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GROWTH OF SIBERIAN STURGEON (*ACIPENSER BAERII*), RUSSIAN STURGEON (*ACIPENSER GUELDENSTAEDTII*) AND HYBRID (F1 *A. BAERII* X *A. GUELDENSTAEDTII*) REARED IN CAGES

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Abstract

The study clarifies the growth of Siberian Sturgeon, Russian Sturgeon and their hybrid grown on an industrial cage farm. Three groups within each genotype of male individuals with different initial body weight were formed, as follows: Russian Sturgeon - I - 2.504±0.060 kg; II - 3.042±0.063 kg; III - 3.693±0.074 kg; Siberian Sturgeon - I - 1.395±0.034 kg; II - 2.277±0.065 kg; III - 2.925±0.066 kg; Hybrid (Siberian Sturgeon x Russian Sturgeon) – I - 2.081±0.050 kg; II - 3.049±0.051 kg; III - 3.704±0.058 kg. It was found that in I and II group of Siberian Sturgeon the relative growth for the whole period was practically the same, respectively 59.1 and 57.9%. The fish from group III had a significantly smaller growth (24.6%). In Russian sturgeon, in the case of fish that are growing slower at the beginning of the growing season, a mechanism for compensatory growth is established. The smallest fish grew best at the beginning of the period and the second and the fish from third group grew at the end of the growing season. In this species, the total relative growth in group I was 39.5%, group II - 15.2%, group III - 12.0%. The relative growth over the whole period in the hybrid of I, II, III groups was 75.3%, respectively; 23.7%, 26.7%.

Key words: *aquaculture, body weight, cage – farm, genotype, sturgeon.*

INTRODUCTION

The development of sturgeon breeding is conditioned, on the one hand, by the delicacy harvested production and, on the other, by the global critical status of natural populations of sturgeon species, which is why their catch in many countries is prohibited (Bloesch et al., 2005; Vasileva, 2015, etc.).

Unlike in Europe, where in general sturgeon breeding is not sufficiently developed (WWF, 2012), regardless of the importance of the industry, in Bulgaria sturgeon breeding is developing intensively.

The country ranks twelfth in the world for total sturgeon biomass and eighth for caviar production (Bronzi et al., 2019). Initially, the Bulgarian sturgeon breeding was based on the Russian sturgeon, but gradually other species were introduced, such as Beluga, Sterlet, and Stellate sturgeon.

In recent years, the share of Siberian sturgeon has increased (Nikolova, 2019). Along with keeping the species in pure condition, hybridization between them is often used to increase production efficiency.

Ponomareva et al. (2019) note that the study of the characteristics related to the fishery productivity of sturgeon hybrids under specific growing conditions enables them to be successfully implemented in aquaculture production.

Kocabaş et al. (2015) emphasize the lack of information on the growth of sturgeons when reared in aquaculture farms, especially in the growth-out phase. The authors have studied the growth of Russian sturgeon in circular fiberglass tanks for 5 years. The growth of Siberian sturgeon in basins has been studied in the Czech Republic (Kurfürst et al., 2000), in indoor fiber-glass tanks in Iran (Zare et al., 2009).

Despite the good development of sturgeon farming in Bulgaria, research in this field is extremely insufficient. Separate studies have been conducted only on natural populations (Peycheva et al., 2004; Dobrovolov et al., 2004, 2005; Tsekov et al., 2008; Tsecov and Tsecov, 2013).

The main technology of sturgeon breeding in Bulgaria involves the separation of fish by sex, with females being used to produce caviar and males not included in breeding flocks being sold

for meat. In this regard, it is necessary to know the patterns of growth, the timing for the rational fattening of male fish in specific conditions when grown on industrial farms.
The purpose of this study is to investigate the growth of male individuals of the Siberian sturgeon (*Acipenser baerii*), the Russian sturgeon (*Acipenser gueldenstaedtii*) and their hybrids (F1 *Acipenser baerii* x *Acipenser gueldenstaedtii*), with different initial body weight, reared on a cage farm.

MATERIALS AND METHODS

The study was conducted at an industrial cage farm.
The cages are located in a warm water reservoir with an average altitude of about 280 m in Southeastern Bulgaria. The reservoir has an area of 16.07 km^2 and a volume of 532.9 x 106. m^3.
At the beginning of the season, experimental groups with average body weight (BW) were formed as follows: 1. For a four-summer old Siberian sturgeon (Ab) - 1.395 ± 0.034 kg (group I); 2.277 ± 0.065 kg (II gr.); 2.925 ± 0.066 kg (III gr.). 2. For six-summer-old Russian sturgeon (Ag) - 2,504 ± 0.060 kg (group I); 3,042 ± 0,063 kg (II gr.); 3,693 ± 0.074 kg (III gr.); 3. six-summer-old Hybrid (Ab x Ag) - 2.081 ± 0.050 kg (group I); 3,049 ± 0,051 kg (II gr.); - 3.704 ± 0.058 kg (III gr.). Each group was grown in a separate cage. The cages are 8x8 m in size, with a depth of water surface of 6 m. Each cage is equipped with double polyamide nets. Planting density was 20 kg m^{-2}.
Samplings were made during the growing season (223 days), weighing 50 randomly selected individuals from each experimental group.
The fish were fed with a factory-specialized completed granulated sturgeon feed. The composition of the feed mixture is shown in Table 1.
The relative increase (K) of fish for each period between samplings was determined by the formula:

