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Research Article

Effects of Size Grading on Growth Performance, Survival Rate and Cannibalism in Russian Sturgeon (*Acipenser gueldenstaedtii*) Larvae Under Small-Scale Hatchery Conditions

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ABSTRACT

Sturgeon aquaculture is important due to the value of their caviar and meat as well as its ecological importance. The current study focused on the effects of different size groups on the final mean weight, specific growth rate, survival rate and cannibalism of Russian sturgeon (*Acipenser gueldenstaedtii*) larvae. The groups were graded with homogeneous small-size larvae in the first group, 50% small and 50% large-size heterogeneous larvae in the second group, and homogeneous large-size larvae in the third group. The highest specific growth rates in each group occurred between days 28-35. After 35 days, the specific growth rate (SGR) in all groups dramatically reduced compared to the first week. The SGR of the larvae were not significantly affected by size (p>0.05). Mortalitiy were high during the first week in all groups, but, decreased as the larvae grew larger during the fourth weeks. At the end of the study, the survival rates were 30% for the small-size, 53% heterogeneous-size, and 64% for the large-size groups. The highest cannibalism rate in the present study occurred in heterogeneous-size group. However, the literature shows cannibalism rates to not be high for any groups of sturgeon. Size grading in the early period may negatively affect the survival rate and growth performance of larvae. Therefore, maintaining optimum larval rearing conditions such as stocking density, and feeding strategy may support higher survival and growth performance, in larvae that are newly acclimated to exogenous feeding.

Keywords: Sturgeon, aquaculture, larvae, size heterogeneity, survival

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INTRODUCTION

Russian sturgeon (*Acipenser gueldenstaedtii*) are distributed throughout the Azov Sea, Black Sea and Caspian Sea as well as in the large rivers that flow into these seas (Hurvitz et al., 2008). Sturgeon populations in the world have decreased due to dams along migration routes, destruction of breeding grounds, and overfishing (Gisbert & Williot, 2002). Russian sturgeon are a critically endangered species on the International Union for Conservation of Nature Red List of Endagered Species (IUCN, 2020). The rapid decline in the sturgeon population has increased interest in their aquaculture, especially in areas where sturgeonare naturally common. In addition, the increases in fish and caviar prices have also increased the interest in sturgeon farming (Hurvitz et al., 2008). The stable improvement of sturgeon farming is extremely important, both in terms of supporting of their natural stocks as well as commercial production.

Caviar production, is the main focus of sturgeon farming, and reached 364 tons annually in 2017, with the forecast for the next 10 years increasing from 500 to 2,000 tons (Tavakoli et al., 2021; Bronzi et al. 2019). The most cultivated species for caviar production in the world were

Acipenser baerii (31%), *Acipenser gueldenstaedtii* (20%) and the *Huso dauricus* x *Acipenser schrenckii* (13%) hybrid, respectively. The top caviar producing countries in order are China, Russia, Italy, France and Poland, (Bronzi et al., 2019).

For the sturgeon aquaculture in Türkiye, Siberian sturgeon (*A. baerii*) fry from France were brought to Ankara University to conduct experimental studies in 1997 (Köksal, Rad, & Kindir, 2000). Afterwards, fertilized eggs of Russian sturgeon (*A. gueldenstaedtii*) were brought from Russian federation, Krasnodar Fisheries Research Institute in 2001. Eggs were hatched in the University of Istanbul, Faculty of Fisheries of the Sapanca Inland Fisheries Production Research and Application Unit (Çelikkale, Timur, Memiş, & Ercan, 2002). In recent years, experimental and conservation studies on sturgeon culture have increased (Akbulut et al., 2011; Kayiş, Er, Kangel, & Kurtoğlu, 2017; Ak, Kurtoğlu, Serezli, Kayış, &Yandı, 2019; Memiş, Yamaner, Tosun, Tunçelli, & Tınkır, 2020). Although Russian sturgeon are a species native to Türkiye, their commercial production has been very limited. Aquaculture techniques should be developed in order for Türkiye gain its share from the increasing sturgeon production in the world.

