

## Effect of concrete pond and net-cage culture systems on growth performance and haematological parameters of Siberian sturgeon (*Acipenser baerii*)

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**Abstract:** The effect of concrete pond and net-cage culture systems on growth and haematological indices of the Siberian sturgeon (*Acipenser baerii*) were studied in a 90-day experiment. A total of 300 fish with a stocking density of  $12.6 \pm 0.37$  kg/m<sup>2</sup> (initial average weight  $1140 \pm 53.8$  g) were stocked in floating net-cages. Also, 276 fish with a stocking density of  $12.6 \pm 0.29$  kg/m<sup>2</sup> and an initial average weight of  $1097 \pm 72.6$  g were stocked in concrete ponds. Throughout the study, the average weight, mean length, and haematological parameters of the fish in each environment were recorded every 30 days. The fish in net-cages displayed higher growth rate (GR), specific growth rate (SGR), and body weight increase (BWI) as well as a lower food conversion rate (FCR) when compared to the fish in concrete ponds. No differences in the condition factor (CF) or survival rate (SR) were found in the trial. In terms of haematological parameters, there was no difference between the ponds and net-cages for the values of red (RBC) and white (WBC) blood cells, haematocrit (Hct), haemoglobin (Hb), MCV, MCH, MCHC, lymphocyte, monocyte, neutrophil, and eosinophil in the initial 30-day and 60-day sampling periods. In the 90-day sampling period, a statistical difference was found in the RBC, MCV, MCH, and WBC values between the ponds and net-cages. Furthermore, in the 90-day sampling period, no statistical difference was found in the Hct, Hb, MCHC, lymphocyte, monocyte, neutrophil, and eosinophil values. Consequently, the Siberian sturgeon culture in net-cages is advantageous to concrete ponds in regards to the growth parameters.

**Key words:** *Acipenser baerii*, concrete pond, culture, growth, haematology, net-cage

### 1. Introduction

Sturgeons are one of the oldest vertebrate species living in the world. They evolved approximately 250 million years ago and survived during the process of extinction of the dinosaurs. Sturgeons have been overhunted by humans due to the high commercial value of their eggs (caviar) and their meat. Nowadays, the stocks of these fish in nature have decreased considerably. Caviar consumption as a fashionable luxury foodstuff began in the seventeenth and eighteenth centuries, and its popularity has increased up until today. Caviar is the most valuable product of sturgeon fishing and from a biological perspective, consists of mature but unfertilized eggs of the female sturgeon [1]. The sturgeon culture in Russia began in 1869 when Ovsjannikov succeeded in breeding sterlet (*Acipenser ruthenus*) eggs and larvae that were artificially fertilised in the Volga river [2]. Today, sturgeon breeding has become quite important due to extreme hunting, destruction of habitat and reproduction areas, and the decrease in natural stocks [3]. The Siberian sturgeon (*Acipenser baerii*, Brandt 1869) offers very good opportunities for aquaculture. This

nonmigrating freshwater sturgeon has demonstrated a fine growth performance in various production systems of different shapes and sizes [4,5]. The results of previous research on Siberian sturgeon feeding and nutritional physiology are very promising in terms of the sustainable fish culture [6]. As a result of increasing consumption, necessary studies should be carried out to obtain higher quality products and to make production more economical, which in turn would increase production. Among these studies, it is especially important to know the rate of feed utilisation and growth performance, and most importantly, to achieve the best development with aquaculture in different environments. Siberian sturgeon has been of great interest to date because it is an especially important species in terms of breeding value [7]. Aquaculture in soil ponds, concrete ponds, fiberglass tanks, and net cages is rapidly developing today.

Haematological values contribute significantly to the determination of impact caused by diseases and environmental factors in fish [8]. Haematology can assist in the assessment of changing environmental conditions

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and normal conditions in the diagnosis between populations and in the determination of information about pollutants in the aquatic environment. It is also a branch of science that determines the effects of nutritional and environmental factors as well as the diagnosis of fish diseases [9].

This study aimed to determine the growth and feed evaluation performance and some haematological parameters of the Siberian sturgeon (*Acipenser baerii*), which is one of the most suitable species for breeding in terms of caviar production under a concrete pond and net-cage culture regime.

