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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Introduce the Siberian Sturgeon (*Acipenser baerii*) to Turkish aquaculture industry: Duoculture possibility with Rainbow Trout

Sibirya Mersin balığının (*Acipenser baerii*) Türkiye su ürünleri endüstrisi ile tanışması: Gökkuşağı alabalığı (*Oncorhynchus mykiss*) ile ikili yetiştirilme olanağı

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Abstract: Duo culture response of Siberian sturgeon (*Acipenser baeri*) and rainbow trout (*Oncorhynchus mykiss*) was evaluated in culture tank conditions. Triplicated culture groups were planned as: mono-culture sturgeon (M, n=10), duo-culture sturgeon (DM, n=10) and duo-culture trout (DA, n=10), and mono-culture trout (A, n=10). Examination of mono and duo culture of each species, showed neither sturgeon nor trout, was indicated any significance on specific growth rate (SGR) and condition factor (CF). As for final biomasses among groups, no significant differences were recorded (p<0.05).

Keywords: *Acipenseriformes, duo-culture, polyculture, sturgeon, trout*

Öz: Bu çalışmada yetiştiricilik tanklarında Sibirya mersin balığı (*Acipenser baeri*) ve gökkuşağı alabalığının (*Oncorhynchus mykiss*) Duo kültür yetiştiriciliğe tepkisi değerlendirilmiştir. Üç tekerrürlü çalışma: mono-kültür mersin balığı (M, n=10), duo kültür mersin balığı ve alabalık (DM ve DA n = 5+5=10) olarak planlandı. Her bir türün mono ve duo kültür şeklinde yetiştirilmesinde büyüme ve gelişme izlendi. Sonuçta birlikte ve ayrı yetiştiriciliğin mersin balığı ve alabalığın spesifik büyüme oranı (SBO) ve kondisyon faktörü (KF) üzerinde herhangi bir önemi olmadığı belirlenmiştir. Grupların çalışma sonu biyomasları arasındaki farklılık önemsiz bulunmuştur (p<0.05).

Anahtar Kelimeler: *Acipenseriformes, duokültür, polikültür, Mersin Balığı, alabalık*

INTRODUCTION

Turkey fish farming production reached up to the total amount of 276502 tons/year in the year of 2017. Trout farming also constitutes 42.8% of this amount. Numerically significant majority of enterprises engaged in trout farming in Turkey are land-based businesses. Capacity utilization success in freshwater water aquaculture was 46.9% (BSGM, 2019). Business management and marketing strategy can be shown as the main reasons for the use of project capacity. The integration of sturgeon farming with similar water quality requirements to trout will increase the profitability of the enterprise and hence the capacity utilization success.

At the same time, sturgeon is a fish with high economic value in terms of caviar and flesh. CITES convention is manage international sturgeon trades, as in other species of extinction (FAO 2019). While 12 sturgeon species are being cultivated for commercial purposes, the most popular sturgeon species are Siberian sturgeon (reared in 22 countries) and Danube sturgeon (reared in 16 countries), because of their culture (Brozni et al. 2010). Despite, the presence of natural sturgeon in Turkish fish diversity, highly valuable sturgeons are not yet grown commercially.

Sturgeons (*Acipenseriformes*) are bony fish that naturally live in the temperate waters of the Eurasia and North America of the northern hemisphere (Birstein, 1993) and valuable food source in terms of its boneless meat and it's quite tasty and valuable caviars (Fopp-Bayat, 2008). Pollution, dam building, and increased water usage have threatened the spawning grounds so sustainability of natural stocks of sturgeons slightly destroyed (Steffens, 2008; Stoyanova and Staykov, 2017; Gisbert and Williot, 2002).

To the recent decate, fifty three countries are widely interested in sturgeon culture in the worldwide (FAO, 2019). Among sturgeon species, Siberian sturgeon (*Acipenser baeri*) has been the most successfully reproduced species in fish farms (Chebanov and Billard, 2001; Bronzi et al., 2011; Mims et al., 2002; Nathanailides et al., 2002), so the sturgeon culture reached more than 8800 tons/year by twenty two countries (Bronzi et al., 2011).

Sturgeons are generally reared in monoculture systems like ponds with appropriate water temperature, fully controlled culture conditions, in the industrial cooling waters or in recirculating aquaculture systems (RAS). Sturgeon and their hybrids are grown with compatible species in the land-based ponds in some countries as mono or polyculture (Pyka and Kolman, 2003).

