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Meristic and mensural morphological characters of juvenile sterlet reared in the Czech Republic and Slovak Republic

Miroslav PROKEŠ[1], Vlastimil BARUŠ[1], Miloš MACHOLÁN[2], Ivan KRUPKA[3] and Juraj MASÁR[4]

[1] *Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, Květná 8, 603 65 Brno, Czech Republic; e-mail: prokes@brno.cas.cz*

[2] *Laboratory of Genetics and Embryology, Institute of Animal Physiology and Genetics, Academy of Sciences of the Czech Republic, Veveří 97, 602 00 Brno, Czech Republic; e-mail: macholan@iach.cz*

[3] *Majerníkova 10, 841 05 Bratislava, Slovak Republic*

[4] *Research Institute of Animal Production, Institute of Fisheries and Aquaculture, 900 89 Častá, Slovak Republic*

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A b s t r a c t . Documented were the values of 7 morphological meristic and 37 mensural characters in samples of 0+ juvenile specimens of the sterlet reared in special aquacultural facilities in the Czech Republic (and originating from Russia), and in the Slovak Republic (originating from the Danube Slovak section). Individual character values were compared with literature data using the method size-pooled samples. Specimens reared in the Czech Republic (CR) and in the Slovak Republic (SR) did not differ in the maximum-minimum range of their meristic characters from the literature systematic description presented for sterlet (*Acipenser ruthenus* Linnaeus, 1758). Regards differences between mean values, the sample from the Czech Republic differed significantly in 4 (of 6) meristic characters, and in 14 (of 27) mensural characters compared. On the basis of multivariate morphometrical analysis (PCA, UPGMA) it was found that the sample of sterlet from the CR clusters well with other samples of the sterlet populations, being morphologically closest to a pair of samples from the Danube River. We suggest that, because of the numerous transfers into the Danube of sterlets reared by aquaculture in the CR, it will be impossible to discriminate them morphologically from those reared naturally in the Danube Slovak section.

Key words: morphometrical characters, juvenile *Acipenser ruthenus*, aquaculture form, comparative morphometrical analysis, repeated introduction

Introduction

In the first half of the 20th century, sterlet *Acipenser ruthenus* (Linnaeus, 1758) occurred naturally in the territory of the present Czech Republic in the lower reaches of the Morava and Dyje rivers. In the second half of this century, gradual and significant reductions of its occurrence took place (B a r u š & O l i v a 1995), and during the last decade, its natural occurrence could not be proved at all (L u s k & H a n e l 1996a,b, 2000, L u s k et al. 1996, 2000), even though reports on its rare catches by angling do exist (H a n e l 1992, P r á š i l 2000, L u s k et al. 2000, Z e l i n k a 2000). In the Slovak Republic, the sterlet occurs naturally, first of all, in the Danube and Tisa rivers (H o l č í k 1998, K r u p k a 2000). Attempts to artificial rear this species in ponds of the Czech Republic occurred as early as at the end of the 19th century in the environs of Třeboň, and during 1935 and 1949–1953 in the environs of Velké Meziříčí and Křižanov (K o s t o m a r o v 1947a,b, H u b á č e k 1950, B a r u š & O l i v a 1995). Its artificial culture, of course, was not successful because the artificial reproduction failed in this species. Other attempts focused on the sterlet culture in special aquaculture facilities in the CR were launched during early 1990s in the Hluboká n. Vlt. Pond Fishery (J i r á s e k 1999a,b; P r o k e š et al. 1995, 1997a,b,c, 1999, 2000a,b, and others). From fertilized eggs imported from Russia, juvenile and adult specimens were reared in the Mydlovary hatchery, which became then economical subjects of that pond fishery company. Since there was a trend of sterlet artificial culture in the territory of the CR, and incidental or deliberate transfers of juvenile specimens into free waters (especially into rivers and flow reservoirs) might not be excluded, the documentation of meristic and morphometrical characteristics in imported and reared specimens was needet. That was done in the Institute of Vertebrate Biology AS CR in Brno. In parallel, the analysis of morphometrical and meristic characters was performed in a sample of sterlet juvenile specimens reared experimentally in the Institute of Fisheries and Aquaculture at Častá (Slovak Republic). Reproductive specimens for stripping were sampled in the Danube, belonging to the autochthonous population. Artificial reproduction in sterlet has been carried out currently in Slovakia since 1987 (K r u p k a 2000).

The biometrical results and their analysis are subjects of the present study, and they complete the research by F l a j š h a n s & V a j c o v á (2000) who, measuring the DNA content in nuclei by flow cytometry and by other methods, analysed the ploidy level in sturgeon juvenile specimens (including sterlet) reared in the Mydlovary Fish Farm during 1994–1996 (P r o k e š et al. 2000a).

According to the literature data, sterlet is included in the species group with 120 chromosomes, distributed in the Adriatic-Ponto-Caspian zoogeographical zone (F o n t a n a 1994, F o n t a n a et al. 1977, H o l č í k 1989, S e r e b r y a k o v a 1979, S o k o l o v & V a s i l y e v 1989, R á b 1986, and others). It belongs to the genus *Acipenser* Linnaeus, 1758, and it was included recently in the subgenus *Sterleta* Gueldenstaedt, 1772 (B e r g 1948, A r t y u k h i n & R o m a n o v 1997). F o n t a n a (1994) and K u z m i n (1996) consider the sturgeon species with 120 chromosomes to be oligochromosomic, diploid, and the species with 240 chromosomes to be polychromosomic, tetraploid. In contrast, B i r s t e i n & V a s i l y e v (1987), B i r s t e i n et al. (1993, 1997) consider the sturgeon species with 120 chromosomes to be tetraploid and those with 240 chromosomes to be octoploid. The research on meristic and mensural characters in sterlet autochthonous populations, according to the literature data known to us, was dealt with by A b d u r a k h m a n o v (1962), B a n a r e s c u (1964), H o l č í k (1989), J a n k o v i ć (1958), K r y l o v a (1980), L u k i n (1979), L u k i n et al. (1981), M e n’s h i k o v & B u k i r e v (1934), N i k o l y u k i n (1972), O l i v a & C h i t r a v a d i v e l u (1972) and P a v l o v (1967, 1968). Electrophoretic studies on proteins of great sturgeon, sterlet, bester and Russian sturgeon were realized by D o b r o v o l o v & D o b r o v o l o v a (1983). Genome structure in interspecific fish hybrids was studied by V l a d y c h e s k a y a & K e d r o v a (1982).