$$K = \frac{W_1 - W_0}{W_0} \times 100\%$$
;

where W_0 is the initial body weight, kg; W1 - final body weight for each period, kg.

IBM SPSS Stasistics 21 was used for statistical processing.

RESULTS AND DISCUSSIONS

The results of the experiment show that when reared in a cage industrial farm Siberian sturgeon, Russian sturgeon and their hybrid have good growth capacity. The fish grew throughout the whole growing season, including the October-December period (Table 2).
However, trends in the growth of individual groups are different. In addition, we found in the comparative analysis that the initial body weight does not always linearly determine the final body weight.

Table 1. Proximate composition of fish diet

Indices	Percent of dry weigh
Crude protein, %	46
Crude fat, %	15
Crude fiber, %	1.4
Ash, %	6.5
P, %	1.03
Ca, %	1.4
Na, %	0.3%
Vitamin A, $IU.kg^{-1}$	10 000
Vitamin C, $mg.kg^{-1}$	520
Vitamin E, $mg.kg^{-1}$	200
Vitamin D_3, $IU.kg^{-1}$	2 303
Gross energy, $MJ.kg^{-1}$	21.0
Digestible energy, $MJ.kg^{-1}$	19.2

With significant intergroup differences in body weight at the beginning of the period, a compensatory growth is observed in some of the groups, which practically eliminates the differences.
In Siberian sturgeon, the fish from the first group (with the lowest BW) were significantly different from the other body weight groups from the beginning to the end of the observed period. The difference between the first and second and first and third groups in May was 0.882 kg ($p<0.001$) and 1.530 kg ($p<0.001$), respectively. In December, the difference between the first two groups increased by 56.2%, reaching 1.378 kg ($p<0.001$), and between the first and third groups - practically remained - 1.425 kg ($p<0.001$). Second- and third-group fish are nearly levelling at BW at the end of the season. The difference in the sign in May is 0.648 kg ($p<0.001$) and in December 0.047 kg ($p>0.05$).

Table 2. Growth indices of individual species and hybrids, kg

Group	Period	Ab (n=600)			Ag (n=600)			Ab x Ag (n=600)		
		$\bar{X}$	SE	SD	$\bar{X}$	SE	SD	$\bar{X}$	SE	SD
I	May	1.395	0.034	0.242	2.504	0.060	0.429	2.081	0.050	0.357
	June	1.445	0.054	0.385	3.180**a**	0.075	0.531	2.780	0.060	0.427
	October	2.022	0.084	0.590	3.365**b**	0.090	0.634	3.238	0.086	0.607
	December	2.220	0.084	0.596	3.492**c**	0.062	0.435	3.647**a**	0.112	0.790
II	May	2.277	0.065	0.458	3.042	0.063	0.447	3.049	0.051	0.361
	June	2.716	0.080	0.564	3.202**a**	0.083	0.583	3.423	0.066	0.470
	October	3.531**a**	0.106	0.749	3.279**b**	0.103	0.727	3.607	0.092	0.652
	December	3.598**b**	0.123	0.867	3.503**c**	0.079	0.561	3.771**a**	0.084	0.592
III	May	2.925	0.066	0.468	3.693	0.074	0.498	3.704	0.058	0.411
	June	3.177	0.070	0.496	3.721	0.074	0.526	3.852	0.068	0.480
	October	3.619**a**	0.092	0.650	3.843	0.096	0.676	4.480	0.084	0.595
	December	3.645**b**	0.064	0.451	4.137	0.099	0.699	4.691	0.107	0.758

The differences between the values without index, within the month, in the columns are significant - p <0.01
The values with the same index in the columns are not significant: a; b; c - p> 0.05

The Russian sturgeon, unlike the Siberian sturgeon, the fish with the highest BW (group III) significantly exceeded the other two groups from the beginning to the end of the observed period. The difference between the third and first and third and second groups in May was 1.189 kg (p<0.001) and 0.651 kg (p<0.001) respectively, and in December, respectively 0.645 kg (p<0.001) and 0.634 kg (p<0.001). The fish in the second group, compared to the first one, in May have 0.538 kg (p<0.001) higher BW, and in June the fish from the two groups practically equalized in the BW, the difference in advantage of the second group is only 0.022 kg (p>0.05). In the period June-October, the fish in the second group continued to lag in growth and at the end of the period the difference is 0.086 kg, although insignificant (p>0.528), was in advantage of the first group. At the end of the growing season, the relevant average body weight of the fish in the two groups is practically the same, with a difference of 0.011 kg (p>0.05) in advantage of the second group.