## 2. Materials and methods

The study was carried out on a commercial Siberian sturgeon (*Acipenser baerii* Brandt, 1869) farm that has concrete ponds on the land (37°18'08"N, 35°42'09"E) and in the floating net-cages in Seyhan Dam Lake (37°03'23"N, 35°20'46"E) in Adana province, Turkey, between 20 March 2018 and 17 June 2018, for 90 days. Three hundred fish (initial live weight of 1140 ± 53.8 g, total length 64.2 ± 6.7 cm) were stocked in three floating net-cages (3 × 3 × 2 m, the underwater part of the net was 1 m, mesh size 30 mm, 100 fish/net-cage, stocking density 12.6 ± 0.37 kg/m<sup>3</sup>) and 276 fish (initial live weight of 1097 ± 72.6 g, total length 62.9 ± 8.1 cm) were stocked in three concrete ponds (2 × 4 × 1 m, 92 fish/pond, stocking density 12.6 ± 0.29 kg/m<sup>3</sup>). Supplied spring water flow rate for each concrete pond was 12 L min<sup>-1</sup>. Twenty-five fish were sampled every 30 days from each pond for growth performance and haematological analyses, for a total of 75 fish at each sampling time. Fifteen fish from net-cages and 15 fish from ponds were used for haematological analyses at each sampling time. Before measurement and haematological analyses, fish were anesthetized with quinaldine sulphate (20 mL/L) [10]. In this trial, basal extruded sturgeon feed (no: 4.5) with the same nutrient content and properties purchased from a commercial firm was used in both environments (Table 1). Fish were fed at 0.75% of live body weight four times a day [11]. Water temperature, dissolved oxygen, and pH were measured every day in both culture systems by using a YSI 6600 CTD multiparameter during the experiment.

Growth and other parameters were calculated according to the following formulas:

Specific growth rate (SGR) =  $(\ln W_t - \ln W_0) / t \times 100$  [12],

Food conversion ratio (FCR) =  $F / (W_t - W_0)$  [12],

Body weight increase (BWI%) =  $100 \times (BW_f - BW_i) / BW_i$  [13],

Growth rate (GR) =  $(BW_f - BW_i) / n$  [13],

Condition factor (CF) =  $100 \times (BW / TL^3)$  [14],

Survival rate (SR) =  $100 \times (\text{total fish count} - \text{dead fish count}) / \text{total fish count}$  [15]. BW<sub>i</sub>: initial body weight (g);

**Table 1.** Formulation of basal sturgeon diet (g/100 g).

Basic content	Amounts
Wheat	15
Dehulled extracted toasted soya	13
Poultry meal	5
Fish meal	37
Blood meal	7
Wheat gluten	8
Lipids	
Fish oil	12
Vitamins and minerals	
Vitamin A	10020 IU/kg
Vitamin C	500 mg/kg
Vitamin E	200 mg/kg
Vitamin D3	1137 IU/kg
Phosphorus	0.9 %
Calcium	1.5 %
Sodium	0.3%
Antioxidants	
Ethoxyquin	100 mg/kg
Butylated hydroxytoluene	32 mg/kg

BW<sub>f</sub>: final body weight (g); n: total number of days the experiment was run; TL: total length; W<sub>0</sub>: mean of initial weight in ponds or net-cages; W<sub>f</sub>: mean of final weight in ponds or net-cages; F: consumed feed.

For haematological analyses, 2 mL of blood were drawn from the caudal vein of each fish using a heparinized syringe [16,17]. The samples were stored on ice and transported to the laboratory. The samples were analysed on the same day. Erythrocyte (RBC) and leucocyte (WBC) blood cells were counted using the Natt-Herrick solution and Thoma haemocytometer [18]. In the determination of haemoglobin (Hb) and hematocrit (Hct), cyanmethemoglobin and microhematocrit methods were used [18,19]. Leukocyte cell types (lymphocyte, monocyte, neutrophil, and eosinophil) were identified in blood smears. Peripheral blood smears were stained with a mixture of May-Grünwald and Giemsa. The percentages of leukocyte cell types were identified using the stained blood smears [20,21]. Erythrocyte indexes were calculated as:

MCV (mean corpuscular volume) ( $\mu^3$ ) =  $Hct (\%) \div RBC (10^6 / mm^3) \times 10$

MCH (mean corpuscular haemoglobin) (pg) =  $Hb (g / 100 mL) \div RBC (10^6 / mm^3) \times 10$

MCHC (mean corpuscular haemoglobin concentration) (%) =  $\text{Hb (g / 100 mL)} \div \text{Hct (\%)} \times 100$  [18,22].