Material and Methods

For biometrical analysis, 40 sterlet juvenile specimens reared in the Czech Republic (CR) and 30 sterlet juvenile specimens reared in the Slovak Republic (SR) were used. Fertilized eggs were imported from the Rybnoye Warm-Water Production Farm (Dmitrovskiy Region, Moscow Province, Russia) on 25.2.1996. Hatching started on 26.2.1996. Eggs were hatched out and free embryos, larvae and 0+ juvenile specimens were reared under heated water (t = 21 °C, O_2 = 8.0 mg) in the Mydlovary Aquaculture Farm (Hluboká n. Vlt. Pond Fishery Co.) during 26.2.–14.5.1996. Further culture of this material was realized within experimental research in the Institute of Landscape Ecology (Institute of Vertebrate Biology at present) AS CR in Brno during 14.5.–29.8.1996. Average water temperature during whole breeding period was about 7.1 °C higher than exists in natural conditions in the lower parts of Dyje and Morava rivers (in Czech Republic). On 29.8.1996, some juvenile specimens were fixed in 4% formaldehyde solution. The fixed material was treated by identifying and reprocessing the values of selected meristic and mensural characters during 1999.

The material obtained from sterlet reproductive specimens reared in the SR had its origin from the Slovak Danube section. They were wild specimens before spawning sampled by seine nets, and were considered to be members of the original autochthonous population. Their stripping and culture (at a water temperature, that of the natural resembling Danube river near Bratislava) of juvenile specimens were carried out in the Častá experimental aquaculture facility, which was in 1996–1999 an accessory field station of the Institute of Fisheries and Aquaculture in Bratislava.

For morphological analysis, 7 meristic and 37 mensural characters were used. Calculations with characters were performed using the standard methods according to Pravdin (1966), Holčík (1989) and Baruš & Oliva (1995). Analysed were absolute and relative values of characters. The relative values of body characters were related to total length (TL), and those of head characters to TL and head length. Analysing the meristic characters, we compared in case of individual characters the values of ranges and means using Student's t-test. The presupposition of insignificant dependence between the respective character and TL values was verified in specimens under study. In order to reveal multivariate morphomeristic affinity of the sample under study, principal component analysis (PCA) was carried out, based on the variance-covariance matrix computed from sample means. Since variances are heavily influenced by the magnitude of raw measurements, the variables were log-transformed prior to analysis. Subsequently, a morphomeristic similarity among the samples, based on matrix of Euclidean distances, was computed from log-transformed variables. In the total, 8 various samples of sterlet, 4 samples of bester (*H. huso* x *A. ruthenus*) and 6 samples of great sturgeon were compared (Tables 4–6, Figs 3,4).

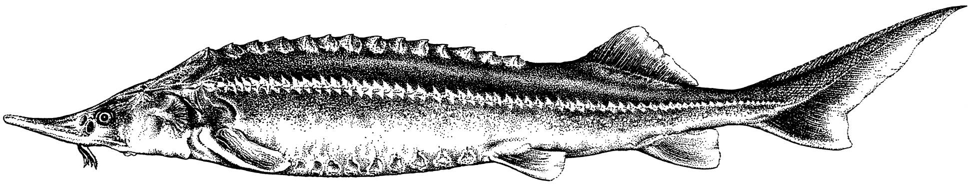

Fig. 1. Juvenile 0+ aquaculture form of sterlet, TL = 346 mm, w = 207,1 g, age = 186 days after hatching. The artificial rearing from eggs was realised in the Mydlovary Hatchery, Hluboká nad Vlt. Pond Fishery, A.S. (CR) and later (from age D80) in Institute of Vertebrate Biology AS CR in Brno. Original by Petr Pelikán, Brno

Analysing the morphometric characters, we first pooled samples to obtain very close or the same mean TL values. In the case of reciprocal comparison of samples from the CR and SR with available individual values for plotting up the mean samples, the data of specimens were used, whose TL occurred within the same size range. In the other case, heterogeneous samples of the TL mean value (literature data were compared), and samples were pooled mathematically from the calculation of regression coefficient values, characterizing the relationship between the respective character mean value and TL mean value in available samples. For this purpose exclusively, character absolute values (in mm) and two regression types, linear or non-linear (polynomial), were used (Tables 3,5,6). For calculations of the condition coefficient and length-weight relationship in the CR material, the TL value used. The basic length and weight characteristics in the own material are presented in Table 1. For making it more simple and unambiguous, we designate below the sterlet aquaculture form reared in the CR as sterlet from the CR (Fig. 1).

Table 1. Basic length and weight values for 0+ juvenile specimens of aquaculture form of sterlet from the CR and SR – explanation for morphological meristic and mensural analysis. Explanations: TL = total length, FL = fork length, SL = standard length, w = weight, R^2 = determination coefficient, CR = Czech Republic, SR = Slovak Republic, S.D. = standard deviation.

Character	Sample	Range	Mean	S.D.
TL (mm)	CR	215-342	289.2	34.32
	SR	155-387	272.9	76.86
FL (mm)	CR	185-304	256.7	30.93
	SR	139-338	239.3	67.39
SL (mm)	CR	170-281	236.8	28.70
	SR	130-316	221.4	62.62
w (g)	CR	36.2-246.6	116.3	48.96
	SR	14.2-230.0	96.4	68.08

FL(CR) = 0.7383 + 0.8851 . TL, R^2 = 0.9647; FL(SR) = 0.4145 + 0.8753 . TL, R^2 = 0.9966
SL(CR) = 1.4796 + 0.8238 . TL, R^2 = 0.9705; SL(SR) = -0.4126 + 0.8128 . TL, R^2 = 0.9953
w(CR) = 3E-07 . $TL^{3.4689}$, R^2 = 0.9565; w(SR) = 3E-06 . $TL^{3.0262}$, R^2 = 0.9859

Results

Meristic characters

Values for the maximum-minimum range of ray number in D and A, number of scutae in dorsal, lateral and ventral lines and number of gill rakers did not differ from those reported in the literature (Table 2). This fact was found in sterlet samples from the CR and also from the SR. However, higher mean values of ray number were found in D and A. In D, the differences in ray mean number from the mean value calculated, presented below as so-called standard values (Table 2), were statistically insignificant (CR – diff. 4.95%, SR – diff. 1.4%). In A, the statistically significant difference was found in the material from the CR (CR – diff. 11.52%, SR – diff. 2.88%). Variation of the ray number mean values in all ten samples examined was significantly higher in A than in D (A – max. diff. 29.35%, D – max. diff. 15.89%).

