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Fish biology

**BIOLOGICAL CHARACTERISTICS OF SALMON (*SALMO SALAR* L.)  
FROM THE FIRTH OF SZCZECIN AND LOWER ODER  
CHARAKTERYSTYKA BIOLOGICZNA ŁOSOSIA (*SALMO SALAR* L.)  
Z ZALEWU SZCZECIŃSKIEGO I DOLNEJ ODRY**

Studies were based on the analysis of mature fish grown in the Baltic Sea. The fish were caught in the Firth of Szczecin and lower Oder. Data have been presented on fish length, weight, age, growth rate, length and weight during sea life, repetition of spawning, and problems of sexual development with attention paid to fish sex.

INTRODUCTION

Studies on salmon (*Salmo salar* L.) in the Firth of Szczecin and lower Oder have been carried out by Chełkowski et al. (1976a), Chełkowski and Chełkowska (1977, 1978, 1979, 1980), and Chełkowski (1987). These papers dealt only with the frequency of salmon in fish catches, average length and weight, and problems of protection. This paper is a continuation of these studies.

Salmon from the Firth of Szczecin and lower Oder spawns in a 4th-order tributary of the Oder i.e. in Drawa River (Fig. 1). This has been confirmed by the studies on tagged fish (Chełkowska and Chełkowski 1976)\*. Biology of salmon in Drawa River has been studied by a number of authors (Bartel 1971), Chełkowski 1982, Chełkowska and Chełkowski 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1983, 1984, Chełkowski 1967, 1975, Chrzan 1961, 1962, 1964, 1969, Iwaszkiewicz 1966, Kaj 1962, Przybył 1976, Seligo 1926, Żarnecki 1962). Salmon in the Firth of Szczecin and Oder basin is noticeably regressing in numbers. It represents the last autochthonous population of this species in Poland, and it is a disappearing fish. Thorough knowledge of its biology is of a high cognitive value as well as of considerable practical importance. The aim of the studies was to present

\* Salmon female (kelt) from Drawa River was tagged in autumn 1975, tag no. P 16809, and released into its native river. It was caught on 27 April 1976 in the Firth of Szczecin.

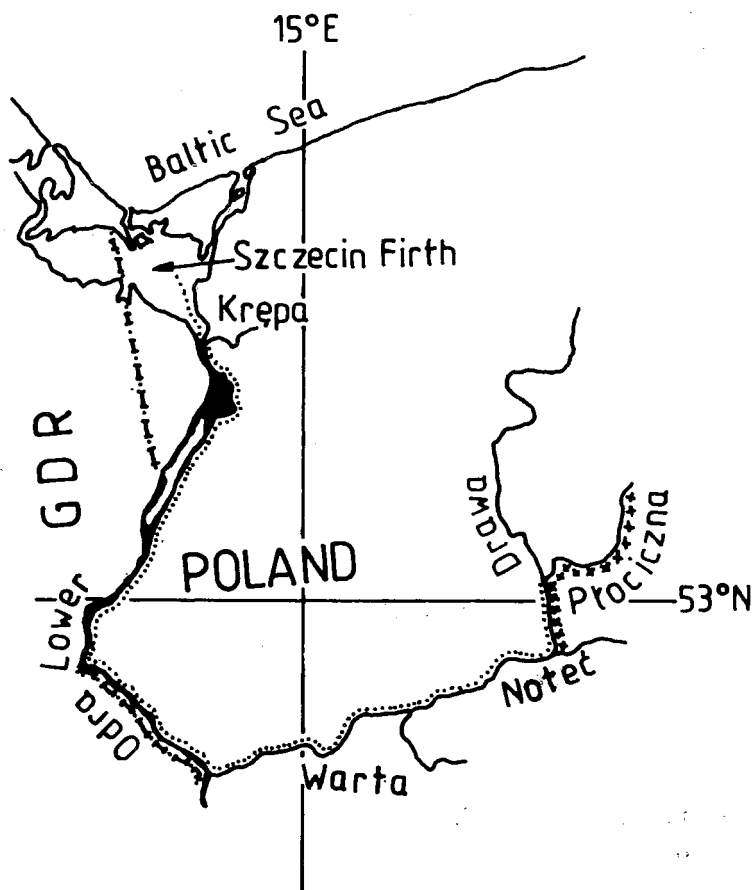


Fig. 1. Scheme of the Szczecin Firth with part of lower Oder basin; ..... course of freshwater migration of salmon from Drawa basin, x x x salmon spawning grounds, - - - - - national border

a biological characteristic of salmon based on the analyses of mature fish grown in the Baltic Sea. Analyses embraced fish during spawning and post-spawning migration. They were caught in the Firth of Szczecin and lower Oder. Special attention was given to length, weight, age, growth rate in consecutive years of river and sea life, length and weight in sea life years, maturation of females and males, and problems of spawning repetition.

A review of literature reveals that biology of salmon from the Drawa River was most broadly discussed by Chrzasn (1969) and Chełkowska (1982). The two authors took into account also other salmon populations. In view of this, this paper is limited to a comparison of own results and those cited by the two authors.

## MATERIALS AND METHODS

Fish catches from Polish part of the Firth of Szczecin and lower Oder\*\* contain grown salmon and sea trout (*Salmo trutta* L.). The two species are very similar morphologically, hence in 1973–1977 their identification to species was performed. Taxonomic analysis was based on diagnostic parameters given by many authors (Berg 1948, Chełkowska 1982, Chełkowski 1964, Schechtel 1925, Żarnecki 1960). In the five consecutive years, 11471 salmon and sea trout specimens were examined, this being 94.3% of the total catch of the two species (Chełkowski et al. 1976a, Chełkowski and Chełkowska 1977, 1978, 1979, 1980). There were 74 salmons in this materials, of total weight 777.09 kg. These were used in the studies. Number of salmons caught in five consecutive years ranged from 10 to 18 (Table 1).

