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RESEARCH ARTICLE

Morphometric characterization of reciprocal hybrids of Atlantic salmon, *Salmo salar* L., and sea trout, *Salmo trutta* L., in the freshwater period of life

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Abstract. The analysis was aimed at identifying the characteristics of hybrids of Atlantic salmon, *Salmo salar* L., and sea trout, *Salmo trutta* L. Nineteen metric characters and 11 meristic characters of reciprocal hybrids of these species aged 0+ and 1+ which were released into and grew in natural watercourses were analyzed. At ages 0+ and 1+, both of the hybrids were similar to trout in head length, minimum body depth, and dorsal fin height. Both hybrids were similar to salmon at the age of 0+ in the length of the caudal fin indentation (fork length as the % of total length) and at age 1+ in upper jaw length (% of head length). Hybrid metric characters were also either intermediate or exceeded the parental species (length of pectoral fins at age 1+). Analysis indicates that metric characters are difficult to use to identify hybrids. Among the meristic characters, low gill raker and pyloric caeca counts can be used to identify hybrids.

Keywords: metric, meristic characters, morphometrics, hybrids, salmonids

Introduction

Under natural conditions, hybridization between *Salmo salar* L., and *Salmo trutta* L. is most often the result of anthropogenic stress (Crozier 1984, Verspoor 1988, Elo et al. 1995, Delling et al. 2000). The levels of hybridization between these species are 0.15% in Finland and Norway (Elo et al. 1995), 0.4% in Ireland (Crozier 1984), 2.3% in Spain (Garcia de Léaniz and Verspoor 1989), 1.0% in Great Britain (Vuorinen and Piironen 1984, Johnson and Wright 1986), and 13.3% in Sweden (locally even 28%) (Jansson and Öst 1997). Hybridization between these species is unfavorable because of introgression and the loss of spawning sites for pure species (Verspoor 1988, Garcia de Léaniz and Verspoor 1989). Studies of Salmonidae hybridization have been conducted for many years and much information has been obtained regarding the various factors influencing this process (Crozier 1984, Vuorinen and Piironen 1984, Hammar et al. 1991, Elo et al. 1995, Delling et al. 2000, Ayllon et al. 2004), levels of hybridization and survivability (Refstie 1983, Youngson et al. 1993, Blanc and Chevassus 1986, Galbreath and Thorgaard 1994), and hybrid morphology (Scott and Crossman 1973; Wilkins et al. 1994). Morphometric analyses of *S. salar* and *S. trutta* performed to date have usually concerned a few individuals or single characters (Garcia de Léaniz and Verspoor 1989, Wilkins et al. 1994). The aim of the current study was to identify the morphological characters that are typical of hybrids. The purpose of the analysis of the metric and meristic characters of salmon and sea trout hybrids was to identify morphological features that are characteristic

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of the hybrids in the first and second years of life. The most significant aspects of the study are that hybrids of known hybridization direction were analyzed, and it included the first and second years of life. It is also important that the hybrids were released into and grew under natural conditions so that the features examined were comparable to those of salmon and brown trout that had been released into and had grown under similar conditions. Identifying hybrids in environments inhabited by pure salmon and sea trout species is very important for their protection and to the restoration programs that have been ongoing for many years (Bartel 1988, 1993).

Table 1
Summary of materials used in the study (data are mean ± SD, and range)

Analysed hybrids	n	Age	Fork length (cm)	Weight (g)
			11.68 ± 1.14	19.42 ± 5.22
			7.92 - 14.21	5.40 - 33.91
trout x			8.55 ± 1.43	7.48 ± 4.17
salmon	45	1+	5.14 - 13.10	2.51 - 24.32
			12.21 ± 1.76	23.30 ± 10.15
	48	0+	5.90 - 20.20	5.50 - 52.10
salmon x			10.03 ± 1.34	12.24 ± 5.91
trout	34	1+	8.25 - 13.14	5.90 - 25.11