Comparing the maximum-minimum number of scutae in dorsal and ventral lines, as found in specimens from the CR and SR, with the data reported in the literature, we found no significant differences (Table 2). The maximum number of scutae in lateral line (73) found in the sample from the SR was by 2 scutae higher than reported hitherto in the literature (Table 2). The mean values of scutae number in dorsal line differed statistically significantly within all samples; in lateral and ventral lines, differences were insignificant (max. diff. 2.58%).

Analysing the gill raker number range (our material versus literature data), we found no statistically significant differences. However, between the maximum and minimum mean values of gill rakers number within all ten samples analysed, the statistically significant difference (30.38%) was found. The number of fulcrae was in the material from the CR 25–45 (mean 35.9) and in that from the SR 29–46 (mean 35.5). The value range of fulcrae number, found by us, was in both samples (CR and SR) statistically significantly higher than the values reported in the literature. The mean values, of course, did not differ statistically significantly.

Comparing in total the material from the CR versus SR regards meristic values, we found in the 7 characters analysed statistically significant differences in mean values of 3 characters: rays in A (diff. 8.40%), scutae in ventral line (diff. 9.23%) and scutae in dorsal line (diff. 22.22%).

Table 2. Meristic characters of 0+ juvenile specimens of sterlet aquaculture form from the Czech Republic and Slovak Republic (our results), and of free-living populations from other localities (literature data). Explanations: 1 – O l i v a & C h i t r a v a d i v e l u (1972); 2 – H o l č í k (1983 – cit. H o l č í k 1989); 3 – our results, SR; 4 – P a v l o v (1968); 5 – J a n k o v i ć (1958); 6 – M e n ' s h i k o v & B u k i r e v (1934); 7 – P a v l o v (1968); 8 – K u c h i n a (1967 – cit S o k o l o v & V a s i l y e v 1989); 9 – L u k i n et al. (1981); 10 – our results, CR. Explanations: Du = rays in D, Au = rays in A, SD = scutae dorsales, SLa = scutae laterales, SV = scutae ventrales, Sp. br. = spinae branchiales.

Char.	Du					Au					SD				
Author	range	mean	$s_{\bar{x}}$	S.D.	n	range	mean	$s_{\bar{x}}$	S.D.	n	range	mean	$s_{\bar{x}}$	S.D.	n
1	39-47	42.6			16	23-39	28.2			16	13-15	13.7			16
2	39-47	38.4	0.35	3.28	86	33-39	21.8	0.39	3.62	87	13-15	13.7	0.20	1.90	87
3	39-48	43.0		2.11	28	22-29	25.0		1.80	28	10-15	12.6		1.18	28
4	36-49	41.6	0.55	3.39	38	22-34	26.5	0.41	2.53	38	11-16	13.9	0.22	1.39	38
5	41-48				300	22-27				300	10-17	13.7			300
Danube	36-49	42.3			468	22-39	24.0			468	10-17	13.7			468
6	39-49	44.1	0.34	2.85	70	20-30	24.7	0.26	2.21	72	12-16	13.5	0.13	1.06	70
7	34-49	42.0	0.32	3.02	89	18-30	24.5	0.28	2.64	89	12-17	13.8	0.13	1.22	89
8	38-48	43.9	0.24	2.21	75	22-28	24.5	0.21	1.73	71	11-18	14.3	0.12	1.33	105
9		40.2	0.27	2.91	116		23.0	0.17	1.83	116		13.3	0.12	1.29	116
10	38-49	44.5		2.30	40	21-32	27.1		2.21	40	13-18	15.4		1.06	40
Others	34-49	41.8			390	18-32	24.4			388	11-18	13.9			420
Total	34-49	42.4			858	18-39	24.3			856	10-18	13.8			888

Char.	SLa					SV					Sp. br.				
Author	range	mean	$s_{\bar{x}}$	S.D.	n	range	mean	$s_{\bar{x}}$	S.D.	n	range	mean	$s_{\bar{x}}$	S.D.	n
1	59-66	62.6			16	12-16	14.1			16	14-23	19.2			16
2	59-66	64.2	0.80	7.47	87	12-16	14.2	0.14	1.35	87	14-23	20.1	0.36	3.35	87
3	58-73	63.5		2.96	28	11-16	13.0		1.27	28	16-25	20.6		1.92	28
4	56-70	63.7	0.44	2.75	39	11-17	14.5	0.22	1.39	40	15-23	18.1	0.31	1.91	38
5	52-70	62.3			300	12-18				300	15-27	19.7			300
Danube	52-73	62.9			470	11-18	14.1			471	14-27	19.7			469
6	58-71	64.3	0.38	3.28	73	12-16	13.4	0.13	1.12	70	15-21	17.8	0.18	1.46	69
7	56-69	63.1	0.29	2.73	89	11-16	13.7	0.14	1.32	89	11-21	15.8	0.20	1.89	89
8	58-70	63.6	0.22	2.25	105	11-20	14.3	0.15	1.53	105	14-24	19.2	0.18	1.78	100
9		62.4	0.23	2.48	116		14.6	0.16	1.72	116		20.4	0.23	2.48	116
10	55-67	61.9		2.82	40	12-18	14.2		1.20	40	16-26	19.4		2.19	40
Others	55-71	63.1			423	11-20	14.1			420	11-26	18.6			414
Total	55-73	63.0			893	11-20	14.1			891	11-27	19.2			883

In the case of multivariate morphomeristic analysis applications, the first principal component explains by far the largest amount of total variation (87.42%), while the other two PCs explain 7.34% and 2.98%, respectively. The first three components account for 97.74% of total morphometrical variation.

As shown in Fig. 3, PC1 discriminates fairly well the two sturgeon species, with the bester being in between. The analysed sample falls well within the group of the sterlet (AR).

