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GROWTH OF STERLET *ACIPENSER RUTHENUS* UNDER EXPERIMENTAL AND FARM CONDITIONS OF THE CZECH REPUBLIC, WITH REMARKS ON OTHER STURGEONS

M. Prokeš, V. Baruš, J. Mareš, M. Peňáz, V. Baránek

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Abstract

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Growth rate of sterlet (*Acipenser ruthenus*) juveniles and adults was studied and compared with other sturgeon species under experimental and farm conditions in the Czech Republic. During the juvenile development (0+ to 5+) the specific growth rate (SGR) decreased successively from 17.67 to 0.05 %.d^{-1}. During the adult period of development (6+ to 13+), the SGR fluctuated from 0.0191 to 0.0562, mean = 0.0410 %.d^{-1}. In addition, body weight condition and length-weight relationship are presented. The adult period commenced at average age from 4 to 5 years. At the end of subsequent 13 years of life (1st–13th), following values of TL/w (in mm/g) in reared sterlet were determined: 250/53, 350/174, 400/250, 440/320, 465/400, 490/462, 516/525, 546/645, 561/720, 596/860, 610/1014, 625/1199, 660/1456. A very fast growth intensity was determined in the young sterlet (1st and 2nd year) while it decreased in the older fish. Growth intensity of other reared greater sturgeon species (*Huso huso, Polyodon spathula, A. gueldenstaedtii, A baerii, A. stellatus*), compared with sterlet in early juvenile period of ontogeny, were mainly higher.

sterlet juveniles and adults, specific growth rate, length-weight relationship, condition factor

In the present article we gather the summarised results of sterlet growth as obtained under experimental and farm conditions in the Czech Republic during first thirteen years of life as monitored within the period 1994–2010. Data observed are compared with published data from aquaculture and natural ecosystems.

A high attention paid to this species is mainly motivated by the fact, that it is an evidentially indigenous species for the lower stretches of the Morava and Dyje Rivers (Jeitteles, 1864; Mahen, 1927; Kux, 1956), and actually after Lusk *et al.* (2010) is critically endangered (CE). The managing of production technology (Gela *et al.*, 2008; Linhart *et al.*, 2010) enables to production of meet and caviar and to repatriate and/or to restaurate the sterlet as well as to produce them in aquaculture for recreational fishery and as ornamental fish.

The major information concerning growth indicators of acipenserid species cultured under experimental and farm condition in the Czech Republic, including the sterlet is mainly contained in the following publications: Adámek *et al.* (2007); Baránek *et al.* (2004, 2006); Baruš, Oliva *et al.* (1995); Hohausová *et al.* (1996); Klívar (1996); Kurfirst *et al.* (2000); Prokeš *et al.* (1996, 1997a, b, c, 2000a, b, 2003a, b) and Rybnikár *et al.* (2011).

Data on the growth of sterlet within its natural distribution area were published by Baruš, Oliva *et al.* (1995); Berg (1948); Holčík (1989, 1995); Iogansen (1946); Jankovič (1958); Kalmykov *et al.* (2009); Kováč (1997); Kovrižnych (1988); Lukin *et al.*

(1981); Musatov (1964); Ostroumov and Ogurtsov (1954); Pavlov and Mochek (2006); Petkevich (1956); Setsko (1976 a,b); Shmidtov (1939); Sokolov and Vasilyev (1989) and Stráňai (1992).

Questions on the status, progression and needs of a acipenserid farm culture in Europe, oriented especially to their active protection, which motivated acipenserid culture in the Czech Republic, are treated by Holčík *et al.* (2006); Bloesch *et al.* (2006); Reinartz *et al.* (2011) and Rosenthal *et al.* (2011).