Materials and Methods

Artificial spawning was performed to obtain study material comprising reciprocal hybrids of salmon and sea trout. Salmon eggs and milt were obtained from individuals reared at a fish farm in Miastko and in the Wieprza River, which both originated from stocks imported from the Daugava River. Trout eggs and milt were obtained from stocks from the Daugava River. The eggs were fertilized and incubated at the Polish Angling Association (PAA) hatchery in Goleniów. The hatch were introduced into small watercourses within the vicinity of Szczecin that flowed into a municipal sewage system: this ensured that the hybrids did not escape from the natural environment and come into contact with pure species. Additionally, no representatives of pure parent species or other predators were noted in the watercourses in which the hybrids were grown. The growing fish were caught regularly using an IUP-12 electric current aggregate (approved by the Local Commission for Ethical Research no. 24/02 of 3.06.2002). The study material comprised 91 hybrids of ♀ trout x ♂ salmon and 82 hybrids of ♀ salmon x ♂ trout (Table 1). The morphometric analysis of 19 metric (Table 2) and 11 meristic (Table 3) characters was performed (Szlachciak 2000). The metric characters of the head are reported in % of head length, while body metric characters are in % of fork length (Szlachciak 2000). Metric characters were measured on fresh material using an electronic caliper to the nearest 0.1 mm, while meristic features were counted on fixed material in smaller individuals under a stereo microscope. The metric and meristic characters were analyzed jointly for males and females since there is no sexual dimorphism at this age (Gharrett and Smoker 1991, Hedenskog et al. 1997, Dębowski et al. 1999, Kirczuk and Domagała 2003, Domagała and Kirczuk 2004). The Kruskal-Wallis test was applied to determine if there were differences in metric and meristic characters among the four groups of salmon and sea trout hybrids aged 0+ and 1+. Factor analysis was performed using the indicators of the metric and meristic characters of hybrids and pure species to identify the most distinguishing characters of the parental species in the hybrids. Statistical analysis was done with Statistica 9.1. (StatSoft Inc., Kraków, Poland).

Results

The metric characters measured for ♀ trout x ♂ salmon and ♀ salmon x ♂ trout aged 0+ and 1+ are listed in Tables 2 and 3. Of the metric characters that are important for Salmonidae species analysis, the following were noted to increase with age in the trout x salmon hybrids: head length, dorsal fin height,

Table 2
Metric characters (mean ± SD, range) of the reciprocal hybrids of salmon and trout in the first year of life. Data after Domagała and Kirczuk (2004)*, Kirczuk and Domagała (2003)**