Larval feeding and fingerling production have been stated as two of the most difficult aspects of sturgeon aquaculture. Managing the transition to nutrition after the larvae have consumed the yolk sac directly affects their survival rate and growth performance (Gisbert et al., 2018). Underfeeding and overstocking can increase competition among larvae, which can then lead to cannibalistic behavior (Manley et al., 2014). Falahatkar & Roosta (2022) stated cannibalism to not occur in sturgeons' normal behavior but to be only observable under unsuitable cultivation conditions such as starvation or high stocking density. In addition, size differences in larvae due to genetic and environmental factors also affect cannibalism rates (Kestemont et al., 2003; Baras & Jobling, 2002; Baras et al., 2003). Larvae have a larger mouth in proportion to their body size compared to adult individuals. Therefore, the larvae may tend to consume smaller individuals (Baras, 1998). In general, having different size groups coexist in aquaculture prevents larger individuals from pressuring smaller ones (Tidwell et al., 2003), as well as the uniform use feed appropriate for the larvae's size. Jobling (2010), stated regular fish-grading to increase survival rate and growth performance. Fish-grading has also been found to positively impact weight gain, feed conversion rate, and specific growth rates (SGR) in juvenile Nile tilapia (*Oreochromis niloticus*; Dikel, 2011). However, fish-grading has also been reported not enhance survival or growth rate among sea bass *(Dicentrarchus labrax)* larvae (Kestemont et al., 2003). Studies in the literature have shown the effects of fish-grading on growth performance and survival rate to vary for several species (Jobling, 2010; Dikel, 2011; Kestemont et al., 2003).

This study, investigates the efficacies of size homogeneity in larvae on survival rate, growth performance and cannibalism in order to increase production regarding Russian sturgeon hatchery management. In addition, this study aims to determine the growth and survival rates of Russian sturgeon larvae under aquacultural conditions.

MATERIAL AND METHODS

Experimental design and fish maintenance

The trial was carried out at the Aquaculture Application and Research Center at Recep Tayyip Erdoğan University in Rize, Türkiye in June 2022. Larvae were obtained by incubating eggs obtained from the research center's broodstock of Russian sturgeon. First feeding of the larvae was initiated seven days post-hatching with *Artemia nauplii* six times a day. The sturgeon larvae were acclimatized to the commercial salmonid starter feed 21 days after having absorbed their yolk. After the exogenous feeding (28 days post-hatching, [DPH]), three separate groups (S, M, and L) were arranged in which Russian sturgeon of different initial body weights (BWi) were reared (0.096 g, 0.273 g, and 0.433 g). The sturgeon larvae were put into nine rectangular tanks. Fish were placed in experimental tanks 3 days before the trial in order to adapt to the conditions. The experimental groups were graded with small-size homogeneous larvae in the first group (S), 50% small- and 50% large-size heterogeneous larvae in the second group (M), and large-size homogeneous larvae in the third group (L). The artificial feeding rate was 15% of total body weight per day. Every seven days, the dose of feed was adjusted after checking their measurements. The water level was about 20 cm deep. The initial stock density of the larvae was 15 gr/L. The total number of fish in each tank was determined according to the stock density. In the trials, aerated well water was fed to the tanks at 0.5 L/min. The pH, water temperature, and dissolved oxygen levels were measured using a multi-parameter water quality measuring device (Hach HQ40d 58,258–00, Loveland, CO). Water pH was measured between 7.18–7.46. Water temperature at 18±0.8 °C, and dissolved oxygen between 6.8 -7.4 mg/L. During the trial, the photoperiod regime was 14L:10D. Three replications were performed for each group.

Growth performance and survival rate

The trial was continued for 5 weeks, with the measurements performed weekly. The mean live weight of each group was measured using a laboratory scale (0.01 mg). The total lengths of the fish were measured using a computer program (TPSdig). Dead sturgeon larvae were removed daily, and this daily count was used to determine the survival rate. The SGR of the larvae in each group was calculated in accordance with Gisbert & Williot (1997) as follows:

$$\text{SGR } (\%\text{day}^{-1}) = 100 \times (\ln W_f - \ln W_0) / t, \tag{1}$$

where W_f and W_0 are the final and initial mean weights in grams, and t is the growth period in days .

The survival rate of the fish over the 5 weeks was calculated from the weekly number of dead larvae in the tanks.