MATERIALS AND METHODS

The growth of sterlet under experimental conditions of both productional and research institutions has been continuously followed in the Czech Republic since 1996. The research started with early 0+ juveniles in the hatchery Mydlovary, Rybníkářství Hluboká nad Vltavou, in the experimental laboratory of the Mendel University in Brno and in the experimental facility of the Institute of Vertebrate Biology ASCR in Brno. The juveniles studied originated from fertilized eggs imported from Russia (Fish farm Rybnoe near Moscow) in 1996 (Jirásek *et al.*, 1997; Prokeš *et al.*, 2000a,b). Hatchery in Mydlovary, thanks to its technical equipment and posssibility to regulate temperature guaranteed the optimum conditions to realize the research required.

The research of 0+ to 5+ juveniles and 5+ to 13+ adults has been realized in the fish farm Velký Dvůr, Rybníkářství Pohořelice. These individuals, tagged individually by means of chip marks, originated from the hatchery Mydlovary (since 1996) and from Slovakia (since 2002). The breeders were captured in the Slovak stretch of the Danube at Radvaň and Iža, artifical reproduction and culture of fry was realized at the experimental station in Častá (Baránek *et al.*, 2004; Meszáros *et al.*, 2004; Holčík *et al.*, 2006). The Danubian sterlets were identified genetically by Reinartz *et al.* (2011). Except of the special growth and production experiments performed in 1996, 2003, 2004, 2005, 2008 and 2009 all tagged specimens were measured and weighed twice every year, always in the spring and autumn. The results of individual experiments and of all annual measurements enabled the computationm of the average growth of juvenile and adult (age 0+ to 13+) sterlet under conditions of aquaculture in the Czech Republic. The growth of larvae is not included in present paper, it was published separately (Rybnikár *et al.*, 2011).

Following growth and production parameters were estimated: daily length and weight increments (DI), specific growth rate SGR = $[(\ln TL_1 - \ln TL_0).t^{-1}].100$, weight conditions expressed by means of the Fulton factor (coefficient), FWC or FCF = $(w.10^5).TL^{-3}$, length-weight relationship (TL:w) calculated as ($w = a.TL^b$) and the relationship between total and standard lengths (TL:SL) expressed as a linear regression (SL = a + b.TL), daily feeding ratio, DFR in % of the weight of fish reared and feeding conversion rate, FCR = $F.(w_1 - w_0)^{-1}$, as the quantitty of the food needed to produce the unit of increment. The feeding intensity was determined in % of the actual fish biomass with corrections according to the actual need, usually in the 1–2 week intervals following the control weighing. The temporal course of growth was documented using the polynomic regression ($y = a + bx + cx^2 \dots gx^6$). The t-test was used when testing the significance of differences found between two variants and the variance analysis for more variants. Methods used for other individual sturgeon species are more particularly described by Hohausová *et al.* (1996); Klívar (1996) and Prokeš *et al.* (1996, 1997a, b, c).

The conditions adjusted in the experimental and production rearing equipments (throughs, basins, storage ponds), as well as the technology and feeds, corresponded with the physiological requirements of concerning developmental stage and age of sterlets (Jirásek *et al.*, 1997; Prokeš *et al.*, 1997a; Baránek *et al.*, 2004, 2006). Except of the self-made feeds (Jirásek *et al.*, 1997), also the commercial feeds Alma, Danafeed and Skretting were applied.

RESULTS AND DISCUSSION

1 Growth during early juvenile period

High values of growth intensity as well as of the condition factor were found in the sterlet during first sixth months of life. Although this is the smallest sturgeon species cultured in the Czech Republic, its growth intensity was higher than that of the stellate sturgeon and only moderately lower than that of the Siberian sturgeon. The values of the parameters analysed (TL, w, FWC, TL:SL, TL:w and SGR) towards the end of the first up to the sixth months of age are indicated in Table I. There are also indicated data ascertained in other sturgeon species reared in similar way in the Czech Republic (Hohausová *et al.*, 1996; Klívar, 1996; Prokeš *et al.*, 1996, 1997a, b, c).