Sterlet, white sturgeon, Siberian sturgeon and American paddlefish (*Poliodon spatula*) are more proper for culture than the other sturgeon species. Polyculture tests showed there is no difference in their survival rate while keeping them with European catfish (*Silurus glanis*). However, it was stated that the sturgeon progress in the polyculture environment was slower than the ones, which were reared in mono cultures (Ćirković et al., 2012).

The marketing of sturgeons is increasing day by day. Thirty-five countries are involved in sturgeon aquaculture for human consumption as meat and caviar. General target of the sturgeon producers is obtaining good quality caviar derived from commonly cultured sturgeon with reasonable prices (Bronzi et al., 2011). Rainbow trout culture is an almost unique aquaculture activity in the north-eastern part of the Turkey. If there are enough culture possibilities of both Siberian sturgeon and rainbow trout species breed together under the polyculture condition, regional and national culture acceptability of the Siberian sturgeon will be achieved more rapidly.

In order to use water sources efficiently in aquaculture operations, the prominent way seems the duo and/or polyculture practices. Factors such as sharing space, hierarchy, cannibalism, competition, feed choice, and environmental requirements should be taken into consideration in culturing of two or more species together. Sturgeons culture, in mono and polyculture with carps and catfish species, were practiced before (Patriche et al., 2002; Chebanov and Billard, 2001), but their culture with trout species has not been tried until today.

The current experiment focused on the duo culture of Siberian sturgeon (*A. baeri*) and rainbow trout (*O. mykiss*) to evaluate their efficiency for aquaculture, the results will help the private sector to encourage them to practice.

MATERIALS AND METHODS

The experiment was conducted in Recep Tayyip Erdogan University, Fisheries and Aquaculture Research and Application Centre in Rize in the Eastern Black Sea Region of Turkey in the year of 2014. The 1^{+}-year-old Siberian sturgeon produced in the research center and rainbow trout were transferred from a local farm.

Fiberglass tanks with 115x115x40 cm (Approx. 500 L) and natural stream water were used without any treatment such as temperature-regulation, filtration, UV-sterilization. Temperature, oxygen, and pH were recorded by a multi-parameter portable device (Thermo Scientific Orion 5-Star™ RDO®) daily.

Totally nine fiberglass experimental tanks, three groups and their replicates were designed. Three different groups were formed in the study. The first of these groups is trout. The trout group is named A. Fish development was also evaluated in A data group. The second group is the sturgeon monoculture group. The Sturgeon group is named M. The third group is the duoculture group. Trout and sturgeon fish were stocked in the same tank. In this group sturgeon and trout are named as DM and DA. Ten fish were transferred into each experimental tank. Five sturgeons and five trouts were put in duo-culture tanks (Table 1).

The experiment started in mid-September and natural photoperiod was applied for 141 days. The initial average length and weight of the sturgeons were 37.4±2.70 cm and 148±26.29 g in (M) groups, 37.2±2.71 cm and 137±21.16 g in (DM) groups, while rainbow trout individuals were 23.0±2.60 cm and 128±22.80 g in (DA) groups, and 22.5±1.46 cm, 125±26.35 g in (A) groups.

Two percent of daily feeding rate was applied considering biomass, and feeding regime was performed four times a day. Fish was fed with 3-9 mm trout diet. (3 mm feed content: 48% protein, 18% fat, 3% cellulose and 12% ash; 4-9 mm developer feed content: 45% protein, 20% fat, 3% cellulose and 12% ash). As fish grew, the pellet size was switched to a larger one. The uneaten feeds were removed from the bottom one hour later following the feeding and then calculated the consumed-feed. In order to follow the fish development, the feed amount given to the groups, the weights and lengths of the fish in the groups were measured at intervals of 15 days. In the periodic measurements, trout individuals were sedated with 50 ppm benzocaine for 3 minutes, whereas sturgeon individuals were not sedated. Because they were easy to handle.

Wet weight of fish was measured by using a laboratory scale (0.1 g). The following formula as mentioned before Memis et al., (2009): The condition factor estimated the formula: $CF=(W/L^3)*100$ and specific growth rate (SGR-%day^{-1}) was calculated using $SGR=100x(lnW_t-lnW_0)/t$ where W_t and Wo represent final and initial mean body weights and t is the growing period in days. Total length (L) was defined to be the distance from the tip of the snout to end of the upper lobe of the tail. Food conversion ratio (FCR) was calculated: FCR=Total feed intake (kg)/Weight gain (kg).