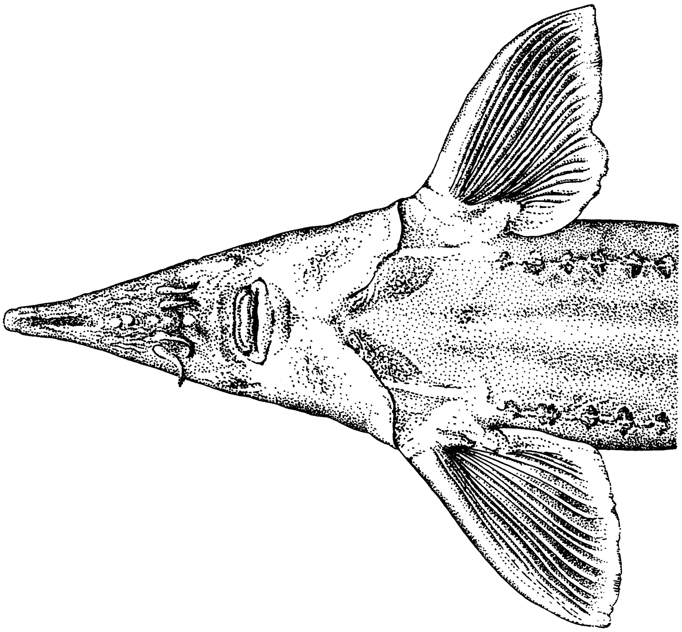

Fig. 2. The head (ventral view) of 0+ juvenile aquaculture form of sterlet, TL = 346 mm, w = 207.1 g.
Original by Petr Pelikán, Brno

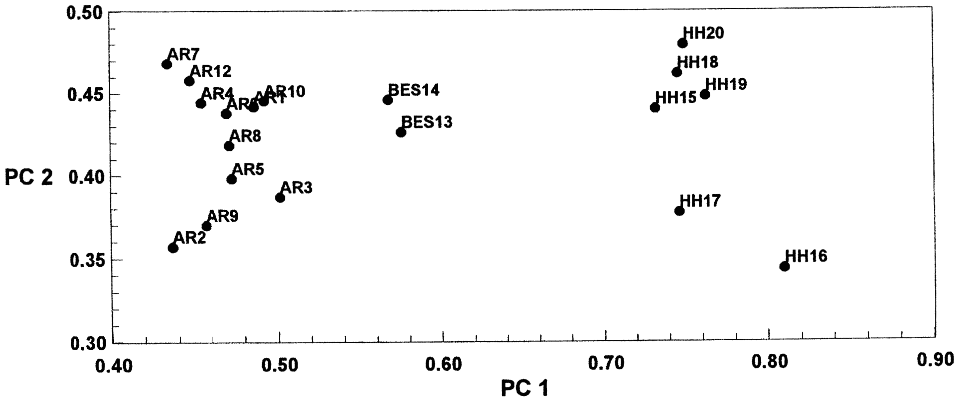

Fig. 3. Principal component analysis of morphometrical afinity into the sturgeon and hybrid samples after 6 meristic markers presented in Table 2. Explanations: AR = *A. ruthenus*; BES = bester (intergeneric hybrid of *A. ruthenus* x *H. huso)*; HH = *H. huso*; samples 1-10 see Table 2; sample (sa.) 12 – K r y l o v a (1980); samples 13 and 14 = F1 and F2 generation of bester after K r y l o v a (1980); sa. 15 – K r y l o v a (1980); sa. 16 – P r o k e š et al. (1995); sa. 17 – P a v l o v (1967); sa. 18 – B e r g (1948); samples 19-20 after A b d u r a k h m a n o v (1962).

The first eigenvector is explained mainly by Du and Sp. br. against SLa and SV whereas the second one is explained mostly by Du and Au against Sp.br.

Results of cluster analysis are shown in Fig. 4. There are two main clusters on the dendrogram, great sturgeon (HH) on the one hand, and sterlet (AR), bester and AR10 (CR) on the other hand. Interestingly, both the bester samples are very close to sterlet according to the 6 meristic markers used and the variation within the whole group is even lower than within the group of great sturgeon populations. As in the case of PCA, the AR10 sample clusters well with other sterlet (AR) populations, being morphologically closest to a pair of samples from the Danube River, analysed by O l i v a & C h i t r a v a d i v e l u (1972), and P a v l o v (1968), respectively.

M e n s u r a l c h a r a c t e r s

Compared size-pooled samples of sterlet from the CR and SR in 18 body characters studied (Table 3), statistically significant differences ($P \leq 0.05$) in one character (P length, diff. = -7.16%) and statistically highly significant differences ($P \leq 0.01$, $P \leq 0.001$) in four characters (A length, D height, caudal peduncle length and A height) with diff. 16.24–36.15% were found. In total, a significant difference was found in 27.78% of body characters compared. In contrast, the least differences (diff. less than 1%) were found in 4 characters (preventral distance, preanal distance, body depth and Smitt length). From the above data it is evident that specimens from the CR compared with those from the SR were noted for shorter pectoral fins, larger anal fin (longer and higher), shorter caudal peduncle and higher dorsal fin. The body shape, location of fins on the body and head length did not differ significantly.

When 14 selected mensural characters measured on the head were similarly compared, sterlets from the CR (versus SR) were noted for greater interocular distance, greater distance between snout tip and barbel bases, smaller distance between barbel bases and mouth margin and for wider head (Table 3). In specimens from the CR (versus SR), the significantly higher mean value of condition coefficient (CR: 0.4434, SR: 0.3835) and a steeper course of the length-weight relationship curve were found (Table 1).

Within morphometric comparisons of sterlet reared in the CR with sterlet mainly from natural conditions of the environment using the comparison of two size-pooled samples (one from the CR and the other as a mean from available data, see Tables 4 and 5), significant differences were found in 6 of 14 body characters analysed, i.e. in 42.9% of characters (Table 5). Within the range from minimum to maximum differences, the following characters are concerned: A length (9.21%), V length (12.77%), A height (14.05%), D length (-14.50%), body depth (14.99%) and D height (-20.66%). From these data it is evident that sterlet reared in the CR differed from the other sterlets (standards) compared in particular for longer head, greater anal fin (longer and higher), longer ventral fins, shorter pectoral fins, greater body depth and lower dorsal fin. In most cases (except for head length), the dependence between TL and analysed individual characters was of linear character. The determination coefficient (R^2) values were 0.9450–0.9999.