Table 1

Numbers of salmon from the Firth of Szczecin and lower Oder in consecutive years of studies and migration phases

Sex	Years	1973	1974	1975	1976	1977	Total
post-spawning migration							
females		1	2	5	5	5	18
spawning migration							
females		5	6	4	8	4	27
males		9	7	7	5	1	29
total		15	15	16	18	10	74

Length (*l. caudalis*) was measured in mm, and weight of gutted fish was recorded up to 10 g. Sex was determined on the basis of gonads. In the fish under study, sex could have been identified from the secondary sexual characteristics, males had typically hooked lower jaw. Phase of migration was determined as spawning and post-spawning. The division was made on the basis of gonad development.

Age of the fish was determined from scales collected directly above the lateral line, between dorsal and adipose fin. 5 scales were collected from each salmon. They were cleaned in 3% ammonia solution. Scale reading was made twice in order to avoid errors

\*\* Lower Oder is the section from the mouth of Warta River to the mouth of Krępa River (see Fig. 1), after Chełkowski 1976.

in the interpretation of annual rings. First reading was made using a stereoscope with transmission light, at 16 or 25 x magnification. Another reading was made from scale projektion, using an overhead projector "Projectina" which gives the magnification of 17.5 times. Oral and lateral scale part were analysed for age determination. The analyses were performed in two different periods, so that the results seem to be fully reliable. When the two readings gave different results, the analyses were repeated on similar scales. The same was done when the scales were unreadable. Years of life in river (r) and sea (s) were recorded in course of age determination. Outer edge ring (dk) was always denoted as "+" irrespective of its size (Backiel 1968). Salmon age (A) which is composed of two life periods, can be expressed as:

$$A = rs +$$

Fish age was determined after Sych (1971). Interpretation of annual rings was based on papers by a number of authors (Jarvi and Menzies 1936, Carlin 1965, Chrzan 1969). Magnified scale pictures allowed for registration of the resorption marks in post-spawners. Scales prepared for age determination were also used for back-calculation of the growth rate. Fish length in the preceding years was calculated according to the method of Lindroth (1963). This method was also used by Chrzan (1969) for salmon from the Drawa River. According to this author, correction should be made when determining the length of river life, because scales grow more rapidly during this time and, thus, linear back-calculation from scales of mature salmon is likely to give higher values than the real length of smolts or fry. On the other hand, no correction is needed for the period of sea life, because scale radius in particular years is proportional to fish length. Measurements of particular scale parameters were made on the oral part, using a measuring microscope of C. Zeiss and transmission light, with an accuracy up to 0.01 mm.

## LENGTH AND WEIGHT

Fish catches in Polish part of the Firth of Szczecin and in lower Odra supplied totally 74 salmons consecutive years, 45 females and 29 males (Tab. 1). Length and weight of these was determined.

Calculations showed that average length for the 74 salmons was  $1030 \pm 11$  mm. Extreme values for females were 725–1140 mm, and for males 760–1260 mm. Average length of females was  $999 \pm 11$  mm, and of males  $1080 \pm 19$  mm. It appeared that males attained bigger size than females. The same was found by Chrzan (1969) and Chełkowska (1982) for mature salmon from Drawa River (Tab. 2).

Average length of males from Drawa River was 8.8% bigger than of females according to Chrzan (1969), and 9.3% bigger according to Chełkowska (1982). In this study the difference amounted to 8.1%.

On the other hand, average lengths of females and males from Drawa River were similar as in this study (Tab. 2).

Table 2

## Comparison of salmon length and weight

Sex	n	M±m	δ	V	Range of variations	Origin	Author
females	172	1059			850 – 1300	Drawa	Chrzan 1969
males	92	1152			840 – 1440	"	" "
total	264	1091			840 – 1440	"	" "
females	183	1016 ± 5.7	77.4	7.6	810 – 1255	"	Chełkowska 1982
males	121	1110 ± 10.0	109.9	9.9	760 – 1408	"	" "
total	304	1053 ± 5.9	102.6	9.7	760 – 1408	"	" "
females	45	999 ± 11	73.6	7.4	725 – 1140	Firth of Szczecin and Lower Oder	own studies
males	29	1080 ± 19	104.1	9.6	760 – 1260	"	"
total	74	1030 ± 11	94.9	9.2	725 – 1260	"	"
weight* in g							
females	85	8720 ± 174	1605	18.4	4800 – 12500	Drawa	Chełkowska 1982*
males	52	12620 ± 498	3589	28.4	5300 – 23200	"	" " **
total	137	10200 ± 270	3158	31.0	4800 – 23200	"	" " **
females	45	8670 ± 360	2400	27.7	1790 – 13100	Firth of Szczecin and Lower Oder	own studies
males	29	13350 ± 730	3910	29.3	4390 – 22600	"	"
total	74	10500 ± 450	3830	36.5	1790 – 22600	"	"

n – fish numbers, M – arithmetic mean, ± m – standard error, δ – standard deviation,