Character	trout x salmon	salmon x trout	salmon*	trout**
in % of fork length				
Total length	106.99±1.29[a] 101.57 - 109.71	107.82 ± 1.16[a] 103.36 - 108.61	107.16 ± 2.79[a] 101.62 - 118.23	104.63 ± 0.68[b] 103.53 - 106.32
Head length	24.02 ± 0.82 22.83 - 26.58	23.66 ± 0.97 19.82 - 25.77	22.77 ± 1.16 19.82 - 25.70	23.82 ± 1.23 20.89 - 27.12
Maximum body depth	21.05 ± 1.54 17.32 - 25.32	20.71 ± 1.40 18.09 - 24.60	21.32 ± 1.72 16.88 - 29.07	21.08 ± 1.44 17.50 - 24.66
Minimum body depth	8.57 ± 0.41[a] 7.59 - 9.71	8.46 ± 0.80[a] 5.56 - 10.08	7.36 ± 0.72[b] 4.66 - 8.95	9.04 ± 0.78[a] 7.32 - 11.25
Body width	10.42 ± 0.51[a] 8.86 - 11.65	10.02 ± 0.66[ab] 8.57 - 11.34	12.6 ± 1.29[b] 10.45 - 17.50	12.08 ± 0.91[ab] 10.59 - 14.29
Length of caudal peduncle	17.79 ± 0.69[b] 16.46 - 19.13	16.69 ± 0.95[b] 13.95 - 17.83	12.31 ± 2.01[a] 9.73 - 19.21	29.67 ± 1.23[c] 26.67 - 31.96
Upper jaw length	10.33 ± 0.46[a] 9.45 - 11.65	10.08 ± 0.72[a] 8.89 - 14.06	8.63 ± 0.77[c] 6.79 - 10.16	9.70 ± 1.38[b] 9.46 - 13.56
Lower jaw length	12.42 ± 0.52[b] 11.63 - 13.92	12.00 ± 0.63[b] 10.69 - 13.40	9.82 ± 0.73[a] 8.07 - 11.40	13.44 ± 1.06[c] 11.04 - 16.95
Predorsal distance	43.24 ± 1.21[b] 40.80 - 45.63	42.77 ± 1.26[b] 39.18 - 45.00	40.30 ± 1.86[a] 34.07 - 44.47	44.96 ± 1.52[c] 41.18 - 49.32
Dorsal fin length	13.17 ± 0.77a 11.81 - 14.91	12.44 ± 0.77b 9.02 - 14.29	12.79 ± 1.09[ab] 10.25 - 16.43	12.56 ± 0.88[b] 10.45 - 14.29
Dorsal fin height	17.41 ± 0.95[a] 15.75 - 19.42	16.39 ± 1.59[b] 13.29 - 25.00	14.42 ± 1.28[c] 11.48 - 17.34	16.81 ± 1.16[ab] 14.55 - 19.64
Pectoral fin length	18.99 ± 0.86[ab] 16.95 - 21.36	18.45 ± 1.30[a] 16.43 - 22.09	19.28 ± 1.27[b] 15.80 - 21.86	18.39 ± 1.38[a] 15.85 - 21.92
in % of head length				
Head depth	59.26 ± 2.70[b] 52.38 - 65.52	55.87 ± 3.11[a] 50.00 - 63.64	64.15 ± 5.01[c] 52.21 - 76.92	66.45 ± 5.10[c] 52.94 - 78.57
Head width	43.42 ± 2.43[a] 33.33 - 48.15	42.41 ± 3.14[a] 35.48 - 50.00	54.04 ± 6.16[b] 46.46 - 69.30	51.40 ± 3.97[b] 41.18 - 64.71
Upper jaw length	43.00 ± 1.61[b] 40.00 - 46.43	42.64 ± 3.13[b] 38.71 - 58.06	37.87 ± 2.70[a] 31.36 - 43.04	45.17 ± 2.89[c] 38.89 - 52.94
Lower jaw length	51.76 ± 1.85[b] 48.15 - 55.56	50.82 ± 3.29[bc] 44.00 - 59.09	43.05 ± 2.70[a] 36.86 - 49.57	56.28 ± 3.95[c] 46.36 - 64.71
Preorbital distance	24.61 ± 2.18 19.05 - 30.00	24.67 ± 2.57 20.00 - 31.82	25.67 ± 1.72 21.37 - 31.05	24.63 ± 2.79 18.05 - 30.43
Postorbital distance	49.43 ± 1.71[a] 46.43 - 53.57	49.59 ± 2.78[ac] 36.36 - 54.84	51.61 ± 2.09[b] 47.62 - 55.56	51.36 ± 2.12[c] 47.06 - 56.52
Diameter of eye	25.95 ± 1.39[a] 23.33 - 29.63	25.74 ± 2.71[a] 18.92 - 31.82	22.87 ± 1.63[b] 18.86 - 16.19	24.01 ± 1.54[b] 19.23 - 28.57