Trends of differences between size-pooled samples of bester reared in aquaculture (F1 and F2) and the sterlet mean sample (mainly from the natural environment) were analogous to differences found between the sample from CR and mean sample values from the literature data (Tables 4 and 5). For parameter dependence determination between head length and TL, the most suitable was the polynomial function with convex curve (Tables 4 and 5).

Analysing 13 mensural characters measurable on head (in sample from the CR versus literary data – Table 6), we found significant differences in 6 characters (i.e., in 46.2%). Specimens reared in the CR differed from the mean sample by longer snout (diff. 8.72%), greater interocular distance (24.22%), higher head (16.23%), greater distance between snout tip and barbel bases (12.59%), smaller distance between barbel bases and mouth margins (-15.25%) and by wider mouth (18.27%). In 7 characters, more suitable for expression of

Table 3. Mensural characters of 0+ juvenile specimens of sterlet aquaculture form from the CR and SR, represented and compared in absolute values (in mm). Explanation: a, b, R^2 = regression and determination coefficients of linear regression between TL and other mensural characters; comparisons = comparison of calculated values in individuals of the same size (TL = 200-350 mm, mean = 275 mm) from the both examples by mean differences (in % and by of Student's t- test, $n_1+n_2-2 = 60$; * P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001.

Character	Sa.	Coefficient			Comparisons				
		a	b	R^2	mean	S.D.	dif.(%)	t	P
Preventral distance	SR	15.219	0.1585	0.8981	58.8	7.09	-0.07	0.0228	0.9819
	CR	16.608	0.1533	0.7431	58.8	6.86			
Preanal distance	SR	-2.2692	0.6633	0.9945	180.1	29.66	0.6	-0.1402	0.889
	CR	-3.1695	0.6705	0.9592	181.2	29.99			
Body depth	SR	1.5464	0.1212	0.9494	34.9	5.24	0.61	-0.1291	0.8977
	CR	-9.1588	0.1609	0.8906	35.1	7.2			
FL	SR	-0.4145	0.8753	0.9966	240.3	39.14	0.99	-0.2333	0.8163
	CR	0.7383	0.8851	0.9647	242.7	39.58			
Predorsal distance	SR	4.3828	0.5805	0.9929	164	25.96	1.11	-0.2639	0.7927
	CR	-4.0752	0.6179	0.9725	165.9	27.63			
SL	SR	-0.4126	0.8128	0.9953	241.1	39.15	1.25	-0.2967	0.7677
	CR	-1.4796	0.8238	0.9705	244.1	39.58			
Body width	SR	2.0845	0.0985	0.9601	29.2	4.41	-1.37	0.3155	0.7535
	CR	-4.2833	0.1201	0.9137	28.8	5.38			
Body depth min.	SR	0.3386	0.0312	0.9615	8.9	1.4	1.48	-0.333	0.7403
	CR	-1.1521	0.0371	0.8991	9.1	1.66			
Range P-V	SR	-2.9407	0.326	0.9722	86.7	14.58	-2.1	0.4328	0.6667
	CR	-24.92	0.3993	0.9224	84.9	17.86			
Head length	SR	15.518	0.1659	0.9413	61.1	7.42	2.25	0.7053	0.4834
	CR	15.325	0.1716	0.8279	62.5	7.67			
Length D	SR	-3.5367	0.1256	0.9458	31	5.62	-3.47	0.8488	0.3993
	CR	4.7917	0.0914	0.7156	29.9	4.09			
Length V	SR	0.0003	0.0769	0.9404	21.2	3.44	4.56	0.1472	0.2558
	CR	3.2481	0.0686	0.7609	22.1	3.07			
Range V-A	SR	-9.4134	0.172	0.9586	37.9	7.69	7.06	-1.4123	0.163
	CR	-2.2289	0.1556	0.8675	40.6	6.96			
Length P	SR	7.1892	0.1307	0.905	43.1	5.85	-7.16	2.304	0.0247*
	CR	12.765	0.0992	0.6896	40.1	4.44			
Length A	SR	-1.7509	0.0536	0.9101	13	2.4	16.24	0.1664	0.0024**
	CR	-1.8143	0.0615	0.7571	15.1	2.75			
Height D	SR	3.1224	0.0598	0.8207	19.6	2.67	20.54	-5.5769	6E-07***
	CR	5.7384	0.0649	0.681	23.6	2.9			
Length of C peduncle	SR	-18.945	0.2004	0.9723	36.2	8.96	-20.85	4.1001	0.0001***
	CR	0.326	0.1029	0.7232	28.6	4.6			
Height A	SR	2.2032	0.0599	0.8734	18.7	2.68	36.15	0.442	0***
	CR	4.1148	0.0775	0.8038	25.4	3.47			

Table 4. Value of characters (in mm) used for comparison. Explanations: abbreviations of characters – see Methods; sample 1 (*A. ruthenus*) – N i k o l y u k i n (1972); sa. 2 (*A. ruthenus*) – K r y l o v a (1980); sa. 3 (*A. ruthenus*) – P a v l o v (1968); sa. 4 (bester F1) – K r y l o v a (1980); sa. 5 (bester F2) – K r y l o v a (1980); sa. 6 (bester F1) – N i k o l y u k i n (1972); sa. 7 (*A. ruthenus*) – our data from the SR; sa. 8 (bester F1) – N i k o l y u k i n (1972); sa. 9 sterlet aquaculture form from the CR (our results); sa. 10 (*A. ruthenus*) – M e n ' s h i k o v & B u k i r e v (1934); sa. 11 (*A. ruthenus*) – Lukin et al. (1981); sa. 12 (*A. ruthenus*) – K u c h i n a (1967 – cit. S o k o l o v & V a s i l y e v 1989); bester F1 and F2 = hybrids of *H. huso* x *A. ruthenus*.