V – coefficient of variability, \* – weight after gutting, \*\* – calculated

A comparison can also be made between average length of salmon under study and that from Drawa River. In this study this length was 1030 mm, while average length of Drawa salmon was 1091 mm according to Chrzan (1969), and 1053 mm according to Chełkowska (1982). Hence, also length of salmon grown in the Firth of Szczecin and lower Oder was similar. The differences between average values were small, 61 mm only. The highest average length was recorded by Chrzan, by Chełkowska, and the lowest in this study. It should be added that the smallest fish were present in the stock under study, the biggest in the spawning stock from Drawa River studied by Chrzan. Extremal lengths of salmon from the Firth of Szczecin and lower Oder were 725 and 1260 mm, and of salmon from Drawa River 840–1440 mm according to Chrzan, and 760–1408 mm according to Chełkowska. Chrzan (1969) stated that size of salmon in a population could be determined on the basis of fish frequency in the length class over 100 cm. According to this author, there were 77% of such fish in the spawning population in Drawa River. Chełkowska (1982) found 66.8% of such fish, while there were 60.9% in this study.

It is interesting that both Drawa salmon studied by Chełkowska (1982) and salmon in the present study were characterized by similar average values and similar statistical parameters. It should be, however, noted that the fish communities under study represented the same mature population.

Fish in course of spawning migration were characterized by better condition than those migrating downstream after spawning. The first group embraced 27 females and 29 males, the other only 18 females (kelts). Fish migrating for spawning were caught in the Firth of Szczecin and lower Oder since the second decade of August till the third of December. Those in course of post-spawning migration were caught since the third decade of March till the first of May. Average weight of females migrating for spawning was 9840 g, and of those migrating downstream after spawning 6900 g. Average weight of males during spawning migration was 13350 g. Male kelts were not present in the fish catch from the Firth of Szczecin and lower Oder.

In view of this, it was expected that statistical data would be characterized by considerable variation coefficients, and this proved to be so (Tab. 2).

It was found that average weight of gutted salmon from the Firth of Szczecin and lower Oder amounted to  $10500 \pm 450$  g. Males weighed more than females:  $13350 \pm 730$  g and  $8670 \pm 360$  g. According to Chełkowska (1982), average weight of gutted salmon spawners in Drawa River was  $10200 \pm 270$  g. Average weight of females was  $8720 \pm 174$  g and of males  $12620 \pm 498$  g. Average values and statistical parameters given in Table 2 revealed that weights calculated for all fish and for the sexes were similar to those obtained in earlier studies.

Extremal weights of gutted fish and fish lengths showed that the biggest fish occurred during spawning migration. This group embraced a male weighing 22600 g and 1260 mm in length, and a female 13200 g in weight and 1140 mm in length. On

the other hand, also the smallest male caught was migrating for spawning. Its weight was 4390 g and length 760 mm. The smallest female was caught during post-spawning migration. Its weight was 1790 g and length 725 mm.

Comparing the results with those obtained by Chrzan (1969) and Chełkowska (1982) it can be concluded that salmon caught in the Firth of Szczecin and lower Oder weighed 1790–23200 g after gutting, its length varying from 725 to 1440 mm.

### AGE

74 salmon were caught in this study. Of these 66 were used for age determination. Scales of 8 fish (10.8%, 7 females, 1 male) had indeterminable rings and were excluded from the analyses. The materials allowed for discussing river and sea life separately as well as age composition of the population.

Period of river life. Analyses of scales showed that salmon males and females remained in river till smoltification i.e. for 1 to 2 years. Smoltification was most frequent after one year of life in the river, irrespective of the fish sex. Percentage of these smolts was 65.2%. Two-years old smolts represented only 34.8% i.e. were twice less numerous. Similar results were obtained by Chrzan (1969) and Chełkowska (1982) for salmon from Drawa River.

Attention was also given to the length of the period before salmon males and females commenced downstream migration to the sea. Data reveal that in the group of one-year old smolts the ratio between females and males was as 1.9:1, while in the group of two-years old smolts it was as 1.8:1. Hence, it may be concluded that females and males remained in the river till smoltification for the same time.

Period of sea life. Scale analyses revealed also that grazing period in the sea of salmon caught in the Firth of Szczecin and lower Oder lasted from age 1+ till age 5+. 2+ and 3+ fish were most frequent, 4+ less so, whereas 1+ and 5+ were sporadic. Totally, 64 salmon (97%) were age 2+, 3+ and 4+, and only 2 (3%) 1+ and 5+. According to Chrzan (1969) salmon from Drawa River remained in the sea for the same period i.e. from 1+ to 5+. Slightly lower range, 2+ to 5+, was found by Chełkowska (1982). Percentages of age groups during sea life given by Chrzan (1969) and Chełkowska (1982) for Drawa salmon were similar as in this study. However, age group 3+ was most numerous according to Chrzan (1969), while Chełkowska (1982) stated that it was 2+ group.

Analysis made separately for males and females supplied even more information. Table 3 presents percentages of females and males of Drawa salmon, given by Chrzan (1969), Chełkowska (1982), and found in this study. In all cases females were most frequent in the age group 2+, and males in 3+. Further comparisons of sea life showed that females as well as males were most frequent in the age groups 2+, 3+ and 4+. Age group 5+ was infrequent both as regards males and females, while

Table 3

Comparison of the share of salmon females and males in the years of sea life (%)

Sex	Years of life in sea					Origin	Author
	1+	2+	3+	4+	5+		
females		42	41	15	2	Drawa Drawa Firth of Szczecin and Lower Oder	Chrzan 1969 Chełkowska 1982 own studies
"		65	32	3			
"		53	29	18			
males	1	26	68	5		Drawa Drawa Firth of Szczecin and Lower Oder	Chrzan 1969 Chełkowska 1982 own studies
"		45	50	4	1		
"	4	25	53	14	4		

Table 4

Comparison of the share of salmon in age groups (%)

Years of life						Origin	Author
2+	3+	4+	5+	6+	7+		
0.4	20.1	55.7	18.5	4.9	0.4	Drawa Drawa Firth of Szczecin and Lower Oder	Chrzan 1969 Chełkowska 1982 own studies
	45.87	37.59	14.66	1.5	0.38		
	27.3	43.9	21.2	6.1	1.5		

age group 1+ embraced only a few males.