The results were compared using a one-way analysis of variance (ANOVA). Duncan multiple comparison test of the one-way ANOVA was used for comparing the mean differences. The differences were assumed significant at  $P \leq 0.05$  [23].

### 3. Results

The highest and lowest values of measured water parameters are given in Table 2. The average body weight and mean standard length of the fish in different culture systems at the beginning of the trial (0 days) and the end of the experiment (90 days) are shown in Table 3. The results showed that growth parameters were affected by different culture systems. Better growth was obtained from net-cages than from concrete ponds (Figure). At the end of the experiment, the average weight was statistically significantly different between the concrete pond and net-cage culture systems ( $P < 0.05$ ), but the mean length in the different culture systems was insignificant ( $P > 0.05$ ). The GR, SGR, and BWI measurement values of fish in the net-cages showed an increase compared to fish in the concrete ponds ( $P < 0.05$ ). The FCR results of fish in ponds significantly increased compared to the values obtained for fish in cages ( $P < 0.05$ ). Regarding the CF and SR values, no statistical difference was detected between the net-cages and the concrete ponds ( $P > 0.05$ , Table 4).

In terms of the tested haematological parameters, there was no statistical difference between ponds and net-cages for the values of the initial (0 days), first (30 days), and second (60 days) sampling ( $P > 0.05$ ). In the third sampling (90 days), a statistical difference was found in the RBC, MCV, MCH, and WBC values between ponds and net-cages ( $P < 0.05$ ). Furthermore, in the third sampling (90 days), no statistical difference was found between the concrete ponds and net-cages for Hct, Hb, MCHC, lymphocyte, monocyte, neutrophil, and eosinophil values ( $P > 0.05$ ). The haematological parameters of the Siberian sturgeon (*Acipenser baerii*) in concrete ponds and net-cages are given in Table 5.

**Table 2.** Lowest and highest  $O_2$ , pH, and temperature values during the experiment.

	$O_2$ (mg/L)	pH	Temperature ( $^{\circ}\text{C}$ )
Pond	6.9–7.5	7.6–7.8	18.5–20.6
Net-cage	7.2–8.8	8.1–8.4	17.3–22.1

### 4. Discussion

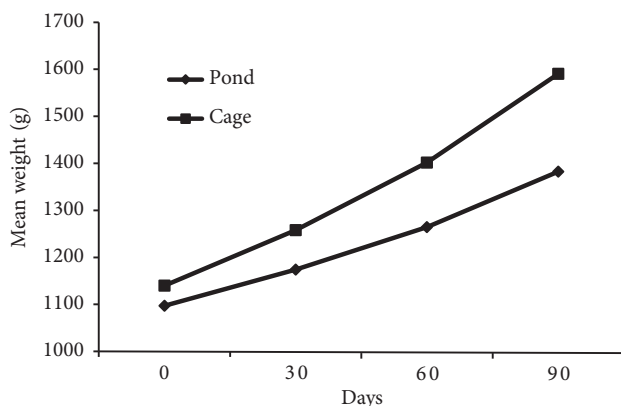
In fish farming, parameters related to growth and haematology are very important from an economic point of view and in terms of monitoring fish health. A comparison of growth performance in the Siberian sturgeon under two different culture systems showed that the fish in net-cages grew faster and were ahead in weight ranking. According to our results, FCR and SGR were better in net-cages (1.92 and 0.37) when compared to ponds (2.83 and 0.25). It may be due to efficient water change and the presence of fish in conditions closer to their natural environment. Similarly, McGinty [24] reported that tilapia had a faster growth rate in a cage culture system when compared to an open pond culture system.