A more intensive growth of Siberian sturgeon was stated in a joint experimental culture of the two equally old groups of sterlet and Siberian sturgeon conducted in the Institute of Vertebrate Biology ASCR from 15 May until 29 August 1996 (Prokeš *et al.*, 1997a). In sterlet. the initial total length (weight) at the start of trial was 170.9 mm (22.8 g), and the final one after 107 days was 300.7 mm (108.2 g), in Siberian sturgeon the initial TL (w) was 153.5 mm (12.7 g) and final 378.3 mm (188 g). Corresponding specific growth rate (SGR) values ranged in sterlet 0.97–3.77% $w.d^{-1}$ and in Siberian sturgeon 2.05–6.06% $w.d^{-1}$. The conversion rate of both species (FCR) ranged 0.95–1.27 and daily feeding ratio (DFR) 3.56–1.03% of the weight. Values of the Fulton's condition factor were higher in the sterlet (0.45–0.37) than in the Siberian sturgeon (0.35–0.37).

According to the published data the sterlet's total length (TL) fluctuates under the natural river conditions within a rather broad range of 112–382 mm towards the end of the first year of

I: *Growth of early sterlet juveniles and others sturgeons reared under conditions of the Czech Republic in DAH 30-180. Explanations: DAH = day after hatching, FWC = factor of weight condition, SGR = specific growth rate, P.s. = Polyodon spathula (after Prokeš et al., 2000a), H.h. = Huso huso (after Hohausová et al., 1996), A.b. = Acipenser baerii (after Prokeš et al. 1996, 1997a), A.g. = A. gueldenstaedtii (after Prokeš et al., 1997b), A.r. = A. ruthenus, A.s. = A. stellatus (after Klívar, 1996).*

Species/Parametr	DAH	A.s.	A.r.	A.b.	A.g.	H.h.	P.s.
TL (mm)	30	28.3	65.4	63.8	63.2	62.5	69.7
	60	60.1	123.5	132.3	124.7	122.3	190.1
	90	97.9	175.1	193.1	193.5	191.3	339.2
	120	131.9	220.1	246.3	247.0	264.6	422.9
	150		258.6	291.7	285.0	313.2	461.0
	180		290.6	329.2	317.0		473.3
w (g)	30	0.18	1.00	0.81	1.49	2.57	1.22
	60	0.76	9.26	10.04	7.70	9.72	38.30
	90	2.94	21.30	27.10	29.00	36.16	148.00
	120	7.95	39.60	50.96	54.00	76.98	259.60
	150		64.10	80.57	85.00	109.77	358.60
	180		94.90	114.89	120.00		430.60
FWC	30	0.7942	0.3539	0.3119	0.5902	1.0527	0.3603
	60	0.3501	0.4916	0.4336	0.3971	0.5314	0.5575
	90	0.3133	0.3968	0.3764	0.4003	0.5165	0.3792
	120	0.3464	0.3714	0.3411	0.3583	0.4155	0.3432
	150		0.3707	0.3246	0.3672	0.3573	0.3660
	180		0.3867	0.3220	0.3767		0.4061
SGR	60	4.80	7.45	8.39	5.47	4.43	11.49
	90	4.51	2.78	3.31	4.42	4.38	4.51
	120	3.31	2.07	2.11	2.07	2.52	1.87
	150		1.61	1.53	1.51	1.18	1.08
	180		1.31	1.18	1.15		0.61

life (Table IV, Fig. 2). Data of the length growth of sterlet and of some other sturgeons and their hybrids observed under experimental conditions are presented and compared by Gershanovich *et al.* (1987); Ronyai *et al.* (1991); Hochleithner (1993); Jähnichen *et al.* (1999); Kolman (1999); Krupka *et al.* (2000); Sadowski *et al.* (2000) and Napora-Rutkowski *et al.* (2009). Total length reaches towards the end of the first year of life 175–310 mm. The weight growth of sterlet in rivers and reservoirs was studied by Jankovič (1958); Frantsuzov (1958); Musatov (1964); Ambroz (1972); Kovrižnych (1988); Pavlov and Mochek (2006) and Kalmykov *et al.* (2009). According to them the 0+ sterlet reaches 20–40 g towards the end of vegetation period while 26–42 g when reaching 1 year of life. Our results from the productional rearing suggest a high growth potential of 0+ individuals. The growth rate of length goes in our case beyond the data known from natural conditions (related to older individuals after wintering). The weight growth is similar to data by Jankovič (1958), however considerably exceeding data by Kovrižnych (1988). The growth and other biological parameters found in sturgeons and their hybrids reared in the Central Europe are summarized by Steffens *et al.* (1990) and in the bibliography by Hochleithner *et al.* (1999).