Data were analyzed by Sigma Plot 12.0 and Excel, experimental groups were compared with parametric tests of t-test and ANOVA. Results were presented mean ±SE. Significant differences with were presented 0.05.

RESULTS AND DISCUSSION

During the 141-day experiment, temperature, pH, and dissolved oxygen were 10±2.1°C, 7.8±0.3 and 9.3±2.02 mg L^{-1}, respectively. Water temperature changes are represented in Figure 1.

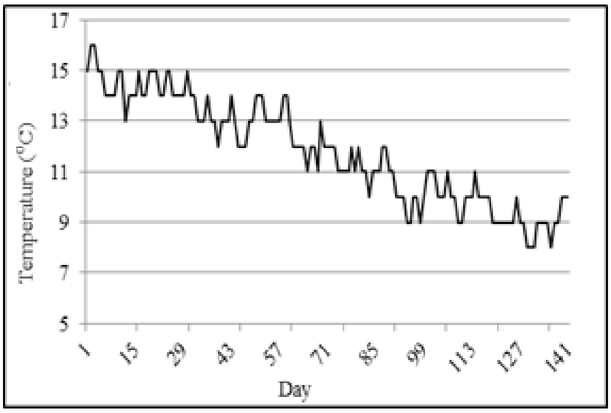

Figure 1. Water temperature changes during the 141-day study (°C).

The growing performances, such as the average total length and weight gain; feed conversion rates (FCR), specific growth rate (SGR) and the condition factor (CF) were obtained from groups at the beginning and at the end the experiments (Table 1). Periodic mean total length changes, which was prepared with the results of fish data, obtained 15 days intervals were given in Figure 2, weight changes are represented in Figure 3 and the stock density changes are represented in Figure 4. The condition factor differentiations, which is an important indicator of fish growth, are given in Figure 5.

During the 141-day experimental period, any pathological findings were not observed in the groups, so any chemical treatment was not used.

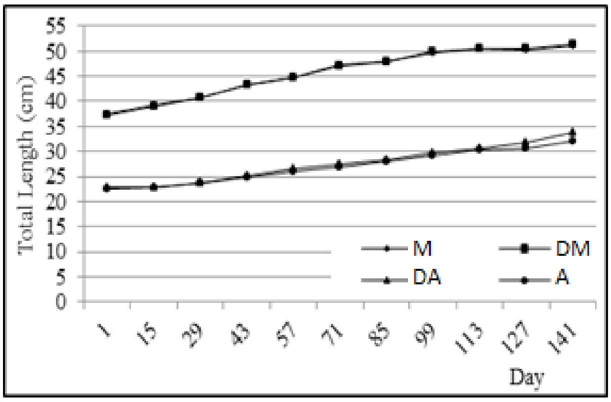

Figure 2. Mean total length changes among the groups (cm)

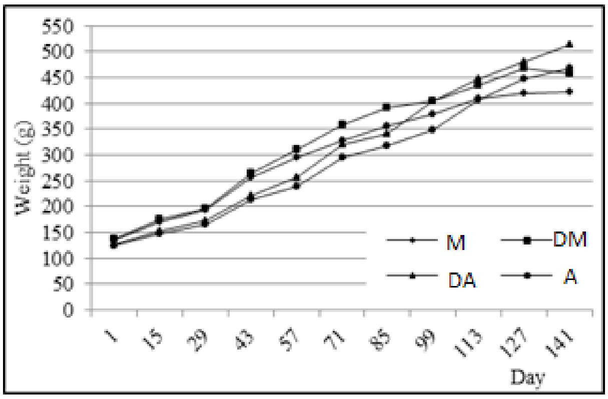

Figure 3. Mean weight changes between the groups (g)

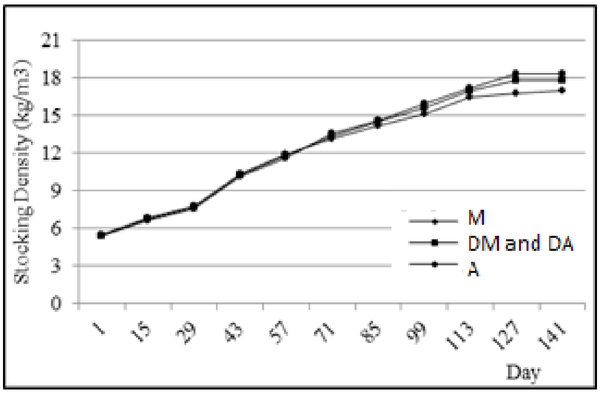

Fig. 4. Stocking density changes within the groups (kg m^{-3})