Character	*A.r.*	*A.r.*	*A.r.*	Hyb. F1	Hyb. F2	H F1	*A.r.* (SR)	H F1	*A.r.* (CR)	*A.r.*	*A.r.*	*A.r.*
Sample	1	2	3	4	5	6	7	8	9	10	11	12
TL	138	208	217	225	229	254	273	283	289	341	523	554
Predorsal distance		124.0	129.5	132.1	136.7		162.8		173.7	203.6	321.1	339.0
Preventral dist.		108.4	113.9	119.0	122.7		139.8			174.3	271.4	290.9
Preanal dist.		136.2	140.6	146.3	152.1		178.8		190.2	224.0	346.7	370.6
Range P-V			66.8				86.0		89.9	106.1	175.2	195.6
Range V-A			27.8				37.5		42.5	48.8	80.5	
Length of C peduncle		23.9		26.3	25.2		26.1		29.8			
Body depth		18.3	24.5	22.3	24.7		34.6		37.0	37.5	55.4	70.9
Body depth min.		5.2	6.5	6.1	6.2		8.9		9.5	10.6	17.3	20.5
Length D		20.2	22.1	23.2	26.3		30.7		30.9	36.8	55.4	64.3
Height D		17.7	14.3	18.2	20.2		19.5		24.6	46.5		
Length A		10.0	11.3	10.4	13.1		12.9		15.9	17.6	27.7	28.8
Height A		17.I	15.0	17.8	20.2		18.5		26.3		48.6	
Length P			40.4				42.9		41.3	56.9	80.0	82.5
Length V			13.0				21.0		23.1		41.3	39.9
Head length	32.8	46.4	52.5	54.2	53.4	52.8	60.8	58.6	65.0	71.3	93.1	98.6
Preocular distance		23.3	25.5	25.6	25.4	27.1	29.5	28.0	31.8	30.4	35.3	40.2
Eye diamater		3.7	4.5	5.9	5.6		4.7		5.1	7.4	8.6	8.7
Supraocular distance		17.9	21.4	23.0	22.8		25.2		26.8	33.7	49.5	
Interocular width		11.4	13.3	13.7	13.8		16.5		20.5			29.7
Head depth		10.4	18.2	18.3	18.6		23.9		25.8		38.8	50.2
Head depth at eye		10.1		11.5	12.0		14.2		16.0			25.2
Snout - mouth distance		26.9	29.1	27.2	27.4		34.5		37.1		43.0	48.5
Snout - barbel dist.	8.8	17.9	19.5	20.1	17.3	19.6	21.7	19.0	25.3	23.2	24.8	29.6
Barbel - mouth dist.		9.1	9.6	10.2	10.2		12.8		11.5		18.6	
Barbel length	6.3	8.0	10.1	11.2	10.8	10.0	10.7	11.0	11.9		20.5	22.3
Snout width at barbels		10.2		10.9	10.5		15.8		16.5			
Head width	15.1	17.4		21.7	21.6	22.9	28.1	27.2	31.7			
Head width at mouth	11.3	14.2		16.7	16.6	18.7	20.8	21.2	22.9			
Mouth width	7.0	8.6	8.1	15.2	13.8	14.0	12.3	15.6	13.2		17.6	20.5

Table 5. Comparison of selected body mensural characters in sterlet (literature published data) and sterlet aquaculture form (CR sa.). Explanations: a,b,$R^2(1)$ = regression and determination coefficients of the linear regression for relation, dependence between TL and other mensural characters; literature published data = calculated mean values (in mm) of the concrete characters for individuals of *A. ruthenus* (see Table 3) with theoretical TL 289 mm (by presented regression); CR sa. = sample from the Czech Republic, absolute mean values (in mm), relative mean values (in % of TL); differ. (%) = differ. of mean value of literature data (summarized sa.) and CR sa.; differ. $R^2(1)/R^2(2)$ = difference between determination coeff. of linear regression $R^2(1)$ and deter. coeff. of polynomial regression $R^2(2)$; differ. H (in %) = difference between *A. ruthenus* (literature published data) and hybrid F1 (bester) and between *A. ruthenus* (literature published data) and hybrid F2 (bester).

Character	Regr. coeff.		Deter. coeff.		Liter. data		CR sa.		Differ.	Differ.	Diff.H (%)	
	a	b	$R^2(1)$	$R^2(2)$	(mm)	(%TL)	(mm)	(%TL)	(%)	R^2	F1	F2
TL					289.0	100	289.0	100	0.00			
Predors. dist.	-7.0532	0.6249	0.9998	0.9998	173.5	60.03	173.7	60.10	0.12	0.00	-1.09	-0.48
Preanal dist.	-5.7256	0.6764	0.9999	0.9998	189.8	65.67	190.2	65.81	0.24	-0.0001	-0.11	1.60
Length D	-3.2836	0.1178	0.9887	0.9874	30.8	10.66	30.9	10.69	0.45	-0.0013	-0.09	11.01
P-V	-17.194	0.3751	0.9947	0.9950	91.2	31.56	89.9	31.11	-1.44	0.0003		
Length C peduncle	13.116	0.0537		0.7105	28.6	9.90	29.8	10.31	4.07		4.37	3.22
V-A	-9.6184	0.1721	0.9999	0.9972	40.1	13.88	42.5	14.71	5.93	-0.0027		
Body depth min.	-2.5843	0.0399	0.9845	0.9852	8.9	3.08	9.5	3.29	6.18	0.0007	-4.59	-5.38
Head length	16.9860	0.1493	0.9825	0.8632	60.1	20.81	65.0	22.49	8.09	0.1193	7.16	4.35
Length A	-1.2207	0.0546	0.9962	0.9854	14.6	5.05	15.9	5.50	9.21	-0.0108	-6.00	16.11
Length V	-2.8671	0.0808	0.9768	0.9697	20.5	7.09	23.1	7.99	12.77	-0.0071		
Height A	-7.7192	0.1065	0.9792	0.9629	23.1	7.99	26.3	9.10	14.05	-0.0163	9.58	21.18
Length P	10.1560	0.1320	0.9889	0.9707	48,3	16.71	41.3	14,29	-14.50	-0.0182		
Body depth	-4.2659	0.1261	0.9462	0.9450	32.2	11.14	37.0	12.80	14.99	-0.0012	-7.49	0.36
Height D	-33.2660	0.2224	0.8464	0.7972	31.0	10.73	24.6	8.51	-20.66	-0.0492	8.50	14.36

Table 6. Comparison of selected body mensural characters in sterlet (literature published data) and sterlet aquaculture form (CR sa.). Explanations: a, b, c, R^2 = regression and determination coefficients of the linear and polynomial regressions for relation between TL and other head mensural characters; literature published data, CR sa., differ. (%) and diff. H (in %) = see explanation in Table 5; % lca = relative value of characters in % of head length.