The hybrid growth trends are similar to those of the Russian sturgeon. The group with the highest body weight at the beginning of the observation (group III) significantly exceed the other two groups throughout the growing season. At the beginning of the season, the difference between the third and the first, and the third and second group is 1.623 kg (p<0.001) and 0.655 kg (p<0.001) respectively, and in December - 1.044 kg (p<0.001) and 0.920 kg (p<0.001). Unlike the Russian sturgeon, however, a similarity of BW between the fish in the first and second group was reported at the end of the period in December, and during the whole period the difference gradually decreased: May - 0.968 kg (p<0.001); June - 0.643 kg (p<0.001); October - 0.369 kg (p<0.001); December - 0.124 kg (p = 390).

The features of the growth of the fish can be clearly seen in the figures, which show the dynamics of relative growth. Figure 1 shows the growth of the Siberian sturgeon. In general, this species is introduced into Bulgarian aquaculture later, compared to Russian sturgeon, but gradually its share is increasing, displacing other sturgeon species. Falahatkar (2018) notes that Siberian sturgeon is one of the best sturgeon for captive breeding and shows high growth rates under different conditions. There is a successful attempt to cultivate the species on trout farms when feeding on trout mixtures (Köksal et al., 2000). Zare et al. (2009), in a study of the growth of three-year-old Siberian sturgeons, found that fish of the species are tolerant of high density stocking, successfully cultivated in fiber-glass tanks and individuals, with an average initial body weight of 460 g have reached an average final body weight of 668.8 g for a period of 61 days. Yazdani Sadati and Vlasov (2006) found that fish growth was dependent on initial body weight in a study of the growth of one-year-old Siberian sturgeon reared in tanks. The biggest ones had higher growth - up to 1.6 times compared to the average ones and up to 1.3 times compared to the smallest ones.

In our experiment, the highest relative increase in Siberian sturgeon - 59.1% had the smallest fish (group I), with fish from the intermediate group (group II) approaching them considerably - 57.9%. The third group of fish grew considerably less, with a relative increase of

24.6%. The difference in relative growth between the first and third group is 2.4 times. At the beginning of the season, the second group of fish increased most intensively, with a relative increase of 19.3% from May to June. In the same period it was 3.6% in the first group and 8.5% in the third. During the period June - October, the fish of the second group continued to grow intensively. Their relative growth was 29.8%, but the highest growth for the period was reported in the first group - 39.9%. Compared to the first group, the fish from the third group increased almost three times less. Between October and December, growth rates decreased considerably, to 9.9% in the first group and up to 1.9% in the second group. The third group of fish did not increase during this period, with a relative increase of 0.7%.

Analyzing the growth dynamics of Russian sturgeon, it can be seen that there is a compensatory growth in the following periods (Figure 2), with the fish growing less early in the growing season. At the beginning of the season, the smallest fish (the first group) grew best, and from May to June they accumulated the major part (27%) of the growth received during the whole period (39.5%). In the period June - October and October - December, the relative growth decreased to 5.8% and 3.8% respectively. At the beginning of the season in the second fish group a relative increase of 5.3% was reported, in June - 2.4%, and in the period October-December - 6.8%. The same trend for intensive growth at the end of the growing season was observed in the group with the highest initial body weight. The fish in this group from May to June, practically did not grow, with a relative growth of 0.8%. From June to October the relative growth increased to 3.3%, and the main accumulation of body weight (7.7%) was obtained at the end of the growing season (October-December). The relative growth in the Russian sturgeon of the highest body weight group was the lowest for the whole study. Generally, it can be stated that in this species the relative growth for the season was the highest for the smallest fish (39.5%), followed by medium (15.2%) and large (12.0%). Fedorov et al. (2017) have studied Russian sturgeon at different ages and different initial body weight when grown in a pond fish farm in a polyculture with herbivorous fish species. The data provided by the authors show that the smallest fish had the best relative growth followed by the big fish. Those with the average initial body weight grew the worst, with the difference with the smallest ones being over 2 times.

The hybrid highest relative growth for the whole period was found in the first group - 75.3% (Figure 3). In the second group of fish it was 23.7% and in the third group - 26.7%. In the first and second group the main growth was in the period May-June, respectively 33.6 and 12.3%. In the period June-October, the growth in these groups decreased to 16.5 and 5.4% respectively. An opposite trend is observed in the third group. In the period May-June, the relative growth was 4%, while in June-October it increased 4 times, reaching 16.3%. In the period October-December, fish from all experimental groups continued to grow at lower levels of intensity - 12.6%; 4.6% and 4.7%, respectively for the first, second and third group. The resulting relative growth in hybrids with the lowest initial body weight (first group) was highest throughout our whole study.