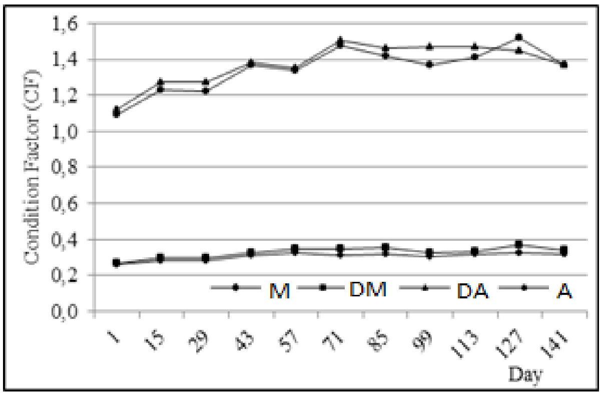

Fig. 5. Mean condition factor changes between the groups

	MONO	DUO		MONO
	M	DM	DA	A
Initial total length (cm)	37.4±2.70	37.2±2.71	23.0±2.60	22.5±1.46
Final total length (cm)	51.0±3.26^{a}	51.4±3.72^{a}	33.7±5.47^{b}	32.2±3.79^{b}
Initial weight (g/individual)	148±26.29	137±21.16	128±22.80	125±26.35
Final weight (g/individual)	423±79.46^{a}	457±79.98^{a}	514±178.5^{b}	468±150.37^{b}
Weight gaining (WG) (%)	185.1	234.3	302.0	275.0
Initial stocking density (kg/m^3)	5.4 ±0.043	5.4 ±0.049		5.3 ±0.009
Final stocking density (kg/m^3)	16.9^{a} ±0.441	17.8^{ab} ±1.079		18.3^{b} ±0.523
Initial condition factor	0.26^{a} ±0.030	0.27^{a} ±0.037	1.1 2^{b} ±0.450	1.09^{b} ±0.168
Final condition factor	0.32^{a} ±0.044	0.34^{a} ±0.047	1.37^{b} ±0.540	1.37^{b} ±0.219
Food conversion ratio (FCR)	2.0	1.4		1.2
Specific growth rate (SGR) (%)	0.8^{a}±0.601 (0.04-2.26)	0.9^{a}±0.653 ((-0.48)-2.30)	0.94^{a}±0.543 ((-0.12)- 1.88)	0.94^{a}±0.495 (0.21-2.02)

Table 1- Obtained data during the experiment related to the species growth performance monoculture sturgeon (M), duo-culture sturgeon (DM), duo-culture rainbow trout (DA) and monoculture rainbow trout (A), (P<0.05).

In this study, the growing performances of the Siberian sturgeon and the rainbow trout individuals in the duo-cultural conditions were examined. The experimental fish were preferred in the range of 130-150 g, the growing performances of the groups were monitored for 141 days.

The stocking density was 5.4 kg/m^3 in each tank at the beginning of the trails. At the end of the study, stock densities were reached to 16.9±0.441, 17.8±1.079 and 18.3±0.523 kg/m^3 in the groups of monoculture sturgeon, duo culture, and monoculture trout, respectively. Group A showed similar improvement with group DA (P<0.05) but better than group M (P<0.05). This difference is due to the fact that the trout have become better feed consumption.

The initial and final stocking density values were found to be consistent with the optimum values that can be achieved for both trout and sturgeon in the tank conditions given in the literature before (Köksal et al., 2000; Abramenko, 1999; Zare et al., 2009).

The SGR values (sturgeon: 0.8-0.9; trout:0.94) were found to be similar to the previous study (Koksal et al., 2000). The optimum growth temperature for sturgeons is 18-26°C, and stagnation of growth is observed at less than 13°C of water temperature (Koksal et al., 2000; Mims et al., 2002; Tzankova, 2007; Pyka and Kolman, 2003). This study was conducted at 8-16°C to integrate both species at an appropriate temperature range. The temperature seems lower than the optimal for sturgeon whereas suitable for trout in this study.

In addition, the established FCR values, relatively in high temperatures (20.3°C), showed similarities with the findings of feeding experiments of sturgeons (Sicuro et al., 2012).