Cannibalism rates were determined over the 28 days according to the formula from Falahatkar & Roosta (2022) as follows:

$$\% = 100 \times (\text{bitten larvae/initially number of larvae}) \tag{2}$$

Statistical analyses

All data are presented as a mean ± standard deviation (SD). One-way analysis of variance (ANOVA), and Tukey tests were used to identify any significant differences among the groups. Differences were considered statistically significant at a $p \leq 0.05$. Data sets were analyzed using the package program SPSS 25 for Windows (version 25, IBM Corp., Armonk, New York, USA).

RESULTS AND DISCUSSION

The effects from the grading were investigated with respect to the larvae's weight gain (WG), SGR, survival, and cannibalism (Table 1). The mean total length of the 56-DPH Russian sturgeon in the S, M, and L groups were respectively 3.5 ± 0.1 cm, 6.7 ± 0,3 cm, and 8.2 ± 0.4 cm, (Figure 1). In addition, the mean weights of the S, M, and L groups were 0.96 ± 0.05 g, 2.65 ± 0.369 g, and 4.56 ± 0.4 g, respectively (Figure 1). Memiş et al. (2009) found the mean weight of *A. gueldenstaedtii* for 22-DPH and 41-DPH larvae to be 0.095 ±0.008 g and 1.18 ±0.36 g, respectively. Similarly, hybrid sturgeon ([*A. baeri* × *A. gueldenstaedtii*] × *A. gueldenstaedtii*) larvae reached a mean body weight of 3.4± 1.3 g on 57-DPH (Szczepkowsk & Kolman, 2002).

Biotic and abiotic factors can cause size heterogeneity between sibling larvae (Kestemont et al., 2003; Dammerman et al., 2015). In Asian catfish larvae, the temperature producing the highest growth also appeared in regard to the lowest size heterogeneity. Furthermore, size heterogeneity of larvae in the same group may have been due to individual growth potentials or the effect of more active larvae on other larvae (Baras et al., 2011).

During the larval stage, sturgeon develop very quickly, when reared under optimum conditions (Deng et al., 2003). The highest specific growth rates for each group occurred between the28th-35th day after day 35. The SGR dramatically decreased in all groups compared to the SGR for the first week (Figure 2). In the first week, the highest growth rate was obtained in the M group (18.9 % day^{-1}) and the lowest was in the L group (11.2% day^{-1};$p < 0.05$). At the end of the trial, the SGRs did not differ significantly among the groups ($p > 0.05$). Similarly, Memiş et al. (2009) declared an SGR of 13.26 %day^{-1} between the 22nd-41st days post-hatching for *A. gueldenstaedtii* larvae, . Similar high SGRs have been described for white sturgeon larvae (9.6–13.0%day^{-1};Deng et al., 2003) and *A. medirostris* fry (7.1%day^{-1} ;Zheng et al., 2015). Falahatkar et al. (2017) found the mean SGR in live artemia feeds to range between 2.27-2.13% day^{-1} for Persian sturgeon (*A. persicus*) 21 days after first feeding. The SGR of larvae was not significantly affected by size ($p > 0.05$). However, the high SGR in the M group during the first period may have been due to the larger larvae consumting the small larvae's feed. Small-size larvae in the M group were detected to have the lowest survival rate during the first period which appears to have increased the M group's SGR due to the large larvae surviving.

Mortalities were high during the first week in all groups; however, this reduced as the larvae grew larger during the first four weeks (Figure 2). The small-size group had the lowest survival rate (30%), while the large size group had the highest (64%;$p < 0.05$). The size grading of the sturgeon larvae showed the large fish to have reached a higher survival rate compared to the small fish (Figure 2). The highest cannibalism rate in the present study typically occurred in group M (Table 1). However, the literature