Pyka and Kolman [7] compared the growth performance and feeding intensity of Siberian sturgeon (*Acipenser baerii*) cultured in pond cultivation. In their study, the growth rate of Siberian sturgeon began to increase at water temperature above  $13^{\circ}\text{C}$  in the spring and reached its highest value in the summer. The growth stopped when the water temperature dropped below  $13^{\circ}\text{C}$ . Mensah et al. [25] conducted a 24-week trial to examine the growth of *Oreochromis niloticus* and *Sarotherodon galilaeus* fish species under different culture regimes (cages and hapa-in-pond). The initial mean weight of *O. niloticus* in the cage increased from  $27.02 \pm 0.42$  g to  $299.67 \pm 16.40$  g (final mean weight), and in the pond it increased from  $27.12 \pm 0.34$  g to  $128.39 \pm 9.04$  g. The weight of the *S. galilaeus* increased from  $26.72 \pm 0.63$  g to  $137.51 \pm 6.22$  g in the cage and from  $26.72 \pm 1.04$  g to  $71.09 \pm 18.47$  g in the pond, respectively. For *O. niloticus* in the cage and

**Table 3.** Average values of weight and length changes of Siberian sturgeon (*Acipenser baerii*) throughout the experiment.

Culture system		Initial sampling (0 day)	1st sampling (30 days)	2nd sampling (60 days)	3rd sampling (90 days)
Pond	Weight (g)	$1097 \pm 72.6$	$1174 \pm 75.8$	$1268 \pm 79.4$	$1386 \pm 85.3$
	Total length (cm)	$62.9 \pm 8.1$	$63.7 \pm 7.7$	$65.1 \pm 7.1$	$66.7 \pm 7.4$
Net-cage	Weight (g)	$1140 \pm 53.8$	$1258 \pm 69.2$	$1405 \pm 76.8$	$1594 \pm 81.1$
	Total length (cm)	$64.2 \pm 6.7$	$66.4 \pm 7.2$	$68.5 \pm 8.1$	$71.9 \pm 8.5$

Data are represented as mean  $\pm$  SE.



**Figure.** Mean weights of Siberian sturgeon (*Acipenser baerii*) during 90-day feeding.

pond culture systems, condition factor, mean daily weight gain (g), specific growth rate (g), mean relative weight gain (%), and FCR values were determined as  $3.83 \pm 0.09$  and  $3.80 \pm 0.05$ ,  $1.38 \pm 0.08$  and  $0.52 \pm 0.05$ ,  $1.22 \pm 0.03$  and  $0.80 \pm 0.04$ ,  $90.88 \pm 0.50$  and  $80.33 \pm 1.20$ ,  $1.58 \pm 0.16$  and  $3.57 \pm 0.49$ , respectively. For *S. galilaeus*, these values were detected as  $3.73 \pm 0.09$  and  $3.77 \pm 0.06$ ,  $0.56 \pm 0.03$  and  $0.23 \pm 0.09$ ,  $0.83 \pm 0.04$  and  $0.49 \pm 0.13$ ,  $79.12 \pm 1.44$  and  $61.10 \pm 5.11$ ,  $1.83 \pm 0.08$  and  $4.19 \pm 0.23$ , respectively. The data here supports the findings of our study. Köksal et al. [5] determined the growth and feed evaluation performance of the Siberian sturgeon (*Acipenser baerii*), which is one of the most suitable species for aquaculture in channel type concrete ponds. They fed 75-day-old Siberian sturgeon juveniles, whose mean initial weight was  $9.20 \pm 0.34$  g, for 135 days, with the mean final weight of the fish reaching  $225.00 \pm 8.00$  g. The survival rate at the end of the trial was 91%, while the specific growth rate ranged from 2.90 to  $1.30\% \text{ day}^{-1}$ . At the end of the experiment, the mean condition factor and feed conversion ratio were calculated