Prokeš *et al.* (1997a) found a mortality rate of 6.38 % in the 0+ sterlet while a null mortality in the 0+ individuals of Siberian sturgeon if the oxygen concentration declined to 1.7 mg.l^{-1}. The oxygen concentration of 1.7 mg.l^{-1}, being the critical one for survival of sterlet, corresponds with data by other authors (more particularly by Prokeš *et al.*, 1997a). This value is somewhat higher than that found e.g. in juveniles of the giant sturgeon (the lower tolerance O_2 limit is 1.2–1.4 mg.l^{-1}) and of the Russian sturgeon (1.1–1.7 mg.l^{-1}).

The food conversion rate, reaching a value of 1.0 at a daily feeding ratio of 2.9–2.5 % of the mean mass of individuals weighing 30–290 g in the experimental breeding realised in the IVB ASCR at Brno (Prokeš *et al.*, 1997a) well illustrates the extraordinary high feeding capability of the sterlet and Siberian sturgeon fed with granulated feeds. The behavioural observations realised during the aforementioned experiments verified the possibility of a joint intense culture of both sturgeons in the Czech Republic. Neither the symptoms of aggressive behaviour nor the health changes were observed in the joint breeding of both sturgeon species, the mortality remained extremely low.

II: *Basic characteristics of age samples (6–13 years) in adult sterlets. detected in fish hatchery Velký Dvůr. Fishery Unit Pohořelice Inc.*

Parametr	Value	6	7	8	9	10	11	12	13
	n	61	62	70	218	134	79	40	40
TL(mm)	Min.	320	435	473	528	570	586	600	630
	Max.	560	585	622	645	665	668	680	720
	Aver.	490.5	515.8	545.9	561.3	595.9	609.7	624.7	659.5
	SD	41.5803	35.1042	29.0763	24.4088	23.3146	20.9446	20.2073	21.1236
w(g)	Min.	116	316	407	446	677	703	900	1100
	Max.	678	822	954	1120	1521	1523	1699	2050
	Aver.	461.5	525.0	644.5	700.9	945.1	1013.5	1198.7	1455.8
	SD	111.3444	106.2157	125.8000	133.1512	151.8835	153.0302	170.3812	201.6075
FWC	Min.	0.3257	0.2903	0.2801	0.2801	0.3406	0.3406	0.3965	0.4078
	Max.	0.4576	0.4887	0.4970	0.5357	0.5427	0.5312	0.5943	0.5983
	Aver.	0.3829	0.3800	0.3908	0.3932	0.4446	0.4457	0.4948	0.5055
	SD	0.0312	0.0406	0.0434	0.0437	0.0409	0.0419	0.0467	0.0443

III: *Total length-standard length relationship (TL:SL) and length-weight relationship (TL:w) in juvenile and adult sterlets from the hatchery Velký Dvůr, Fishery Unit Pohořelice Inc. Explanations: a, b = regression coefficients. R^2 = determination coefficient.*

Relation shipp	Range TL (mm)	Coefficient			n
		a	b	R^2	
TL:SL	141–460	11.376	0.9048	0.9842	149
TL:SL	400–720	52.820	0.7510	0.8406	1656
TL:w	141–460	2.00E-07	3.4834	0.9671	149
TL:w	400–720	7.00E-08	3.6553	0.8649	1656

2 Growth during juvenile and adult period

The sterlet, cultured at the hatchery Velký Dvůr, exhibited the following mean values of total length and weight towards the end of the first up to the 13th year of life (TL in mm/w in g): 250/53, 350/174, 400/250, 440/320, 465/400, 490/462, 516/525, 546/645, 561/720, 596/860, 610/1014, 625/1199, 660/1456. The data concerning the first five years were analysed already by Prokeš *et al.* (2003b) and Baránek *et al.* (2004, 2006) while data concerning the age 6 to 13 years, are presented in Table II and III. Sterlet are distinguished with a very good growth intensity during the first two years of life, however, compared with other sturgeons, it is slowing down during the following years which is related to its smallest size.