Character	Coefficients				Liter. data		CR sa.		Differ.	Diff. H	(in %)
	a	b	c	R^2	(mm)	(% lca)	(mm)	(% lca)	(%)	F1	F2
Head length	-0.7981644	0.2702763	-1.681884E-04	0.9965	63.5	100.00	65.0	100.00	2.38	4.96	1.85
Preocular dist.	-2.499165	0.1503448	-1.401042E-04	0.9414	29.3	46.06	31.8	48.92	8.72	5.61	3.34
Eye diameter	-4.184089	4.739464E-02	-4.361906E-05	0.9553	5.9	9.24	5.1	7.85	-13.11	38.17	27.85
Supraocular dist.	-0.8245	0.0972		0.9907	27.3	42.99	26.8	41.23	-1.71	9.29	6.37
Interocular width	1.9661	0.0503		0.9907	16.5	25.98	20.5	31.54	24.22	3.13	-0.63
Head depth max.	-10.7796	0.1324485	-5.366514E-05	0.9317	23.0	36.25	25.8	39.69	12.08	12.27	11.11
Head depth at eye	-6.946413	9.633884E-02	-6.915667E-05	0.9999	15.12	23.81	16.0	24.62	5.82	2.40	4.44
Dist. snout-mouth	6.601086	0.1219645	-9.055405E-05	0.9567	34.29	54.00	37.1	57.08	8.19	-7.67	-7.99
Dist. snout-barb.	-7.869319	0.1560135	-1.765388E-04	0.9474	22.47	35.39	25.3	38.92	12.59	-6.99	9.84
Dist. barb.-mouth	-8.997121	0.1093581	-1.082038E-04	0.9999	13.57	21.37	11.5	17.69	-15.25	0.69	-1.64
Barbel length	0.8347	0.0381		0.9907	11.8	18.58	11.9	18.31	0.46	-5.31	19.06
Snout width at barb.	-7.7200	0.0862		0.9999	17.2	27.09	16.5	25.38	-4.02	-6.64	-12.64
Head width at mouth	18.36147	-0.1126091	4.452057E-04	0.9999	23.00	36.22	22.9	35.23	-0.44	7.31	4.26
Mouth width	2.4271	0.0311		0.9668	11.4	17.95	13.5	20.77	18.27	35.57	61.28

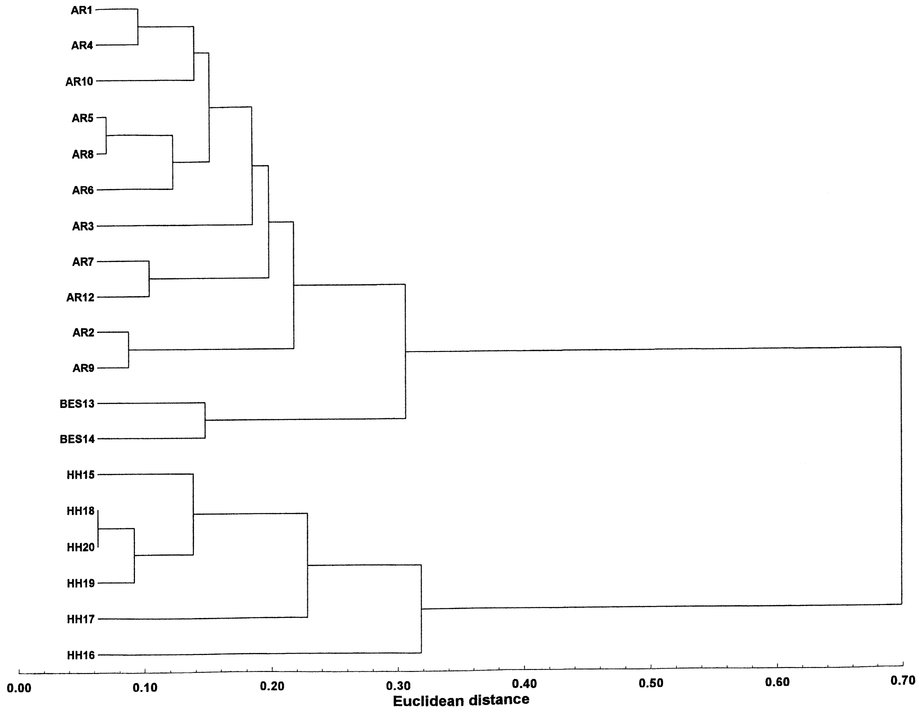

Fig. 4. UPGMA phenogram of morphometric affinity into the 11 sterlet samples, 2 bester samples and 6 great sturgeon samples. Explanations see Fig. 3.

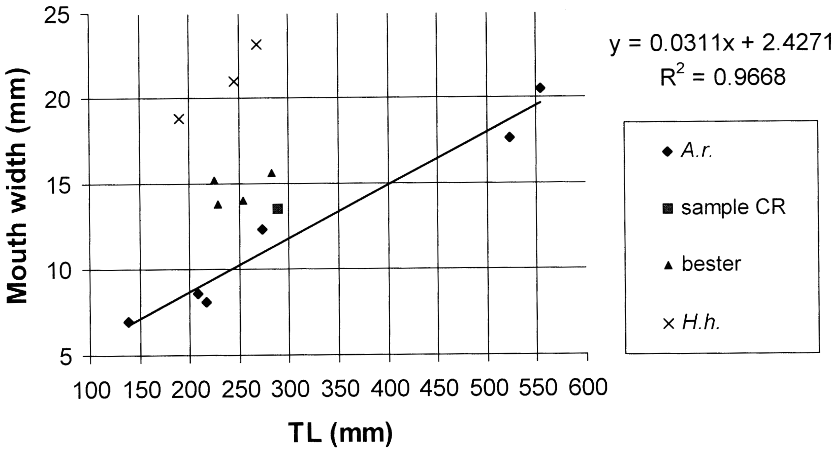

Fig. 5. Relationship between the mouth width and TL in specimens of sterlet, giant sturgeon and intergeneric hybrids, *H. huso* x *A. ruthenus* (bester) and in specimens reared in the CR.