Taking into account years of sea and river life, it can be stated that salmon females belonged to 6 age groups: 1.2+, 1.3+, 1.4+, 2.2+, 2.3+, and 2.4+. The group with one year of river life and over 2 years (2+) of sea life was most frequent. Males belonged to 8 age groups: 1.2+, 1.3+, 1.4+, 2.1+, 2.2+, 2.3+, 2.4+, and 2.5+. Group 1.3+ was most numerous i.e. most males remained in the sea a year longer than females.

The oldest salmon caught was a male aged 7 years (7+). It spent 2 years in the river and over 5 years in the sea.

The youngest specimen was a male which spent over one year (1+) in the sea as a two-years old smolt.

Salmon age. Total fish age, embracing both river and sea life, allowed for a more thorough biological characteristics of salmon caught in the Firth of Szczecin and lower



Oder. The fish under study were aged from 3+ to 7+. Age group 4+ was most numerous, groups 3+ and 5+ less so, while groups 6+ and 7+ were infrequent.

Females were age from 3+ to 6+, males from 3+ to 7+. Females were most frequent in the age groups 3+, 4+ and 5+, males in the group 4+.

Similar results were obtained by Chrzan (1969) and Chełkowska (1982) for salmon from Drawa River. Age group 2+ was the only exception; it was found by Chrzan (1969) in the spawning population although its frequency was very low (0.4%) (Tab. 4).

### GROWTH RATE

Within the group of salmon for which age was determined from scales ( $n = 66$ ), there were 9 fish with marks of having spawned in the preceeding years, and 57 fish which spawned for the first time. The latter group embraced fish in course of spawning migration (gonads in stages IV, V, and VI) as well as those in course of post-spawning migration (gonads in stage VIII according to Maier's scale. This group was represented by 30 females and 27 males. Back-calculations were made for these fish of length ( $l$ ) and growth rate ( $t$ ) in the preceeding years.

Growth in river. Calculations of growth rate revealed that average length of one-year old smolts was  $131 \pm 1.8$  mm, two-years old ones  $165 \pm 0.4$  mm. Average length of all smolts was  $142 \pm 2.8$  mm. Extremal values for one-year old smolts were 107 and 159 mm, for two-years old ones 139 and 207 mm, of all smolts 107 and 207 mm. Differences in the growth rate between one-year old female and male smolts were small; average lengths differed by 4 mm only. The same was true for 2-years old smolts, for which this difference was 2 mm. Average lengths of all females and males were also similar:  $144 \pm 4.1$  mm for the first, and  $141 \pm 3.8$  mm for the latter. It may be concluded that rate of growth in the river (until smoltification) was similar for the two sexes (Tab. 5).

On the other hand, two-years old smolts attained average length of  $97.9 \pm 3.2$  mm in the first year of river life, whereas the average for females was  $92 \pm 5$  mm, and for males  $104 \pm 3.1$  mm.

Two-years old smolts of Drawa salmon reared in a stocking centre in Jaźwiny reached average length of 191 mm according to Chełkowska and Chełkowski, see Christensen and Larsson (1979), the range of variations being 130–290 mm. Hence, smolts reared in this centre were by 4.9 mm longer (on the average) than the average length of the fish under study, at much larger range of variations. On the other hand, average length of smolts in Drawa River was 150 mm (Chrzan 1969) i.e. only a little bigger than in this study (142 mm). Also Chrzan's results on average length of females and males of one- and two-years old smolts were similar to those obtained in the present study, and so was average length of all smolts. The same was true of two-year-old smolts in the first year of river life.

Table 5

Growth of salmon smolts from the Firth of Szczecin and lower Oder (mm)

Years of live in river	Females				Males				Total			
	n	M ± m	δ	V	n	M ± m	δ	V	n	M ± m	δ	V
1	20	133 ± 2.8	12.35	9.3	18	129 ± 2.3	9.95	7.7	38	131 ± 1.8	11.27	8.6
2	10	166 ± 7.2	22.63	13.6	9	164 ± 3.5	10.43	6.4	19	165 ± 4.0	17.46	10.6
total	30	144 ± 4.1	22.58	15.7	27	141 ± 3.8	19.63	13.9	57	142 ± 2.8	21.09	14.9

Table 6

Growth (l) and increments (t) of salmon from the Firth of Szczecin and lower Oder  
in the years of sea life (mm)