Different values of the specific growth rate (SGR) may be ascertained during the juvenile (0+ – 5+ yrs) and the adult (5+ to 13+ yrs) periods of development. The maximum SGR values reaching 18.00–7.00 $\%.d^{-1}$ were found in late larvae and early juveniles (DAH 30 – 60; age 0+). During the subsequent part of juvenile period, from DAH 60 up to the age 5+, the SGR values subsequently diminished from 7.00 to 0.05 $\%.d^{-1}$. Under the routine culture we found the SGR value 2.3489 $\%.d^{-1}$ during the second year of life (age 1+), 0.3259 $\%.d^{-1}$ during the third year (2+) and 0.0996 $\%.d^{-1}$ during the fourth year (3+). In the adult individuals, aged 6+ to 13+, the SGR values ranged 0.0191–0.0562, averaging 0.0410 $\%.d^{-1}$. Somewhat higher SGR values were obtained in some specific feeding experiments lasting less than one year (Fig 1). Very good production parameters were achieved during the experiment realised in 2003: in age category 1+ (initial mean weight of 99.5, 71.2 and 53.8 g) using DFR 1.6, 1.7 and 2.1 %, respectively, SGR 0.88, 0.73 and 0.59 $\%.d^{-1}$, resp., and FCR 1.35, 1.39 and 1.42, respectively.

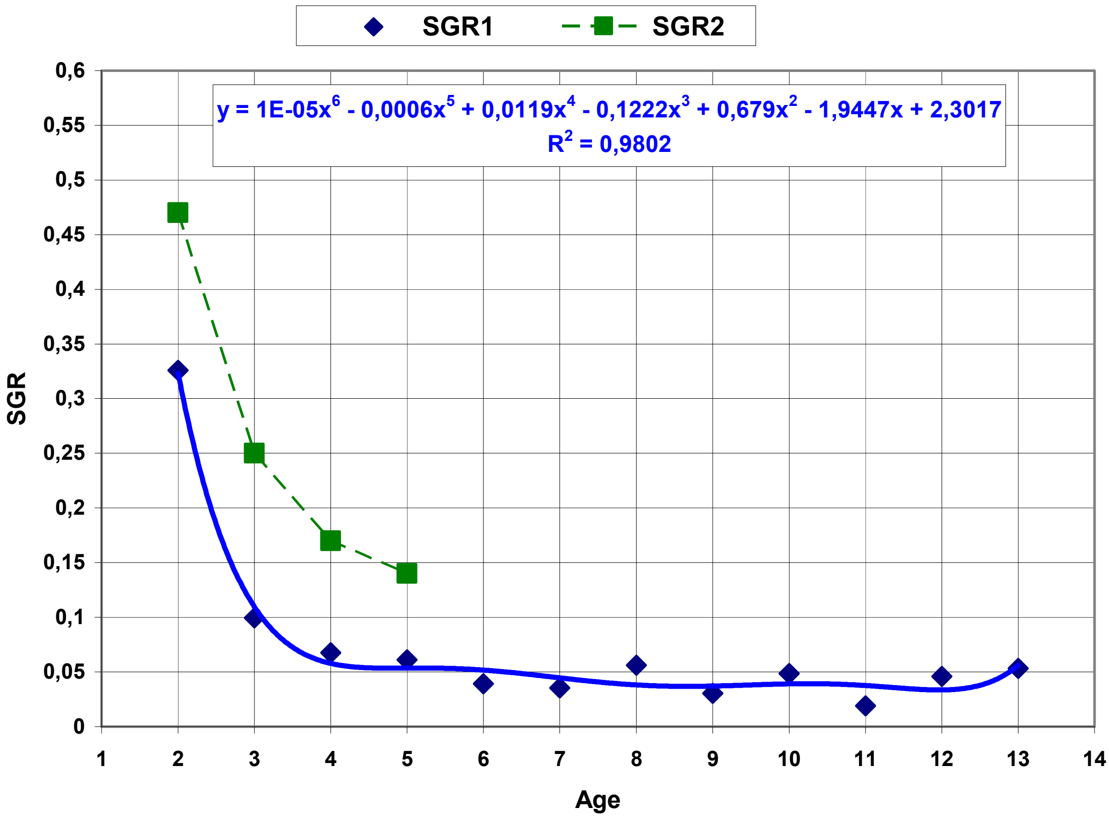
When analysing the weight condition (FWC), a distinct increase was found during the first two years of life (0.34–0.40). During the age range from 2+ to 9+ the FWC values reached 0.38–0.41, however they significantly increased (0.41–0.51) during the following period (age 9+ – 12+).