dependence between the respective character value and TL was the polynomial function with convex curve (Table 6), which corresponds to the fact that the head relative size decreases with increasing TL and age in juvenile and adult specimens. The character of differences between size-pooled samples of bester (F1, F2) and the sterlet mean sample (standard value) was not analogical, as it was in the case of differences between the sample from the CR and standard of sterlet mainly from autochthonous populations (Table 5). The dependence course in important determinative mensural (head) character, mouth width, is expressed conclusively in Fig. 5. It is evident that the mouth width in sterlet from the CR is significantly greater than that calculated in so-called sterlet standard (diff. 18.22%), but simultaneously smaller than that in bester (diff. from -17.3% to 43.0%). The mouth shape in the material (juvenile specimens) from the CR is identical with that typical for sterlet. As well, the presence of barbel lashes (papillae) was proved in specimens from the CR and SR (Fig. 6).

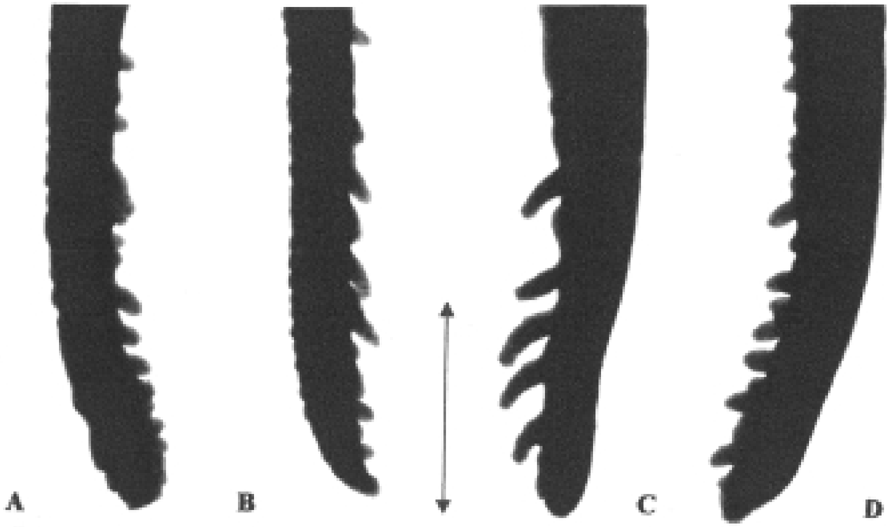

Fig. 6. Detail of barbels with touch papillae (lashes) situated in the lower third of their total length (A,D = outside barbels; B,C = inside barbels; line = 2 mm). Aquaculture form of sterlet reared in the CR.

Photo by B. Koubková

Discussion

The used method of morphometrical data comparisons between samples from the CR and SR and the data reported in the literature, using calculations of parameters of so-called standard regressions for each character analysed individually and in absolute values (in mm), appears in our case really applicable and needed regards elimination of errors, which could arise in comparisons of specially non-adjusted data, or in comparisons of relative values. According to the conclusions by J a n k o v i ć (1958), P a v l o v (1967, 1968) and other authors, sterlet is not noted for sexual dimorphism and significant biometrical differences within natural populations inhabiting various catchments. Therefore, it is possible to pool parameters of different samples into one set representing the so-called pure species (zoological taxon). Since the amount of the literature available data on meristics and mensural morphological characters of sterlet were largely limited as to sample numbers, we had to use all data available to us for calculations of needed regressions.

The conclusions found by analyses of meristic characters enable to the opinion that the samples from the CR and SR did not differ by character value ranges from the actually accepted morphometrical description for the sterlet species (Du 32–49, Au 16–34(39), SD 11–18, SL 56–71, SV 10–20, Sp. br. 11–27, Fu 25–45; H o l č í k 1989). However, as regards the mean values, 4 of 6 assessed meristic characters (66.6%) in the sample from the CR differed from the mean so-called standard data and this topic is discussed below. The trend of changes was in all cases towards the values found for bester F1 and F2. Significantly higher number of rays in A in specimens from the CR (27.1) as compared with the standard (but within 23–28 in individual samples) may be assessed as the result of environmental effects in special culture facilities, that of natural variability (cf. P a v l o v 1968), but also as the result of artificial reproduction and breeding. K r y l o v a (1980) found the mean number of rays in A in great sturgeon 30.79, in sterlet of 25.87, and in bester F1 and F2 28.06 and 28.27 respectively. The increased number of scutes (25.4) in the dorsal line in the CR sample, as compared with the standard, can be similarly of ecological and breeding consequences. K r y l o v a (1980) found in great sturgeon 13.81 scutae, in sterlet 13.7 scutae and in bester F1 and F2 14.92 and 14.13 scutae respectively. Significantly reduced number of scutae (13.0) in the ventral line in the SR sample, as compared with the standard (14.1) occurs outside the range of all other samples (13.4–14.6) and is close to the value found for bester F1 (13.06; K r y l o v a 1980). Statistically insignificantly increased value in ray number in D (in sample from the CR = 44.5), but outside the value range of all other samples (sterlet range = 38.4–44.1), occurs towards the value in bester F2 (47.96; K r y l o v a 1980). Statistically insignificantly decreased value in the mean number of scutae in lateral line in sample from the CR (44.5), again outside the species range (62.3–64.3), occured towards the value found in great sturgeon (45.38; K r y l o v a 1980). Significantly greater mouth width in sterlet from the CR is, according to our opinion, a phenomenon manifesting the adaptation to more productive aquaculture rearing, as we also found in Siberian sturgeon (P r o k e š et al. 1997a,b).

As regards the fact that, according to the results by F l a j š h a n s & V a j c o v á (2000), potential theoretical influences by sturgeon with 240 chromosomes can be excluded in the case of sterlet sample from the CR. On the basis of assessed and compared characters, we consider specimens reared in the Mydlovary Water Production Farm in the CR to be sterlet aquaculture population, with their meristic, mensural and other typical morphological characters, are close to the sterlet autochthonous population. Specimens reared under aquaculture in the SR approach very close to the Danube autochthonous sterlet population.

A c k n o w l e d g e m e n t s

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