Sex	For data	Years of life in sea									
		l					t				
		1	2	3	4	5	1	2	3	4	5
females	n	30	30	10	1	—	30	30	10	1	—
	M	573	875	1009	1096	—	429	302	182	95	—
	$\pm m$	12.4	11.8	11.2	—	—	12.2	10.3	18.1	—	—
	$\delta$	67.93	64.76	35.29	—	—	66.62	56.61	57.17	—	—
	V	11.9	7.4	3.5	—	—	15.5	18.7	31.4	—	—
males	n	27	26	19	4	1	27	26	19	4	1
	M	566	889	1030	1139	1214	425	323	165	154	148
	$\pm m$	11.5	17.8	15.1	30.1	—	11.1	11.8	13.6	18.4	—
	$\delta$	59.47	90.65	65.76	62.18	—	57.87	60.06	59.23	36.80	—
	V	10.5	10.2	6.4	5.5	—	13.6	18.6	35.9	23.9	—
total	n	57	56	29	5	1	57	56	29	5	1
	M	570	881	1023	1130	1214	427	312	171	142	148
	$\pm m$	8.4	10.4	10.6	25.6	—	8.2	7.9	7.8	18.4	—
	$\delta$	63.58	77.43	5.73	57.14	—	62.10	58.72	58.10	41.23	—
	V	11.2	8.8	5.6	5.1	—	14.5	18.8	34.0	29.0	—

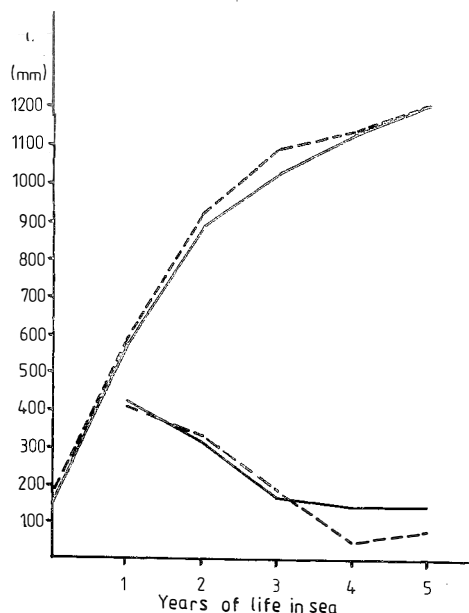


Fig. 2. Back-calculation of salmon growth and length increments;  
 - - - - Drawa River (Chrzan 1969), — Szczecin Firth and lower Oder (own studies)

Growth in the sea. Data related to all fish revealed that salmon from the Firth of Szczecin and lower Oder attained average length of  $570 \pm 8.4$  mm in the first year of sea life,  $888 \pm 10.4$  mm in the second,  $1023 \pm 10.6$  mm in the third,  $1130 \pm 25.6$  mm in the fourth, and 1214 mm in the fifth. Average increments in length amounted to  $427 \pm 8.2$  mm in the first year of sea life,  $312 \pm 7.9$  mm in the second,  $171 \pm 7.8$  mm in the third,  $142 \pm 18.4$  mm in the fourth, and 148 mm in the fifth (Tab. 6). Hence, rate of growth in the sea decreased with time. Most rapid growth took place in the first year of sea life. Thereafter, it became slower and slower (Fig. 2). Decreasing trend of the increments in salmon length may be presented comparing the ratio between the increments in each year to that in the first year. When the increments in the first year (427 mm) are taken as 100%, the increments in the subsequent years are: 73.1% in the second, 40% in the third, 33.3% in the fourth. Attention was also given to length and its increments in particular years of sea life separately for males and females. The most rapid growth took place in the first year both as regards males and females. It can also be noted that females grew slightly more rapidly in the first year of sea life than males. In the next years males grew more rapidly than females. Generally however, the differences in growth between males and females were small, at least in the first two years of sea life.

In addition to this, growth and length increments were calculated for the two sexes in particular years of sea life, with attention paid to smolt age. Average values revealed

that growth rate of females and males in the first year of sea life was more rapid in case of fish grown from two-years old smolts. And thus, salmon grown from two-years old smolts attained in the first year of sea life 594 mm (females) and 569 mm (males), whereas those grown from one-year old smolts attained 562 mm (females) and 565 mm (males). However, in the next years of sea life salmon originating from one-year old smolts grew more rapidly, this being true for females as well as males.

Length increments of salmon grown from one-year old smolts were bigger than of those grown from two-year-old smolts in all years of sea life. Generally however, both females and males grown from one- and two-years old smolts had similar growth in the consecutive years of sea life. The differences between comparable means were very small, 32 mm in the first year of sea life, 26 mm in the second, 18 mm in the third. It seems that growth rate of females and males in consecutive years of sea life did not depend much on smolt age.

Comparisons were also made with the data obtained by Chrzan (1969) for Drawa salmon. It appeared that average values obtained by this author for females and males were very similar to those obtained for salmon from the Firth of Szczecin and lower Oder.

These similarities were especially noticeable in case of length increments in the first three years of sea life. Average increments for Drawa salmon given by Chrzan (1969) were: 433 mm in the first year of sea life, 331 mm in the second, and 180 mm in the third, while the same values for salmon from the Firth of Szczecin and lower Oder were 427 mm, 312 mm, and 175 mm (Fig. 2). It seems that growth of both Drawa salmon and that from the Firth of Szczecin and lower Oder is not stabilized. Most rapid growth was observed in the first year of sea life. Thereafter, length increments decreased. Females and males were characterized by similar rate of growth in the first two years of sea life. In the remaining years males grew more rapidly than females.

## LENGTH AND WEIGHT IN THE YEARS OF SEA LIFE

Fish for which age and growth rate were determined from back-calculations ( $n = 57$ ) were used to present length and weight of salmon in particular years of sea life, from 1+ to 5+. Data reveal that in the group 2+ years of sea life females and males grown from two-years old smolts were slightly bigger than those grown from one-year old smolts. However, length of females and males in older groups (3+ and 4+ years of sea life) was slightly bigger in case of fish grown from one-year old smolts.