In general, the interest in various hybridization schemes in the sturgeon breeding is conditioned by the intention to increase production efficiency. Siberian sturgeon hybrids with other sturgeon species are considered dominant in the leading sturgeon breeding countries (Shen et al., 2014; Bronzi et al., 2019). Main studies of hybrid (Siberian x Russian sturgeon) growth indicators are in the juvenile stage (Guo et al., 2011, 2012). The hybrids of Siberian and Russian sturgeon show high productive performance in different production systems (Efimov, 2004; Iskakova and Kulmanova, 2014; Miburo, 2018).

They grow well both in mountainous reservoirs with lower water temperatures (Magomaev and Chipinov, 2011) and in RAS (Levina et al., 2015). Growing in RAS allows hybrids to show their high performance for high productivity. Thus, according to Ponomareva et al. (2019), individuals with an average body weight of 0.726 kg were obtained from fish with an initial body weight of 0.020 kg for 8.5 months from a study of the growth of hybrid Russian and Siberian sturgeon in RAS. Our study shows that under the conditions of an industrial cage farm located in a warm water reservoir in Southern

Bulgaria, the hybrid of Siberian and Russian sturgeon grows well and may be one of the most perspective for cultivation. At the same (six-year-old) age, hybrids had a higher relative growth than Russian sturgeon by 25.7%, 7.7%, and 13.1%, respectively, for the lowest, middle, and highest weight group.

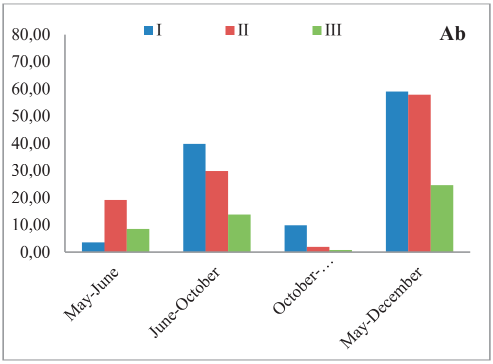

Figure 1. Relative growth of Siberian sturgeon from different groups, %

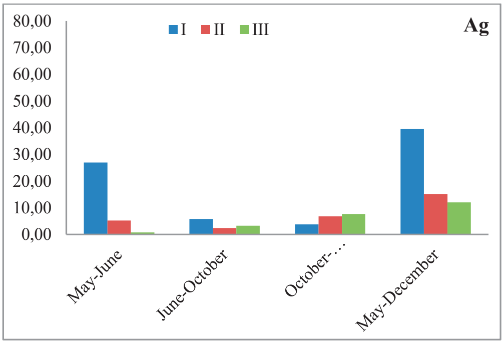

Figure 2. Relative growth of Russian sturgeon from different groups, %

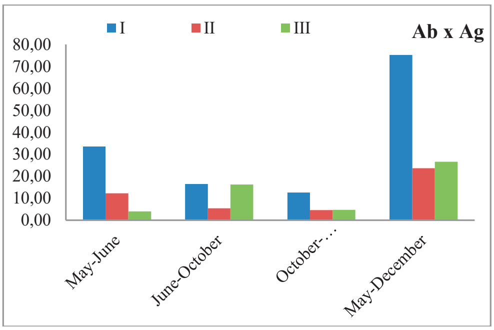

Figure 3. Relative growth of the hybrid from different groups, %

CONCLUSIONS

Siberian sturgeon, Russian sturgeon and their hybrid have good growth capacity when reared on an industrial cage farm. The fish have been growing throughout the growing season, including the October-December period.

It was found that in I and II group of Siberian Sturgeon the relative growth for the whole period was practically the same, respectively 58.6 and 57.9%. The fish from group III had a significantly smaller growth (24.57%).

In Russian sturgeon, in the case of fish that are growing slower at the beginning of the growing season, a mechanism for compensatory growth is established. The smallest fish grew best at the beginning of the period and the second and the fish from third group grew at the end of the growing season. In this species, the total relative growth in group I was 39.46%, group II - 15.15%, group III - 12.02%.

The relative growth over the whole period in the Hybrid of I, II, III groups was 75.25%, respectively; 21.71%, 26.65%.

The hybrid of Siberian and Russian sturgeon grows well under the conditions of an industrial cage farm located in a warm water reservoir in southern Bulgaria and may be one of the most perspective for cultivation.

At the same (six-year-old) age, hybrids had a higher relative growth than Russian sturgeon by 25.7%, 7.7%, and 13.1%, respectively, for the lowest, middle, and highest weight groups.

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