Values marked with different letters show the significance of differences between the metric characteristics of different groups of fish (Kruskal-Wallis test, $P < 0.05$)

pectoral fin length (in % of fork length) and head width (in % of head length). These characters are important because they are helpful in distinguishing trout from salmon. The characters were similar for the ♀ salmon x ♂ trout hybrids, and differences were noted in upper and lower jaw lengths (% of head

Table 3

Metric characters (mean ± SD, range) of the reciprocal hybrids of salmon and trout in the second year of life. Data after Domagała and Kirczuk (2004)*, Kirczuk and Domagała (2003)**

Character	trout x salmon	salmon x trout	salmon*	trout**
in % of fork length				
Total length	107.06 ± 1.02^{a}	106.05 ± 1.83^{b}	104.77 ± 1.02^{ab}	105.55 ± 1.41^{b}
	105.71 - 111.84	103.41 - 114.56	103.09 - 108.18	102.27 - 114.10
Head length	25.44 ± 0.81^{a}	24.95 ± 1.07^{a}	23.82 ± 0.85^{b}	25.10 ± 1.26^{a}
	23.02 - 27.63	22.48 - 26.32	22.06 - 25.61	21.57 - 26.92
Maximum body depth	19.51 ± 0.92^{a}	20.04 ± 0.87^{ab}	19.23 ± 1.09^{bc}	20.22 ± 1.42^{ac}
	17.19 - 21.79	17.89 - 21.88	16.25 - 21.74	15.19 - 22.28
Minimum body depth	8.63 ± 0.43^{a}	8.73 ± 0.47^{a}	8.47 ± 0.46^{b}	8.69 ± 0.38^{a}
	7.61 - 9.47	7.95 - 9.80	7.32 - 9.43	7.92 - 9.33
Body width	11.60 ± 0.58^{a}	12.21 ± 1.04^{b}	11.40 ± 0.95^{b}	11.07 ± 1.19^{a}
	10.39 - 12.82	10.85 - 16.25	9.41 - 13.33	8.70 - 13.40
Length of caudal peduncle	17.06 ± 0.79^{a}	16.80 ± 0.96^{a}	15.60 ± 1.26^{b}	26.79 ± 1.92^{c}
	15.58 - 19.23	15.63 - 18.95	12.79 - 18.64	23.44 - 33.63
Upper jaw length	10.62 ± 0.50^{a}	10.85 ± 0.81^{a}	10.23 ± 0.44^{b}	11.70 ± 0.62^{c}
	9.52 - 11.59	9.45 - 13.75	9.09 - 11.24	10.13 - 13.48
Lower jaw length	12.33 ± 0.57^{ab}	10.93 ± 0.82^{a}	12.43 ± 0.60^{b}	13.21 ± 0.74^{bc}
	10.98 - 13.19	10.00 - 13.75	10.91 - 14.14	10.92 - 14.34
Predorsal distance	40.96 ± 1.09^{a}	42.22 ± 1.03^{bc}	41.43 ± 1.50^{b}	43.13 ± 1.75^{c}
	38.82 - 43.42	40.20 - 45.00	37.50 - 43.52	36.22 - 46.41
Dorsal fin length	13.77 ± 0.80^{a}	12.67 ± 1.36^{b}	12.13 ± 0.83^{b}	12.81 ± 0.73^{b}
	11.96 - 15.29	10.23 - 16.25	9.52 - 13.64	11.70 - 14.64
Dorsal fin height	19.65 ± 1.04^{a}	18.03 ± 1.64^{a}	17.32 ± 1.14^{b}	18.44 ± 1.46^{a}
	16.67 - 22.08	14.17 - 21.95	14.81 - 20.22	15.98 - 21.67
Pectoral fin length	20.57 ± 1.06^{a}	19.31 ± 1.61^{b}	16.87 ± 1.29^{c}	18.03 ± 1.45^{c}
	18.25 - 23.08	13.54 - 21.95	11.86 - 20.00	15.11 - 21.15
Metric characters in % head length				
Head depth	58.45 ± 2.46^{ab}	55.08 ± 3.30^{a}	66.21 ± 3.41^{b}	66.44 ± 3.40^{ab}
	52.38 - 64.52	50.00 - 62.50	59.09 - 73.33	51.74 - 67.22
Head width	45.61 ± 2.24^{a}	48.94 ± 3.32^{ab}	49.68 ± 2.68^{b}	46.45 ± 4.56^{a}
	40.00 - 50.00	44.00 - 61.90	42.86 - 54.55	37.22 - 59.09
Upper jaw length	41.77 ± 2.19^{a}	43.47 ± 2.57^{a}	43.00 ± 2.16^{a}	46.00 ± 8.00^{b}
	38.10 - 45.83	40.00 - 52.38	38.10 - 46.43	43.33 - 50.79
Lower jaw length	48.55 ± 2.76^{a}	51.81 ± 2.46^{b}	52.24 ± 2.66^{ac}	52.65 ± 2.57^{c}
	42.86 - 54.55	48.00 - 57.14	46.15 - 61.54	45.58 - 56.72
Preorbital distance	24.15 ± 1.60^{a}	24.50 ± 2.55^{a}	25.27 ± 2.36^{b}	25.68 ± 2.58^{a}
	21.74 - 28.57	19.05 - 30.00	20.00 - 30.43	21.40 - 34.43
Postorbital distance	50.31 ± 2.21^{a}	51.04 ± 3.07^{a}	51.61 ± 2.09^{b}	55.02 ± 1.75^{b}
	43.75 - 54.84	42.86 - 56.00	47.62 - 55.56	51.15 - 59.20
Diameter of eye	25.54 ± 1.92^{a}	24.45 ± 2.16^{a}	23.20 ± 1.68^{b}	25.22 ± 2.89^{a}
	21.43 - 31.25	20.00 - 29.17	19.35 - 26.32	18.44 - 30.96

Values marked with different letters show the significance of differences between the metric characteristics of different groups of fish (Kruskal-Wallis test, $P < 0.05$)

length), and these values were observed to increase with age. While the length of the upper and lower jaws (% head length) in trout x salmon hybrids decreased with age, it increased in reverse hybrids.

The two types of hybrids aged 0+ differed statistically significantly with regard to metric characters (Kruskall-Wallis test, $P < 0.05$). The mean values of dorsal fin height and dorsal fin length (in % of fork

Table 4
Meristic characters (mean ± SD, range) of the reciprocal hybrids of salmon and trout in the first year of life. Data after Domagała and Kirczuk (2004)*, Kirczuk and Domagała (2003)**