Comparison of average length of salmon in consecutive years of sea life reveals that males attained greater size than females. For example, females in age group 2+ attained average length 972 mm and males attained 1044 mm, in 3+ group females attained 1050 mm and males 1099 mm, in group 4+ females attained 1120 mm and males 1205 mm.

It is to be underlined, for the salmon length's range, in the following year of the sea life, to be essential and equal to: for females of age 2+ and 3+ to 910 to 1060 mm and 990 to 1120 mm, respectively, while for males of age 2+, 3+ and 4+, 960 to 1105 mm, 990 to 1200 mm and 1155 to 1230 mm respectively.

Males grown from two-years old smolts were slightly heavier in consecutive years of sea life than males grown from one-year old smolts. The same was true of females. This was especially noticeable in the most numerous group 2+ years of sea life.

In case of females grown from one-year old smolts, those migrating downstream after spawning weighed 6.4 kg on the average, while those grown from two-years old smolts weighed 6.6 kg. Females migrating for spawning weighed 8.8 kg when grown from one-year old smolts, and 10.1 kg when grown from two-years old ones.

Males grown from one-year old smolts attained 11 kg during spawning migration, and those grown from two-years old smolts – 13 kg. It appeared also that males were always heavier than females in the same years of river and sea life. Average weight of males and females for the whole period of studies was also compared. It was found that weight of males in consecutive years of sea life was always higher than of females.

A general view on average length and weight of salmon during sea life is also interesting. And thus, salmon from the Firth of Szczecin and lower Oder attained 76 cm and 4.4 kg at the age of 1+, 99 cm and 9.1 kg at the age of 2+, 108.1 cm and 12.3 kg at 3+, 118.4 cm and 16.2 kg at 5+, 126 cm and 22.6 kg weight of gutted fish.

Data on length and weight during sea life were similar to those obtained for Drawa salmon by Chełkowska (1982), this being especially true for fish length. When comparing the weight, it should be remembered that salmon males were caught during spawning migration, and females during migration to and from spawning, whereas salmon from Drawa River was always caught during spawning. Condition of fish in terms of Fulton's coefficients deteriorated noticeably during the reproductive migration in fresh waters (Chełkowski 1987).

#### THE PROBLEM OF SPAWNING REPETITION AND SEXUAL MATURITY

As mentioned before, in the group of salmon with determined age ( $n = 66$ ) there were 9 fish with scale marks of having spawned previously. These were 7 females and 1 male with one spawning mark, and 1 female with two marks. These fish embraced also 5 kelts (females) which reproduced for the second time in their life, and 4 fish (3 females and 1 male) in course of spawning migration. Subsequent analysis of scales revealed that 6 females repeated spawning without a pause, and 1 male and 2 females repeated spawning after a one year pause. The possibility of repeated spawning with no pause, i.e. consecutive spawning seasons, has been confirmed by 3 tagged salmon females from Drawa River (Chełkowska and Chełkowski 1972, 1976). Numerical data

revealed that there were 13.6% of fish with marks of previous spawning. Spawning population of salmon from Drawa River also comprised fish with spawning marks on scales, their percentage being more or less the same. According to Chrzan (1969) there were 12.5% of such fish, and according to Chełkowska (1982) 7.3%. In the fish population under study, there were 8 salmons (12.1%) with one spawning mark, and 1 (1.5%) with two marks. In the spawning population from Drawa River, percentages with one and two spawning marks were similar. According to Chrzan (1969) there were 11.7% of fish with one spawning mark, while Chełkowska (1982) found 5.9% of such fish. As regards fish with two marks, the first authors gave their percentage as 0.75% and the latter as 1.4%. It is interesting to know the percentage of fish with spawning marks separately for males and females. For a total number of 38 females under study, there were 8 fish (21%) with spawning marks. 7 of them (18.4%) had one spawning mark, and 1 (2.6%) had two. From among 28 males, only 1 (3.6%) had one spawning mark. There were no females with three, and no males with two spawning marks. The female with two spawning marks was in course of the third spawning migration, and the male with one mark was in course of the second spawning migration. Hence, the spawning population can comprise females which spawn for the third time, and males which spawn for the second time. Also Chrzan (1969) and Chełkowska (1982) stated that spawning population from Drawa River could embrace males which spawned for the second time. Percentage of males and females with spawning marks was similar for the salmon population under study and for the populatio from Drawa River.

From the biological point of view it was interesting to note the ratio between fish which repeated spawning and those reproducing for the first time, both as regards females and males. As regards salmon from the Firth of Szczecin and lower Oder, within 38 females there were 8 which attained sexual maturity for the second time or which spawned for the second time, and 30 which attained maturity for the first time. Hence, their ratio was 1:3.8. Among 28 males there was 1 maturing for the second time and 27 maturing or having spawned for the first time. Hence, the ratio was 1:27. These data suggest that females repeat spawning more frequently than males.

The same was noted for the spawning population of salmon from Drawa River. Calculations made by Chrzan (1969) revealed that the ratio between females which repeated spawning and those which spawned for the first time was as 1:4.6. Chełkowska (1982) found this ratio, to be 1:8. As regards males, the respective ratios were 1:45 according to Chrzan (1969) and 1:57 according to Chełkowska (1982). Generally, spawning population of salmon from the Firth of Szczecin and lower Oder, and from Drawa River, embraced 5.6 females spawning for the first time per one female which repeated spawning, and 46.2 males per each male which repeated reproduction.