3 Comparison of sterlet growth under farm and natural conditions

The growth of length of the sterlet reared under farm conditions compared to the population living under natural conditions of the Slovakian Danube (in years 1–8), reported by Kovrižnych (1988); Stráňai (1992) and Kováč (1997) was faster (Table IV). The sexual maturation of sterlet in artificial culture first appears when reaching TL of 400 mm at age of 5 years. A similar experience was obtained also by Kovrižnych (1988) in native Danube population and later repeatedly confirmed on hatcheries Mydlovary (since 2001) and Velký Dvůr (since 2006) where succesful reproduction in aquaculture, egg incubation and rearing of larvae have been conducted. This was first times since the end of

IV: *Length growth of sterlet (TL mm) in aquaculture of the Czech Republic (Fishery Unit Pohořelice Inc.) and in the Slovakian stretch of Danube River. Explanations: Aquac. CR = aquaculture in the Czech Republic, Danube-1 = after Kovrižnych (1988), Danube-2 = after Stráňai (1992), Danube-3 = after Kováč (1997)*

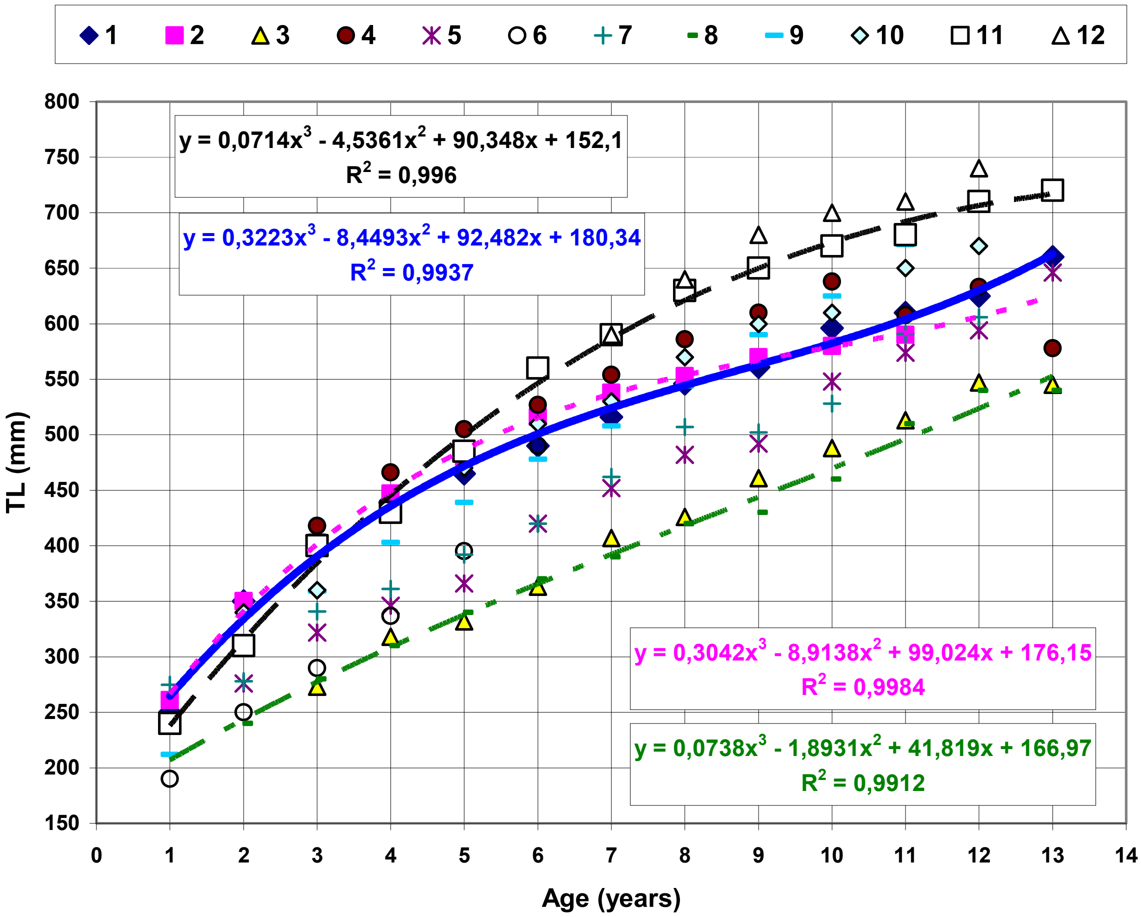
Age	Aquac. CR	Danube – 1	Danube – 2				Danube – 3	
			long rostrum		short rostrum			
	aver.	aver.	range	aver.	range	aver.	range	aver.
1	250	252	156–250	195	151–281	212	173–339	251
2	350	319	222–345	287	217–379	304	264–422	332
3	400	365	297–388	339	292–417	359	313–485	386
4	440	396	322–456	377	348–484	403	359–507	413
5	465	430	341–490	419	347–568	439	427–448	438
6	490	462	415–505	451	407–592	478		
7	516	499	442–540	484	437–627	508		
8	546	530	468–570	522	465–662	544		
9	561	574	541–580	561	553–680	590		
10	596	620	565–600	582	586–704	626		
11	610				610–730	671		
12	625				680–750	713		
13	660							