Character	sea trout x salmon	salmon x sea trout	salmon*	sea trout**
Dorsal fin ray count	12.04 ± 0.70[a] 10 - 13	12.10 ± 0.88[a] 10 - 14	11.39 ± 0.74[b] 10 - 13	11.05 ± 0.75[c] 9 - 12
Anal fin ray count	10.15 ± 0.84[a] 9 - 12	10.21 ± 0.85[a] 8 - 12	9.16 ± 0.51[b] 8 - 10	9.26 ± 0.56[b] 7 - 10
Pectoral fin ray count	13.15 ± 0.63[a] 12 - 14	12.10 ± 1.12[b] 10 - 14	13.29 ± 0.62[a] 12 - 15	11.82 ± 0.69[b] 10 - 13
Pelvic fin ray count	8.91 ± 0.46 8 - 10	8.85 ± 0.62 7 - 10	8.96 ± 0.19 8 - 9	8.89 ± 0.29 8 - 10
Number of lateral line scales	123.54 ± 4.97[c] 112 - 139	119.35 ± 3.29[b] 110 - 126	118.18 ± 3.65[abc] 112 - 126	117.15 ± 1.34[a] 114 - 120
Number of scales above lateral line	23.00 ± 1.26[ab] 20 - 26	23.42 ± 0.79[a] 22 - 26	21.96 ± 1.46[b] 18 - 26	18.75 ± 0.83[c] 17 - 21
Number of scales below lateral line	25.00 ± 1.53[a] 22 - 28	22.65 ± 1.12[b] 18 - 25	19.67 ± 1.66[c] 16 - 22	17.80 ± 0.68[d] 17 - 19
Number of scales below adipose fin, above lateral line	11.28 ± 0.75[ab] 10 - 13	11.69 ± 1.00[b] 10 - 14	10.99 ± 0.43[a] 10 - 12	11.37 ± 0.88[ab] 10 - 13
Gill raker count	17.70 ± 0.87[ac] 16 - 19	18.40 ± 1.46[a] 14 - 20	19.18 ± 1.77[b] 16 - 22	17.41 ± 1.55[bc] 15 - 20
Pyloric caeca count	36.72 ± 6.78[a] 25 - 55	41.83 ± 12.93[b] 21 - 79	64.65 ± 6.15[c] 51 - 77	48.12 ± 5.12[b] 34 - 64
Branchiostegal ray count	11.02 ± 0.70[a] 10 - 12	10.96 ± 0.72[a] 9 - 12	10.75 ± 0.93[b] 10 - 14	11.70 ± 0.46[a] 10 - 11

Values marked with different letters show the significance of differences between the meristic characteristics of different groups of fish (Kruskal-Wallis test, P < 0.05)

length) and depth of head (in % of head length)were all higher in the sea trout x salmon hybrids. Statistically significant differences were noted in individuals aged 1+ for total length, body width, predorsal distance, pectoral fin length, dorsal fin height, and dorsal fin length (in % of fork length) and lower jaw length (in % of head length).

In comparison to the reciprocal hybrids, age 0+ trout x salmon hybrids had more lateral line scales, more scales below the lateral line, and fewer pyloric caeca (Table 4). At age 1+ trout x salmon hybrids surpassed salmon x trout hybrids in the numbers of dorsal fin rays and scales below the lateral line, while they had fewer scales below the lateral line and fewer gill rakers and branchiostegal rays (Table 5). These characters differed significantly among both hybrids at the ages of 0+ and 1+ (Kruskal-Wallis test; P < 0.05). In the first year of life salmon x trout hybrids had more pyloric caeca, gill rakers, and branchiostegal rays compared to individuals one year older, while at age 0 + the salmon x trout hybrids had more pyloric caeca than they did at age 1+.

Discussion

Metric characters

Authors of literature on *S. salar* and *S. trutta* hybrids usually describe their appearance as either “trout-like” or “salmon-like”, and present the analyses of one or the other type of hybrid (Wilkins et al. 1994, Gephard et al. 2000) of an unknown direction of hybridization (Hedenskog et al. 1997). Often the specimens studied were caught at random, and they

Table 5

Meristic characters (mean ± SD, range) of the reciprocal hybrids of salmon and trout in the second year of life. Data after Domagała and Kirczuk (2004)*, Kirczuk and Domagała (2003)**

Character	trout x salmon	salmon x trout	salmon*	sea trout**
Dorsal fin ray count	12.29 ± 0.51[a] 11 - 13	11.58 ± 0.79[b] 10 - 13	11.50 ± 0.54[a] 10 - 12	10.50 ± 0.5[ab] 10 - 11
Anal fin ray count	10.04 ± 0.67[a] 9 - 11	9.67 ± 0.60[a] 9 - 11	9.81 ± 0.49[a] 9 - 11	9.00 ± 0.83[b] 8 - 11
Pectoral fin ray count	13.07 ± 0.58[a] 11 - 14	12.97 ± 0.68[a]b 12 - 14	18.08 ± 0.27[ab] 11 - 14	12.47 ± 0.61[b] 11 - 13
Pelvic fin ray count	8.98 ± 0.15[a] 8 - 9	9.00 ± 0.00[a]	9.00 ± 0.00[a]	8.86 ± 0.35[a] 8 - 9
Number of lateral line scales	120.29 ± 3.00[a] 108 - 126	120.88 ± 2.63[a] 116 - 128	116.58 ± 1.75[b] 112 - 124	120.78 ± 3.41[a] 113 - 130
Number of scales above lateral line	24.38 ± 0.96[a] 23 - 26	22.39 ± 0.56[b] 21 - 23	17.79 ± 0.82[b] 19 - 22	20.39 ± 1.08[b] 18 - 23
Number of scales below lateral line	25.84 ± 1.15[a] 23 - 28	24.00 ± 0.61[a] 22 - 25	18.04 ± 0.66[b] 17 - 19	23.94 ± 1.69[a] 20 - 27
Number of scales below adipose fin, above lateral line	10.42 ± 0.66[a] 9 - 12	11.27 ± 0.67[b] 10 - 13	10.27 ± 0.91[b] 9 - 12	12.28 ± 0.88[c] 11 - 14
Gill raker count	15.89 ± 3.19[a] 10 - 21	19.24 ± 1.80[b] 14 - 23	17.13 ± 2.75[b] 16 - 18	17.00 ± 1.83[a] 13 - 19
Pyloric caeca count	27.40 ± 10.26[a] 15 - 73	33.71 ± 13.18[ab] 17 - 63	63.59 ± 4.54[c] 56 - 73	42.28 ± 6.48[b] 29 - 69
Branchiostegal ray count	9.80 ± 1.22[a] 6 - 12	11.35 ± 0.55[b] 10 - 12	10.92 ± 0.62[b] 9 - 12	11.25 ± 0.94[b] 9 - 12