Numbers of salmon from the Firth of Szczecin and lower Oder which attained sexual maturity for the first time and which repeated spawning are presented in Table 7. As results from this table, females spawning for the first time belonged to three age

Table 7

## Sexual maturation of salmon in the years of sea life

Fish detail	Years of life in sea					Total number %	Origin	Author
	1+	2+	3+	4+	5+			
	females							
spawning for the first time		99	48	5	1	152	Drawa	Chełkowska 1982
repeating spawning		*	3*	15	1	19		
total number		99	51	20	1	171		
total %		57.9	29.8	11.7	0.5	100		
	males							
spawning for the first time		51	57	5	1	114	Firth of Szczecin and Lower Oder	own studies
repeating spawning		*	*	2		2		
total number		51	57	7	1	116		
total %		44.0	49.1	6.0	0.9	100		
	females							
maturing for the first time or after first spawning		20	9	1		30	Firth of Szczecin and Lower Oder	own studies
maturing for the second time or after second spawning		*	2*	6		8		
total number		20	11	7		38		
total %		52.6	29.0	18.4		100		
	males							
maturing or mature for the first time	1	7	15	3	1	27	Firth of Szczecin and Lower Oder	own studies
maturing for the second time		*		1		1		
total number	1	7	15	4	1	28		
total %	3.6	25.0	53.5	14.3	3.6	100		

\* - years in which the fish with repeated spawning spawned for the first time



groups: 2+, 3+ and 4+ years of sea life. 2+ females were most frequent, those aged 3+ less so, and 4+ the least. Females with repeated spawning were most numerous in age group 4+, less so in 3+ years of sea life. Females which repeated spawning attained sexual maturity at the age of 2+ and 3+ years of sea life. Range of years in which salmon males attained maturity was much wider. Males which took part in spawning belonged to five age groups, from 1 to 5 years of sea life. Group 3+ was most frequent, groups 2+ and 4+ less so, while 1+ and 5+ were rare. The male which repeated spawning at the age 4+ years sea life spawned for the first time at the age 2+ years of sea life. Hence, it may be concluded that males spawned usually at the age of 3+, and females at 2+ years of sea life. As seen from the data presented in Tab. 7, sexual maturation and repetition of spawning were very similar in salmon from the Firth of Szczecin and lower Oder and from Drawa River (Chełkowska 1982). The same is true of the percentage of salmon in particular years of sea life.

Catches of salmon from the Firth of Szczecin and lower Oder supplied females and males in course of spawning migration, and females in course of post-spawning migration (Tab. 1). Lack of male kelts in five consecutive years of the studies is very interesting. Studies on reproductive rings on scales of salmon from the Firth of Szczecin, lower Oder, and Drawa salmon (Chrzan 1969, Chełkowska 1982) revealed that males repeated spawning very rarely. Hence, it may be concluded that males usually died after reproduction, this happening in the region of the spawning ground i.e. in Drawa catchment area, or after having reached lower Noteć and Warta rivers (Fig. 1). As results from the materials related to salmon in Drawa River (Chrzan 1969, Chełkowska 1982), all males which spawned at the age 4+ and 5+ years of sea life died afterwards. On the other hand, males spawning for the first time at the age 1+ to 3+ years of sea life, sometimes repeated reproduction. In the population under study there were 23 males aged 1+, 2+ and 3+. From among these, 1 male spawned at the age 2+, and repeated the reproduction at the age 4+ years of sea life. Percentage of this was 4.3%. In the spawning population from Drawa River (Chełkowska 1982) there were 108 males aged 2+ and 3+ years of sea life, and only 2 males i.e. 1.8% repeated spawning at the age 4+. It may be concluded that in case of males aged 1+ to 3+ years of sea life, possibility of repeated spawning is 1.8–4.3%. Hence, from 95.2 to 98.2% of males die after their first reproduction. In view of this, salmon males used for the reproduction should not be released again into the river.

Females repeated spawning more frequently, this being especially true of females which spawned for the first time at the age 2+ and 3+ years of sea life. Females spawning for the first time at the age 4+ and 5+ do not repeat spawning. The same can be concluded from the data presented by Chełkowska (1982) on Drawa salmon.

From among 29 females which spawned for the first time at the age 2+ and 3+ years of sea life, 8 (27.6%) are likely to repeat spawning. As regards Drawa salmon studied by Chełkowska (1982), from among 147 females in the same age groups, 19 (12.9%) were likely to repeat spawning. The data suggest that from 12.9 to 27.6% of females spawning

at the age 2+ and 3+ years of sea life are likely to participate in another spawning.

At present, when salmon populations are so weak, it is necessary that all females aged up to 3+ (inclusive) which are caught in Drawa River for reproduction be afterwards released into their native river, so that they could continue the post-spawning migration. On the other hand, older females (aged 4+ more) may be sold as they are not likely to repeat spawning.

All females and males caught by fishermen in course of salmon migration in fresh waters, i.e. in the Firth of Szczecin, lower Oder, Warta, and Noteć rivers, should be protected. This refers to salmon being in course of spawning and post-spawning migration.