1: *Average values of specific growth rate (SGR1) in the sterlet juvenile and adult individuals, ascertained in yearly intervals at routine breeding in the fish hatchery Velký Dvůr, Fishery Unit Pohořelice Inc.(continuous line). Comparison with values (SGR2) reach in to juvenile individuals at specific feeding experiments in intervals shorter than one year (dashed line).*

nineteenth century when the first attempts were made to reproduce and culture the sterlet in the CR.

A breeding shoal, reproducing in a closed cycle, was thus created of adult sterlets originating from Danubian population. This breeding shoal is registered as a genetical source of commercially important fish species of the CR (Flajšhans *et al.*, 1999).



2: *Length growth (TL) of sterlet (A. ruthenus) in aquaculture of the Czech Republic (1– full line) and in natural conditions of rivers Danube (2, 9); Volga (3, 10, 11, 12); Kama (5); Oka (6); Ob (7); Irtysh (8) and in the Kuybishev Reservoir (4). Explanations: 1 – aquaculture in the Czech Republic (continuous line); 2 – Danube short-snout form, Jankovič (1958) (dotted line); 3 – Volga, Lukin (1937), citation according to Berg (1948); 4 – Kuybishev Reservoir (river Volga), Lukin et al. (1981); 5 – Kama, Shmidtov (1939); 6 – Oka, Musatov (1964); 7 – drainage area of the Ob River, summary from Pavlov & Mochek (2006); 8 – Irtysh, Berg (1948) (dot-and-dashed line); 9 – Danube, Slovakian section, short-snout form, Stráňai (1992); 10 – Volga near Volgograd, Kalmykov et al. (2009); 11 – Volga, Eastern delta, Kalmykov et al. (2009) (dashed line); 12 – Volga, Western delta, Kalmykov et al. (2009).*

All this, with respect to the growth rate and condition achieved as well as to the favourable course of maturation, is indicative of a high sterlet productive prosperity in aquaculture.