Atar et al., (2008) indicated that 9 g of Siberian sturgeon reached to 225 g in weight and 75.4% survival in a 135-day experiment and it was indicated in their study that Siberian sturgeon was one of the most proper species to the aquaculture in terms of their living rates and growth performances. In addition, in the present study, no death was observed neither in sturgeons nor in the trout. It was presented that this study showed a better production performance than similar studies (Mims et al., 2002; Bailey and Alanara, 2006).

The stocking density, feed content, feeding techniques, and other management procedures have notable effects on fish response to the stressors and toleration to stress (Overli et al., 2005; Ashley, 2007). Preventing the adverse outcomes of chronic stress implies good welfare for fish. It was observed that fish under stress showed similar growth performances in the aquaculture of pure species, while low-affected ones grew better than the high-affected ones in the culture of mixed species. High stock density may cause serious problems such as retarded growth, the decline in feed intake, worse feed conversion and in turn nutritional deficiency, fin deformation, gill damage, decrease in immune capacity and changes in fish behavior (Pottinger and Carrick, 2001; Ashley, 2007).

Aggressive behavior and abnormal activity caused by chronic stress will run up consumption of energy, metabolic activity, deteriorating the feed evaluation and impairing immune function. In addition to the social stress, firstly, the attacks of individuals of same groups caused fin deformation and secondly, it frequently caused the development of infections partly in these fishes with the suppression of immune system (Ashley, 2007).

During the experiment, it was observed that the stocking density had no adverse effect on the groups. The values of the stock density of the groups did not differ from the given values in the literature.

Both species have different feeding ground preferences. Rainbow trout intakes feed pellet from the water surface and mid-water column until feed settled to the bottom, while Siberian sturgeon prefer bottom to feed.

Mims et al., (2002) stated in their report that juveniles might have 1-1.4 of FCR value, while adults might have 1.6-2.0 FCR value. The values obtained from the present study, it was observed that the (DM) group showed similarity with these values, while (M) group of fish were close to the lower limit but not out of limit.

In another study conducted with the fish at the weight of 1733 g which were fed daily with different rates according to their weight in the water temperature of 19-22°C, the FCR value was estimated as 1.23-2.43 (Rad et al., 2003). It was observed that similar FCR values were seen in the groups, which were fed at the rate of 1-1.25% of biomass. These values were better than the values obtained from the feeding at the rate of 1.5%.

In polyculture experiment conducted with catfish, it was observed that the FCR value was estimated as 0.87 in polyculture environment, while it was estimated as 2.09 in sturgeon tank. The difference was accredited with the waterline usage and competitive behavior of catfish, and the increase of relative ground factor led to the improvement of FCR value (Ćirković et al., 2012). The FCR values of this study conducted with the fishes preserved under the polyculture conditions and our results were found similar.

In this study, the best growth performance in sturgeon groups was observed in (DM) group, while the worst growth performance was also observed in (DM) group at the 11th period depending on the decrease of water temperature (Table 1). When examining the average values, it was observed that a relatively better average SGR value could be obtained when sturgeon individuals were kept with similar sized rainbow trout. No difference was observed in trouts in respect of their average SGR value. Polyculture condition affected both species positively. It was thought that reason for these differentiations prefers of each species a different water column for feeding. When sturgeon individuals had bottom feeding behavior, while trout take a feed from the water column. It may be due to that, the sturgeon individuals are perceiving their food with their chemical receptors, while trout perceive food visually.

In an experiment on Siberian sturgeon by Rad et al., (2003) at 19°C with 1% of feeding rate, SGR value was calculated as 0.88 days^{-1} (Rad et al., 2003). Our result showed SGR value became higher than the values of (M) group and lower than the values of the (DM) group. Whereas Rad et al., (2003) had a regular feeding process at the rate of 0.75-1.5% of daily weight and with the banded feeder, the feeding process was carried out at the rate of 2% of feeding and for 4 times day^{-1} in our experiment. At the end of 141 days-experiment, the overall SGR rate became lowest for M compare to the other groups. The increased SGR began to decline as the temperature decreased (Figure 1 and Figure 6).

In another experiment by Medale et al. (1991), the SGR was found 0.31 in Siberian sturgeons, which were at the weight of 1700 g and kept in 18°C of water temperature. The SGR values of our study were better than the values of this study. In our study, fishes being in a smaller reflected the positive SGR value.