### SUMMARY AND CONCLUSIONS

The paper presents biological characteristics of salmon based on the analyses of fish grown in the Baltic Sea and caught in the Firth of Szczecin and lower Oder. In course of five-year studies (1973–1977) 74 fish were obtained, in this 45 females and 29 males. The fish were caught during spawning migration (56 fish) as well as post-spawning migration (18 fish). The first group comprised 27 females and 29 males, the latter only females. Fish migrating upstream for spawning were caught from the 2nd decade of August till the 2nd decade of December. Those migrating downstream after spawning were caught since the 3rd decade of March till the 1st of May. Average length (l.c) of salmon under study was  $1030 \pm 11$  mm, average weight of gutted fish was  $10500 \pm 450$  g. Salmon under study spent 1 or 2 years in river, until smoltification. One-year old smolts were more-frequent (65.2%) than two-years old ones (43.8%). Females and males spent similar period in river. Period of sea life embraced 1+ to 5+ years. Fish aged 2+ (40.9%) and 3+ (39.4%) were most frequent, those aged 4+ less so (16.7%), and aged 1+ and 5+ the least (1.5% each).

Back-calculation of growth rate, according to the method by Lindroth (1963), revealed that smolt length was  $142 \pm 2.8$  mm on the average. Length of one-year old smolts was  $131 \pm 1.8$  mm, and of two-years old  $165 \pm 4.0$  mm.

Salmon attained  $570 \pm 8.4$  mm in the first year of sea life,  $881 \pm 10.4$  mm in the second,  $1023 \pm 10.6$  mm in the third,  $1130 \pm 25.6$  mm in the fourth, and 1214 mm in the fifth.

Fish aged 1+ (years of sea life) attained average length 760 mm and weight (gutted fish) 4.4 kg, aged 2+ 990 mm and 9.1 kg, 3+ 1081 mm and 9.1 kg, 4+ 1184 mm and 16.2 kg, and 5+ 1260 mm and 22.6 kg. Females spawning for the first time belonged to 3 groups (2+, 3+ and 4+) and males to 5 groups of the years of sea life (1+, 2+, 3+, 4+ and 5+). Females aged 2+ and males aged 3+ were most frequent.

It may be concluded that the results of own studies on average length and weight, age, growth rate, length and weight in the years of sea life, frequency of spawning marks on scales and sexual maturation of salmon from the Firth of Szczecin and lower Oder are similar to the results obtained by Chrzan (1969) and Chełkowska (1982) for salmon from Drawa River.

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CHARAKTERYSTYKA BIOLOGICZNA ŁOSOSIA *SALMO SALAR* L.  
Z ZALEWU SZCZECIŃSKIEGO I DOLNEJ ODRY

STRESZCZENIE

W połowach w polskiej części Zalewu Szczecińskiego oraz w dolnej Odrze w latach 1973–1977 stwierdzono występowanie 74 wyrosłych łososi; 45 samic i 29 samców — stanowiących przedmiot badań. Łososie znajdowały się w okresie wędrówki tarłowej (56 sztuk) i potarłowej (18 sztuk). W grupie pierwszej wystąpiło 27 samic oraz 29 samców, a w drugiej tylko 18 samic. Ryby ciągnące na tarło pozyskano w okresie od II dekady sierpnia do II dekady grudnia, natomiast będące w wędrówce potarłowej w okresie III dekady marca do I dekady maja. Średnia długość (l.c.) badanych łososi wyniosła  $1030 \pm 11$  mm, natomiast średnia masa po wypatroszeniu  $10500 \pm 450$  g. Badane łososie spędziły w rzece do okresu smoltyzacji 1 lub 2 lata. Jednoroczne smolty wystąpiły liczniej (65.2%) w stosunku do dwurocznych (34.8%). Zarówno samice jak i samce do okresu smoltyzacji spędzają w rzece podobnie długi okres. Okres życia w morzu badanych łososi obejmuje od 1+ do 5+ lat. Najliczniej wystąpiły ryby w wieku 2+ i 3+ (39.4%), w mniejszych ilościach w wieku 4+ (16.7%), a najmniej w wieku 1+ i 5+ (po 1.5%).

Z obliczeń wstecznego tempa wzrostu, według metody opracowanej przez Lindrotha (1963) wynika, że długość smoltów wyniosła  $142 \pm 2.8$  mm; jednorocznych  $131 \pm 1.8$  mm i dwurocznych  $165 \pm 4.0$  mm.

W pierwszym roku życia morskiego łososi osiąga długość  $570 \pm 8.4$  mm; drugim  $881 \pm 10.4$  mm, trzecim  $1023 \pm 10.6$  mm, czwartym  $1130 \pm 25.6$  mm oraz piątym  $1214$  mm.

Łosoś w wieku 1+ (lat życia morskiego) osiąga średnią długość 760 mm i masę po wypatroszeniu 4.4 kg, w wieku 2+ odpowiednio 990 mm i 9.1 kg, w wieku 3+ — 1981 i 9.1 kg, w wieku 4+ — 1184 mm i 16.2 kg oraz w wieku 5+ 1260 mm i 22.6 kg. Samice przystępują do pierwszego rozrodu w 3 grupach (2+; 3+; i 4+) a samce w 5 grupach lat życia morskiego (1+; 2+; 3+; 4+; 5+). Najliczniej przystępują do rozrodu samice w wieku 2+ a samce w wieku 3+.

W konkluzji można stwierdzić, że wyniki badań własnych dotyczące średniej długości i masy, wieku, tempa wzrostu, długości i masy w morskich latach życia, częstotliwości występowania znaków tarła na łuskach i osiągnięcia dojrzałości płciowej łososi z Zalewu Szczecińskiego i dolnej Odry są podobne do łososi z Drawy za Chrzaniem (1969) i Chełkowską (1982).

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