). Elongated period of the riverine life of those smolts up to 4 or 5 years, causes differences in their length in individual years of their life. In the period of their downstream migration however, they have a similar size as the smolts form Polish rivers. According to Bohlin et al. (1993) one of the smoltification factors can be specific size of the body attained by a fish.

Table 4

Growth rate of the smolts of the brown trout in consecutive years of life based on the scale analysis of the adult fish

Author [river or country]	Length of smolts in consecutive years of life [cm]				
	I	II	III	IV	V
Dixon 1930 [Reda]	7.3^{3}–9.0^{2}	13.4^{3}–16.1^{2}	19.7	—	—
Dixon 1931 [Dunajec]	6.8^{3}–9.0^{2}	12.0^{3}–17.4^{2}	19.7	—	—
Żarnecki 1963 [lower Vistula]	8.4^{s}–9.4^{w}	18.6^{s}–18.2^{w}	—	—	—
Sych 1970 [lower Vistula]	—	15.3	—	—	—
Dahl 1910 [Norway]	—	13.1	14.8	16.8	20.1
Berg 1949 [Ponoj, White Sea, Russia]	5.0	10.0	15.0	21.0	—
Berg 1949 [Kovda, White Sea, Russia]	4.6	10.8	17.3	23.4	—
Berg 1949 [Gulf of Finland, Russia]	6.0	13.0	20.0	—	—

[2] two-year-old smolts; [3] three-year-old smolts; [s] summer trout; [w] winter trout

CONCLUSIONS

The determined relationship between the body length and the scale radius as well as the growth rate calculated for the smolts of the migratory morphotype of the brown trout of the Gowienica River allow to draw the following conclusions:

1. The relationship between the body length and the scale radius of the smolts studied is represented by the following formula: $L = 148.62 \cdot S + 36.307$. The correlation coefficient (r) equals 0.944. The course of the above function is consistent with the assumed back-reading method of the growth rate according to Rosa Lee.
2. The mean length of the smolts in their first year of the riverine life was 109 mm, while in the second—158 mm. The estimated length in the third year was 237 mm. The highest annual increment amounting to 109 mm was reached by the smolts in their first year of life. The increment in the second year was considerably lower, reaching 65 mm.

REFERENCES

Anonymous, 1949: Szczegółowy podział dorzecza Odry i rzek Przymorza [Detailed description of the Odra River drainage basin and the maritime rivers]. Pr. PIHM 90. (In Polish).

Antoszek O., 1999: Age structure of the smolts of the migratory morphotype of the brown trout (*Salmo trutta* m. *trutta* L., 1758) from the Gowienica River. Acta Ichth. Piscat., **29**, 1: 63–82.

Berg L.S. (ed.), 1949: Promyslovye ryby SSSR [Industrial-importance fishes of the U.S.S.R.]. Ministerstvo Rybnoj Promyšlennosti SSSR: 182. (In Russian).

Bohlin T., C. Dellefors, U. Faremo, 1993: Optimal time and size for smolt migration in wild sea-trout (*Salmo trutta*). Can. J. Fish. Aquat. Sci., **50**: 224–232.

Chełkowski Z., 1966: Introdukcja troci do rzeki Gowienicy [Introduction of the brown trout into the Gowienica River]. Gosp. Ryb., 1: 18–19. (In Polish).

Chełkowski Z., 1978: Studies on trout (*Salmo trutta* L.) wild smolts of the river Rega. Acta Ichth. Piscat., **8**, 2: 41–58.

Chełkowski Z., B. Chełkowska. 1982: Biological characteristics of trout (*Salmo trutta* L.) smolts grown in river Mołstowa catchment area. Acta Ichth. Piscat., **12**, 1: 57–68.

Chełkowski Z., B. Chełkowska. 1995: Biological characteristics of sea trout smolts (*Salmo trutta* m. *trutta* L.) grown in river Gowienica catchment area. Acta Ichth. Piscat., **25**, 1: 35–47.

Chełkowski Z., B. Chełkowska, M. Ciupiński, 1994: Period of downstream migration of sea trout (*Salmo trutta* L.) smolts grown in Gowienica river. Acta Ichth. Piscat., **24**, 1: 145–152.

Dahl K., 1910: The age growth of salmon and trout in Norway as shown by their scales. The Salmon and Trout Association, 1: 1–144.

Dixon B., 1930: Troć rzeki Redy [The brown trout of the Reda River]. Pam. PINGW, **11**, 1: 218–263. (In Polish).

Dixon B., 1931: Wiek i szybkość wzrostu troci (*Salmo trutta*) z rzeki Redy i Dunajca [Age and the growth rate of the brown trout (*Salmo trutta*) from the Reda and Dunajec rivers]. Pr. PINGW, **46**: 1–13. (In Polish).

Grudniewski C., 1961: Rozwój niektórych morfologicznych cech okresu larwalnego troci jeziorowej (*Salmo trutta* morpha *lacustris* L.) z jeziora Wdzydze [Development of some morphological features of the larval period of the lake morphotype of the brown trout (*Salmo trutta* morpha *lacustris* L.) from lake Wdzydze]. Rocz. Nauk Roln., Ser. D, **93**: 595–626. (In Polish).

Greń J., 1984: Statystyka matematyczna. Metoda i zadania [Mathematical statistics. Method and exercises]. PWN, Warszawa. (In Polish).

Heese T., 1992: Optymalizacja metody określenia tempa wzrostu ryb za pomocą odczytów wstecznych [Optimization of the method for determination of the growth rate of fishes using back reading]. Wydawnictwo Uczelniane, Wyższa Szkoła Inżynierska, Koszalin. (In Polish).

Sych R., 1970: Some comparison on the background of an eleven-year study on the growth of sea trout *Salmo trutta*. Acta Hydrobiol., **12**, 2–3: 225–249.

Żarnecki S., 1963: Występowanie populacji sezonowych u łososia atlantyckiego (*Salmo salar* L.) oraz u troci (*Salmo trutta* L.) w rzece Wiśle [Occurrence of seasonal populations of the Atlantic salmon (*Salmo salar* L.) and the brown trout (*Salmo trutta* L.) in the Vistula River. Acta Hydrobiol., **5**, 2: 255–294. (In Polish).

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CHARAKTERYSTYKA TEMPA WZROSTU SMOLTÓW TROCI WĘDROWNEJ (*SALMO TRUTTA* M. *TRUTTA* L., 1758) Z RZEKI GOWIENICA

STRESZCZENIE

W latach 1980–1984 pozyskano z wód rzeki Gowienica w miejscowości Widzieńsko (12,6 km od ujścia), 2 010 sztuk smoltów troci wędrownej (*Salmo trutta* m. *trutta* L.), z czego do badań nad tempem wzrostu przeznaczono losowo 277 ryb.

Obliczona zależność długości ciała od promienia łuski badanych smoltów ma postać $L = 148{,}62 \cdot S + 36{,}307$, przy współczynniku korelacji $r = 0{,}944$. Przebieg powyższej funkcji jest zgodny z przyjętą metodą obliczeń tempa wzrostu drogą odczytów wstecznych według Rosy Lee.

Średnia długość smoltów w całym okresie badań w ich pierwszym roku życia rzecznego wyniosła 109 mm, w drugim roku – 158 mm. Dla trzeciego roku życia ryb można podać tylko wartość przybliżoną – 237 mm. Największe przyrosty roczne wynoszące 109 mm, osiągały smolty w pierwszym roku życia; w drugim zaś przyrost był już znacznie mniejszy i wyniósł 65 mm.

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