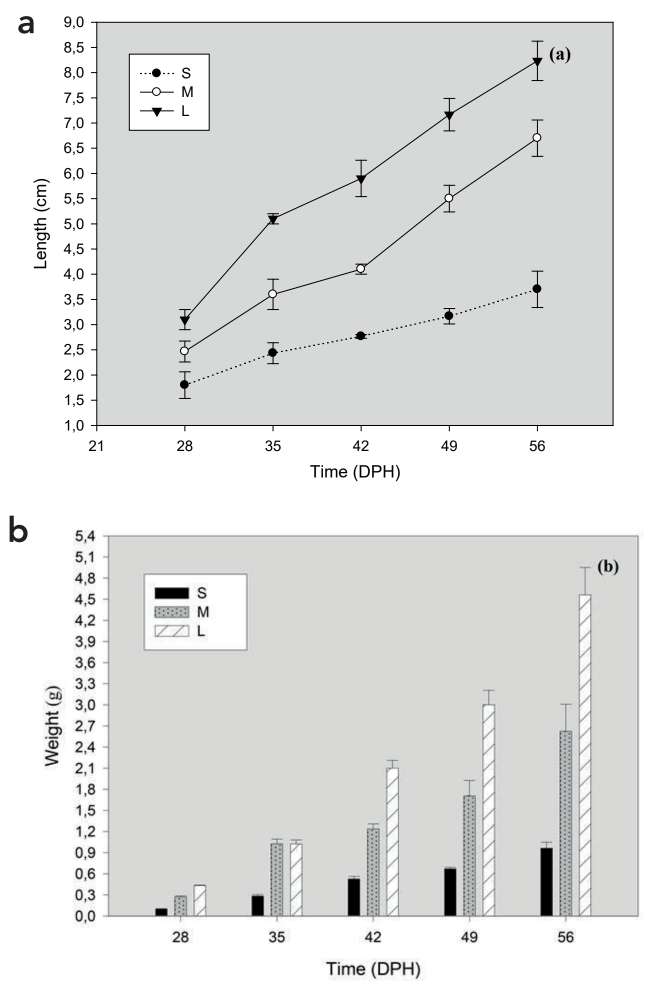

Figure 1. Mean (±SD) individual length (a) and weight (b) of Russian sturgeon larvae during the experiment. S, M and L assigned as small size larvae, heterogeneous size larvae and large size larvae, respectively. DPH; Day Post Hatching.

shows low cannibalism rates for all size groups . Falahatkar & Roosta (2022) observed cannibalism rates in Persian sturgeon larvae that were starved and kept under different stocking densities, determining the highest cannibalism rate of Persian sturgeon larvae to have occured in the starved small size group (40%). Memiş et al. (2009) reported mortality rate to be affected by cannibalism and feeding antagonism among the *A. gueldenstaedtii* larvae between the14th-22nd DPH. Szczepkowski & Kolman (2002) previously reported mortality rates for two hybrid sturgeon larvae. The researchers noted that the species had different rates of cannibalism due to their behavioral differences. The cannibalism is influenced by behavioral and environments parameters such as food availability, stocking density, water quality, light and feeding frequency (Li & Mathias, 1982; Braid & Shell, 1981; Hecht & Pienaar, 1993; Khan, et al., 2021).

Mortality was noted in all groups, though mainly among weaker individuals that did not feed. These weak larvae showed poor swimming activity, which triggered the cannibalistic behavior of the fast-growing larvae. However, cannibalism-based mortality showed no significant percentage difference compared to the overall mortality rate. Low cannibalism rates may have been ensured due to the selected feeding rate and frequency in the heterogeneous-size group compared to previous studies. Krol et al. (2014) reported their cannibalism rate to be the main contributor to the mortality of European catfish (*Silurus glanis*) larvae. Similarly, studies are found to have stated cannibalism to be an important cause of mortality in *Sander lucioperca* (Hamza et al., , 2007), *Perca fluviatilis* (Babiak et al., 2004), and *Lates calcarifer* (Khan et al., 2021). The cannibalism rate of Russian sturgeon larvae as observed in this study was quite low compared to these other species.