In the present study, there was no statistically significant difference between mono and polyculture trout groups' calculated mean SGR. Although there was no statistically significant difference between mono and polyculture sturgeon groups' SGR means, polyculture groups had relatively high. During the experiment, monoculture sturgeons had lower SGR value (Figure 6). Water temperature was 10.05±2.1°C. Because of that, feeding competition did not occur at a high level. Required temperatures of both species might be cleared that territorial competition effects.

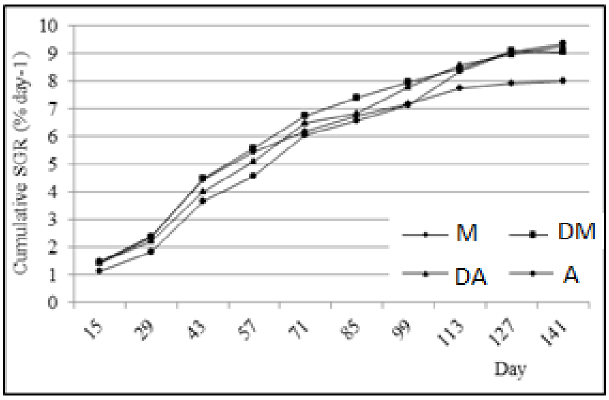

Figure 6- Cumulative SGR differentiation of the groups during the experiment

Sicuro et al., (2002) researched the effects of using alternative herbal protein sources in diets to the hybrid sturgeon (*A. naccari x A. baeri*) in their study. They stated that at the water temperature of 20.3°C, SGR values showed alterations between the values of 0.19 and 0.53. FCR and SGR values remained at a low degree in the later periods of low water temperature, while they were higher in the first half of the conducted study. Despite the temperature difference, it was observed that the average SGR values obtained from the study conformed to the present study. The relative differences between the studies were accredited with the feeding frequency.

Mims et al., (2002) compared the growth of 720 g sturgeon and 100 g catfish, under the polyculture conditions in their study. While the catfish of polyculture group showed a faster growth than the monoculture group, it was observed in the study that this situation had an adverse effect in sturgeons. The SGR values of catfish in polyculture and monoculture were determined as in the order of 2.0% and 1.6% and the values of sturgeons were determined as 0.86% and 0.26%.

Bailey and Alanara, (2006) researched the effect of serving amount to the growth of rainbow trout in different temperatures. It was observed in their study that FCR value was in the range of 0.9-1.2 in rainbow trout at the water temperature of 10°C. These values confirmed with the SGR values of (DA) and (A) groups of trout when the water temperature was high. The deceleration in food intake of fish, especially trout, led to a decrease in SGR values in the periods when the water temperature was close to the low levels.

When they analyzed the growth performances and FCR values, a similar growth performance with the results of Atar et al., (2008) was confirmed.

Results of this study showed that rearing rainbow trout and Siberian sturgeon together, at 37 cm length and 137 g weight for sturgeon and 23 cm length and 128 g weight for trout, wouldn't have a negative effect on growth for both. Besides this, both species mostly prefer different water column for feeding and the other metabolic activities. For example, whereas trout fish intakes the feed pellets from the water surface or mid-water column, sturgeons feeds from the bottom. Rainbow trout cannot appraise feeds pulling down to the tank ground, therefore, the uneaten feeds can be consumed by the sturgeons. The share of the water column in this way may have a positive result for effective feed utilization. In addition, Aramenbko, (1999) suggested that monoculture of sturgeons is commercially preferable over polyculture systems, especially when growing together with carp and trout for which operational compromises must sometimes be made.

In this study, it was planned to investigate whether Siberian sturgeon and rainbow trout have negative effects on co-grower in tank conditions. As a conclusion, Siberian sturgeon and trout could be stocked under the same water reservoirs, victoriously. It was observed that trout do not prefer feed on the bottom of the tank, while sturgeon take a feed from the bottom of the tank. Thus, sturgeons can consume the uneaten feed by trout individuals that sank to the tank bottom. In addition, swimming on the ground of the sturgeons had been moving the organic solids to the water exiting of the tank. Thereby, the wastes did not accumulate at the bottom of the pool. As a result, there was no disadvantage in the same size as the sturgeon and the trout culture in the same culture tank conditions. However, different sizes of both fish groups and different type of tank structures, as earthen or concrete, might be studied to be generated to this duo culture performance relationship achievement.

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