Values marked with different letters show the significance of differences between the meristic characteristics of different groups of fish (Kruskal-Wallis test, $P < 0.05$)

were analyzed based on a few metric characters (García de Léaniz and Verspoor 1989, Wilkins et al. 1994). Other studies have focused on hybrids from fish farms (Alm 1955, Chevassus 1979). The hybrids analyzed in the present study were released into and grew in natural watercourses in the Pomerania region (Kirczuk and Domagała 2003, Domagała and Kirczuk 2004). The metric characters most often used for identification of salmon and trout and used in the descriptions of the hybrids are the upper jaw length, caudal peduncle length, minimum body depth, and total length (% fork length) (Scott and Crossman 1973, Wilkins et al. 1994).

The two hybrids did not differ significantly from trout at the ages of 0+ and 1+ (Kirczuk and Domagała 2003) regarding head length, minimum body depth, or dorsal fin height (Tables 2 and 3). Furthermore, at the age of 0+ both of the hybrids were similar to salmon (Domagała and Kirczuk 2004) with regard to the length of the caudal fin indentation (fork length in % of the total length), and at age 1+ with regard to upper jaw length (as % of head length). Piggins (1964) reported that the relative length of the upper jaw in salmon x trout hybrids is highly variable, which is consistent with the current results. Pectoral fin lengths in both groups of hybrids aged 0+ were similar, while at age 1+ they were longer than the parental species (Kirczuk and Domagała 2003, Domagała and Kirczuk 2004). However, according to Alm (1955), the size of the pectoral fin in trout x salmon hybrids is the same as in salmon. Some of the characters, such as lower jaw length (0+) and caudal peduncle length (1+), were intermediate in both groups of hybrids in comparison to the parent species. In a study by Wilkins et al. (1994), the length of the caudal peduncle in the salmon x trout hybrid was close to that of trout. For other hybrids, e.g. *Barbus longiceps* Val. x *Capoeta damascina* (Val.), metric characters also often assume intermediate values between those of the parental species. According to Stoumboudi et al. (1992), despite the identification of a few characters that distinguish hybrids from parental species, positively identifying them based on external features is difficult. This conclusion is confirmed by the results of Wilkins et al. (1994) in their analysis of 5 metric characters in salmon x trout hybrids. The trout x salmon and salmon x trout hybrids aged 1+ analyzed in the current study did not differ significantly from the parental species in 31.5% and 42% of metric characters, respectively. The percentage of natural salmon and trout hybrids of unknown hybridization direction in Swedish rivers was 52.8% (Hedenskog et. al. 1997). According to the metric characters some hybrids were identical to their parents. Another's hybrids were intermediate in metric characters (Kirczuk and Domagała 2003, Domagała and Kirczuk 2004). These results are similar to the data of Chevassus (1983) which indicate that, most often, morphometric characters of hybrids present values that are intermediate between those typical of the parental species.

Meristic characters

Many studies of hybrids focus on analyzing selected meristic features such as dorsal fin ray count, the number of scales on the lateral line (Stanley and Jones 1976), pyloric caeca count (Suzuki and Fukuda 1973, Leary et al., 1983, Ma and Yamazaki 1986, Hammar et al. 1991), gill raker count (Błachuta and Witkowski 1983, Leary et al. 1983, Kazakov et al. 1984, Gharrett and Smoker 1991, Hammar et al. 1991, Pitts et al. 1997), pectoral fin ray count, pelvic fin ray count, anal fin ray count, branchiostegal ray count (Cowx 1983 Leary et. al. 1983, Gharrett and Smoker 1991, Baxter et. al. 1997), and the number of scales from the lateral line to the dorsal and anal fins (Cowx 1983). In the present study, 11 meristic characters were analyzed (Table 4).