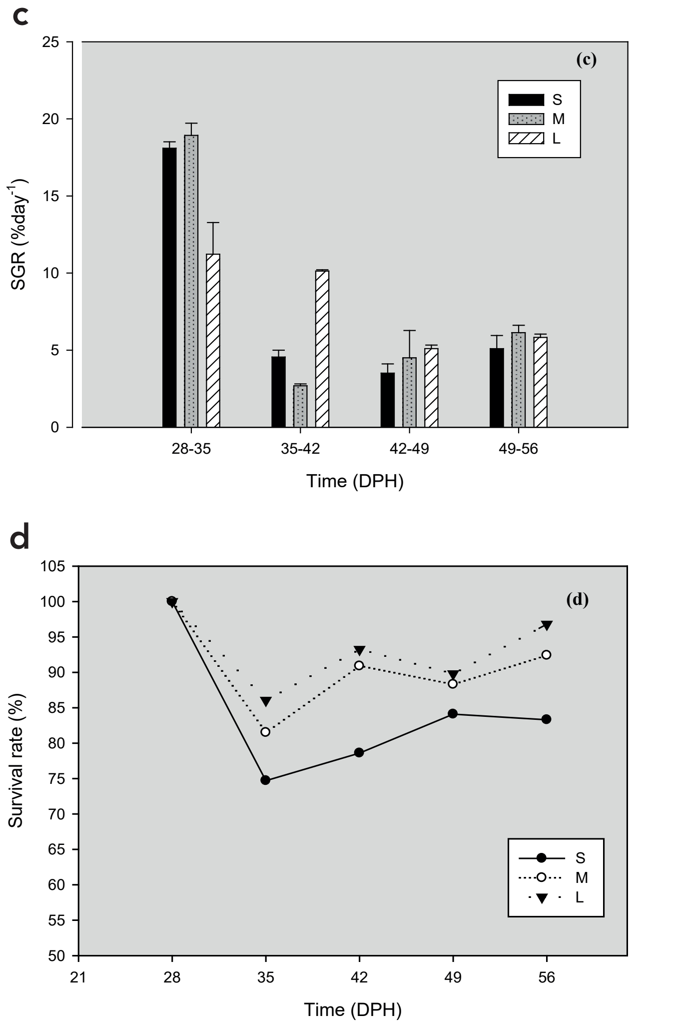

Figure 2. Specific growth rate (c) and survival rate (d) of Russian sturgeon larvae during the experiment. S, M and L assigned as small size larvae, heterogeneous size larvae and large size larvae, respectively. DPH; Day Post Hatching.

This study, observed the small-size larvae to bite large-size larvae from the tail direction as a form of cannibalistic behavior. This behavior not only caused the death of the prey larva but also the death of the predator larvae. This type of predation is known type-I cannibalism (Cuff, 1980). Normally in type-I cannibalism, the head is discarded after the tail is digested (Baras & Jobling, 2002). However, this study observed the predator Russian sturgeon larvae to have died in with their prey in their mouths. This may be sturgeon-specific cause due tosturgeon larvae have much larger heads than their bodies. In brief, the high mortality rate among theRussian sturgeon larvae appears to have resulted based on body weight, larval size and difficulties in accepting artificial feed at the start of feeding. For this reason, revealing the factors that cause size difference in Russian sturgeon is important for larval culture.

CONCLUSIONS

Overall, this study confirmed that size grading did not significantly improve the survival or specific growth rates of the small larvae group regarding Russian sturgeon larvae; however, it did influence the cannibalism rate. Size grading in the early DPHmay negatively affect the survival rate and growth performance of the larvae because of their weak tolerances. Therefore, maintaining optimal rearing conditions such as stock density, and feeding strategy may support higher survival and growth performance rates, especially in larvae that are newly acclimated to exogenous feeding. Increasing the number of daily meals, collecting the dead larvae in a timely manner, and may contribute to the reduction of cannibalism in Russian sturgeon fry pre-feeding, thus increasing the survival rate.

The fact that, the natural distribution areas of sturgeon are in Türkiye makes the aquaculture of this species important. Developing effective culture methods for Russian sturgeon larvae is crucial both for conservation and commercial production.

Table 1. Total Length, Weight, SGR, Survival, and Cannibalism Rates of Russian Sturgeon Larvae at the End of the Experiment.

Group	W0 (g)	Wf (g)	L0 (cm)	Lf (cm)	SGR (%day-1)	SR (%)	Cannibalism
S	0.108±0.006	0.964±0.05	1.5±0.1	3.5±0.3	7.5[a]	30[a]	%2[a]
M	0.273±0.015	2.612±0.35	2.2±0.2	6.7±0.4	8.0[a]	53[b]	%9.3[b]
L	0.433±0.009	4.563±0.4	3.1±0.2	8.2±0.4	8.42[a]	64[c]	%5.1[c]

Note: Significant differences of SGR, survival rate and cannibalism among treatments assigned by different letters (a, b, c) ($P < 0.05$). W_0, initial weight; W_f, final weight; L_0, initial length; L_f, final length; SGR, specific growth rate, SR, survival rate. Values are the mean ± standard deviations of three replicates.

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Ethics committee approval: This study was conducted after approval of Ethical Local Committee of the Recep Tayyip Erdogan University.

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