The length growth (TL) of sterlet in the hatchery Velký Dvůr and in natural conditions of rivers Danube, Volga, Kama, Oka, Ob, Irtysh and in the Kuybishev Reservoir is presented in Fig. 2. The length growth of individuals reared in the Czech aquaculture seems to be similar to most of native sterlet populations inhabiting natural distribution area only during the juvenile period of life at the age of 1+ to 4+. A slightly slower growth rate appears from the age 5+, obviously as a consequence of sexual maturation. Jankovič (1958) found a very similar growth pattern in sterlets from the Serbian Danube stretch (Fig. 2). The values of sterlet's length growth observed in the Czech aquaculture can be considered as a mean one within the known range. This fact can be considered as evidence of a good adaptation to the conditions of aquaculture.

SUMMARY AND CONCLUSIONS FOR FARMING AND CONSERVATION ACTIVITIES

All the hitherto results of the culture bear the evidence that both the sterlet sturgeon and Siberian sturgeon must be considered valuable species suitable for intensive aquaculture in the Czech Republic. Sterlet is an autochtonous species for the ichthyofauna of the Czech Republic and the Slovak Republic (Baruš, Oliva *et al.*, 1995; Lusk *et al.*, 2010), however its natural occurrence there is presently dependent on artificial stocking (Lusk, 1992; Hanel and Lusk, 2005; Holčík *et al.*, 2006; Lusk *et al.*, 2010). Management technology of artificial reproduction and breeding of fish for stocking are succesfully elaborated and economically efficient. According of Reinartz *et al.* (2011) and Lenhardt *et al.* (2004), the genetically and morfometrically defined breeding shoal of sterlet originating from the Slovak Danube stretch is available for reintroduction and repatriation into the lower reaches of the Morava and Dyje Rivers. Sufficient theoretical and user-oriented bases were created to corroborate and realize the project aiming at acquirement of conservation goal, i.e. the biodiversity conservation after recommendation by Rosenthal *et al.* (2011).

It is highly recommendable to stock the sterlet, the indigenous species for the Czech Republic, into running waters (up to at least 15–30 thousands of juveniles are available and may be stocked yearly). In neighbouring Germany and Austria was e.g. 8 tons small sturgeon in the year 1999 produced (Williot *et al.*, 2001). Siberian sturgeon is, due to its high resistance and higher growth rate, a more productive species for aquaculture only. Because it is non-native for the CR, the introduction of this species into the natural waterbodies of the CR comes not into question. Its natural reproduction can not be anticipated not even in cases of accidental escape.

Experimental breeding and research of other four sturgeon species (*H. huso, P. spathula, A. gueldenstaedtii* and *A. stellatus*) continues under conditions of the Czech Republic, nevertheless they seem to be less significant and more problematic for the time being. Under natural environmental conditions, eventually in aquaculture of other countries, the growth of these greater species is significantly faster than in sterlet (Baruš, Oliva *et al.*, 1995; Holčík, 1989).

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Address

Ing. Miroslav Prokeš, CSc., prof. Ing. Vlastimil Baruš, DrSc., Ing. Milan Peňáz, DrSc., Ústav biologie obratlovců AV ČR, v. v. i., Květná 8, 603 65 Brno, Česká republika; prof. Ing. Vlastimil Baruš, DrSc., Katedra zoologie a rybářství, Česká zemědělská univerzita v Praze, Kamýcká 129, 165 21 Praha 6, Česká republika; doc. Ing. Jan Mareš, Ph.D., Ústav zoologie, rybářství, hydrobiologie a včelařství, Mendelova univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika; Ing. Vít Baránek, Ph.D., Povodí Moravy, s. p., Dřevařská 11, 601 75 Brno, Česká republika; e-mail: prokes@brno.cas.cz, barus.vl@seznam.cz, milan.penaz@volny.cz, mares@mendelu.cz, baranek@pmo.cz