The ranges of variation in the number of fin rays and scales in the two hybrids analyzed aged 0+ and 1+ were most often greater, sometimes narrower, and sometimes close to those known for parental species (Kirczuk and Domagała 2003, Domagała and Kirczuk 2004). The characters that were at the lower minimum range of variation compared to the parental species were the gill raker count, pyloric caeca count, branchiostegal ray count, which all stemmed from the head deformities of the hybrids (Kirczuk and Domagała 2009). These characters also differed significantly from those of the parental species, and salmon x sea trout hybrids with branchiostegal membrane deformations had fewer than 9 branchiostegal rays (Kirczuk and Domagała 2009). The lesser number of gill rakers in hybrids as compared to the parental species (Tables 4 and 5) resulted from their absence on the short arm of the gill arch; this was noted in 52% of the salmon x trout and 12% of the salmon x trout hybrids (Kirczuk and Domagała 2009). Kazakov et al. (1984) also reported the lack of gill rakers at the ends of the gill arch filament, and uneven distribution in some hybrids. The gill raker count in the salmon x trout hybrids age 1+ in the current study was similar to that in Wilkins et al. (1994). Both types of hybrids had much lower pyloric caeca counts than did salmon (Berg 1948, Chełkowska 1982, Domagała and Kirczuk 2004) and trout (Brylińska 2000, Chełkowski 1970, Kirczuk and Domagała 2003) juveniles and adults. The pyloric caeca of the hybrids analyzed were often atypical, unevenly distributed, and tumorous (Kirczuk and Domagała 2009). In hybrids of *Salvelinus alpinus* (L.) x *Salvelinus fontinalis* Mitchill, the gill raker count did not differ significantly from that in data for the parental species, nor did the authors report any atypical features in this part of the alimentary tract (Hammar et al. 1991).

According to the factor analysis of the metric and meristic characters, two factors were identified: the value of factor 1 depended on the pyloric caeca count, caudal peduncle length, predorsal distance, head length, lower jaw length, body width, and eye

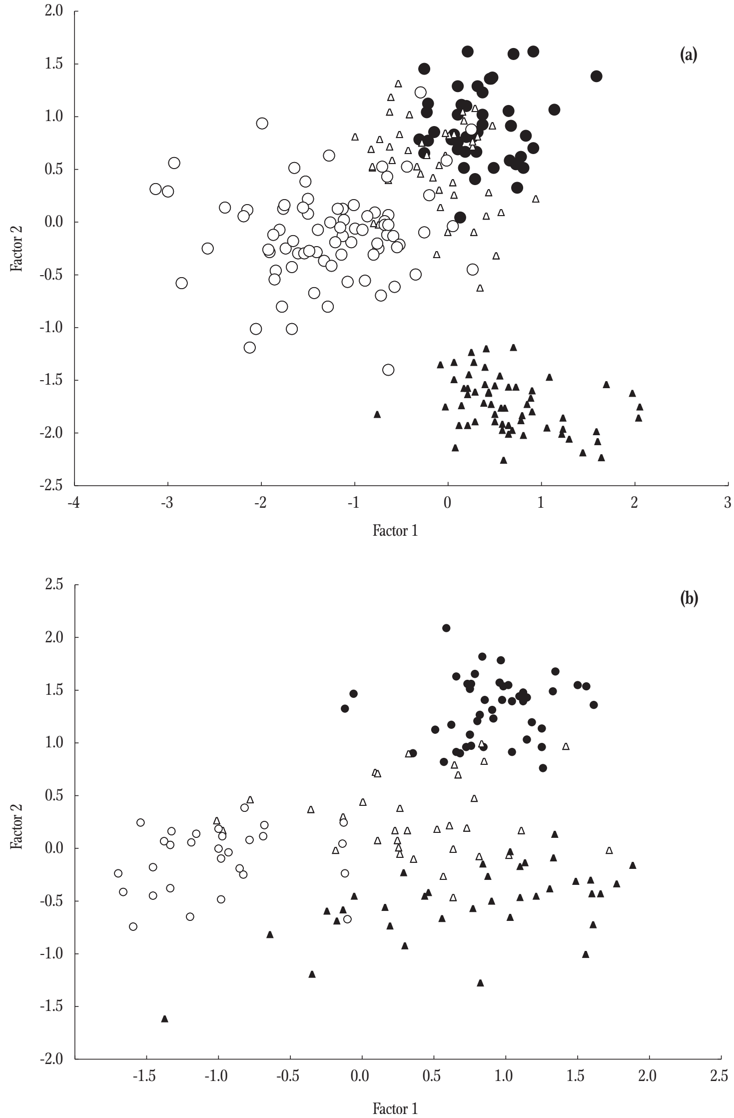

Figure 1. Values of the factors constructed in using the factor analysis of the metric and meristic characters of 0+ old (a) and 1+ old (b) Δ trout x salmon hybrids, ● salmon x trout hybrids, ○ salmon*, ▲ trout**. Data after Kirczuk and Domagała (2004)*, Kirczuk and Domagała (2003)**.

diameter, while the value of factor 2 depended on the dorsal fin ray count, anal fin ray count, and the number of scales above and below the lateral line. The graphic presentation of factor analysis show that hybrids aged 0+ corresponded to two partially overlapping areas with characters tending to be more like those of salmon (Fig. 1a). At age 1+, the trout x salmon hybrids corresponded to the area between those assigned to the parent species, while the salmon x trout hybrids corresponded to a separate area (Fig. 1b).

Meristic characters are often used to identify hybrids, especially when they differ from the parent species and when the values of such characters in hybrids are of intermediate values (Suzuki and Fukuda 1973, Whitmore 1983, Ma and Yamazaki 1986, 1993, Pitts et al. 1997, Rosenfeld 1998, Delling et al. 2000). This occurs in hybrids of *B. longiceps* x *C. damascina* (Stoumboudi et al. 1992), *Salvelinus malma* (Walbaum) x *Salvelinus confluentus* (Suckley) (Baxter et al. 1997), *Abramis brama* (L.) x *Rutilus rutilus* (L.) (Cowx 1983), while in hybrids of *R. rutilus* x *Blicca bjoerkna* (L.), only 1 of 10 characters assumes values that are intermediate between those of the parental species (Penczak 1978). The analysis of the meristic characters of reciprocal hybrids of salmon and trout has shown that they vary widely, and the majority of the characters analyzed are significantly different from the values they assume in the parental species. Wide ranges of variation in meristic characters were also reported for the hybrids of *S. alpinus* x *S. fontinalis* (Hammar et al. 1991), while values of these characters that were higher than those of the parental species were noted in hybrids of *S. confluentus* x *S. fontinalis* (MacGregor and MacCrimmon 1977, Leary et al. 1983).

The analysis of the metric characters of reciprocal salmon and sea trout hybrids indicated they were highly variable, and the application of these characters to identify hybrids is limited. However, among meristic traits, low gill raker and pyloric caeca counts plus any other accompanying distortion can indicate a hybrid. The identification and elimination of hybrids from the environments of pure species is crucial for the protection of salmon and sea trout and the preservation of biodiversity.

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Streszczenie

Charakterystyka morfometryczna obustronnych hybrydów łososia *Salmo salar* L. i troci *Salmo trutta* L. w słodkowodnym okresie ich życia

Obustronna hybrydyzacja pomiędzy *Salmo salar* L. i *Salmo trutta* L. występuje w wielu rejonach gdzie gatunki te są sympatryczne. Analizowane hybrydy pochodziły ze sztucznego tarła, podczas którego obustronnie skrzyżowano łososia z trocią. Zapłodnienie nastąpiło w wylęgarni PZW w Goleniowie, gdzie też inkubowano ikrę. Wylęg wsiedlono do cieków okolic Szczecina, które kończą swój bieg w kanalizacji miejskiej. Badaniom poddano obustronne hybrydy tych gatunków w wieku od 0+ i 1+. Analiza obejmowała 22 cechy wymierzalne i 11 przeliczalnych. Pomiary głowy przedstawiono w % długości głowy, a ciała w % długości ogonowej. Cechy wymierzalne mierzono na świeżym materiale, za pomocą suwmiarki elektronicznej z dokładnością do 0,1 mm, a cechy przeliczalne na utrwalonym materiale u mniejszych osobników z wykorzystaniem binokularu. Pod względem cech wymierzalnych hybrydy troć x łosoś w wieku 0+ i 1+ były zbliżone do łososia lub troci lub też zajmowały pośrednie miejsce w stosunku do nich z wyjątkiem długości wcięcia w płetwie ogonowej i długości płetw piersiowych, które u osobników 1+ przewyższały dane gatunków rodzicielskich. Podobnie układały się te cechy u hybrydów łosoś x troć w wieku 0+i 1+ (w wieku 1+ tylko długością płetw piersiowych przewyższały dane gatunków rodzicielskich). Pod względem cech przeliczalnych analizowane hybrydy miały w większości szersze zakresy zmienności w stosunku do danych gatunków rodzicielskich. Jednakże nie były one na tyle charakterystyczne, aby można było wykorzystać je do identyfikacji hybrydów. Cechą charakterystyczną u części obustronnych hybrydów była niska liczba wyrostków filtracyjnych oraz pylorycznych co może być przydatne w ich identyfikacji.