as  $0.35 \pm 0.003$  and 1.70, respectively. In the present study, it was determined that the survival rate was 93.84%, the specific growth rate  $0.25 \pm 0.004\% \text{ day}^{-1}$ , condition factor  $0.46 \pm 0.009$ , and FCR  $2.83 \pm 0.01$  in our pond results. In the experiment, the specific growth rate decreased with increasing age and the feed conversion ratio increased. Kaushik et al. [26] examined the growth performance of Siberian sturgeon (*Acipenser baerii*) in concrete tanks ( $1.5 \times 1.5 \times 0.3$  m) having a water temperature of  $17.5 \pm 1$  °C. In their study, they reported that the bodyweight increases rate (BWI) of the Siberian sturgeon with an initial weight of 90 g was 179%. In our research, this rate was found to be  $26.3 \pm 0.05\%$  in concrete ponds and  $39.8 \pm 0.03\%$  in net-cages. This difference between Kaushik et al. [26] and our trial is thought to be due to the decrease in BWI ratio as the age of Siberian sturgeon increases. In their study, the weight of the *Acipenser baerii* in the cage system in Marksovskiy region (Russia) increased from 100 g to 837 g after 5 months. The water temperature was in the range of 17–28 °C and the survival rate was 93.0% [27]. In another experiment, the specific growth rate and nutrient conversion rate of Siberian sturgeon were determined with different daily feeding rates [28]. The fish with a mean weight of  $1736 \pm 37$  g were kept in fiberglass tanks with a water temperature of 19–22 °C and they were fed at a rate of 0.75% of their body weight. The specific growth rate and food conversion ratio were measured as  $0.47 \pm 0.06\% \text{ day}^{-1}$  and  $1.71 \pm 0.33$ , respectively. Medale and Kaushik [29] reported that the daily food intake of 1700 g Siberian sturgeon at 18 °C was at the rate of 0.5% of their body weight and the specific growth rate was  $0.31\% \text{ day}^{-1}$ . Celikkale et al. [30] studied the juvenile Russian sturgeon (*Acipenser gueldenstaedtii*) breeding performance in experimental net-cages in the Sapanca Lake (freshwater). They used two experimental stocking densities of 12 ( $3.3 \text{ kg m}^{-3}$ ) and 8 ( $2.2 \text{ kg m}^{-3}$ ) fish  $\text{m}^{-3}$ . The fish were grown at water temperature ranging from 15 to 29.8 °C during a 203-day experimental

**Table 4.** Mean values of GR, SGR, BWI, CF, FCR, and SR obtained in the pond and net-cage culture systems for Siberian sturgeon (*Acipenser baerii*).

Culture systems	Pond	Net-cage
Growth rate (GR) ( $\text{g} \cdot \text{day}^{-1}$ )	$3.2 \pm 0.02^a$	$5 \pm 0.06^b$
Specific growth rate (SGR) ( $\% \text{ day}^{-1}$ )	$0.25 \pm 0.004^a$	$0.37 \pm 0.009^b$
Body weight increase (BWI) (% in total duration)	$26.3 \pm 0.05^a$	$39.8 \pm 0.03^b$
Condition factor (CF)	$0.46 \pm 0.009^a$	$0.42 \pm 0.007^a$
Food conversion ratio (FCR)	$2.83 \pm 0.01^a$	$1.92 \pm 0.02^b$
Survival rate (SR) (%)	93.84 <sup>a</sup>	96.33 <sup>a</sup>

Data are represented as mean  $\pm$  SE. The values in the same line with different superscripts are significantly different ( $P < 0.05$ ).

**Table 5.** Haematological analysis results of Siberian sturgeon (*Acipenser baerii*) raised in ponds and net-cages.

		Initial sampling (0 day)	1 <sup>st</sup> sampling (30 days)	2 <sup>nd</sup> sampling (60 days)	3 <sup>rd</sup> sampling (90 days)
RBC ( $\times 10^6/\text{mm}^3$ )	Pond	0.93 $\pm$ 0.05 <sup>a</sup>	0.87 $\pm$ 0.07 <sup>a</sup>	0.99 $\pm$ 0.04 <sup>a</sup>	0.89 $\pm$ 0.05 <sup>a</sup>
	Net-cage	0.97 $\pm$ 0.03 <sup>a</sup>	0.91 $\pm$ 0.09 <sup>a</sup>	0.95 $\pm$ 0.06 <sup>a</sup>	1.19 $\pm$ 0.03 <sup>b</sup>
Hct (%)	Pond	27.1 $\pm$ 1.59 <sup>a</sup>	25.3 $\pm$ 1.95 <sup>a</sup>	28.2 $\pm$ 1.73 <sup>a</sup>	26.9 $\pm$ 1.55 <sup>a</sup>
	Net-cage	25.9 $\pm$ 1.18 <sup>a</sup>	28.5 $\pm$ 1.67 <sup>a</sup>	27.6 $\pm$ 1.92 <sup>a</sup>	25.6 $\pm$ 1.88 <sup>a</sup>
Hb (g/dL)	Pond	9.4 $\pm$ 0.40 <sup>a</sup>	8.5 $\pm$ 0.11 <sup>a</sup>	9.1 $\pm$ 0.16 <sup>a</sup>	9.3 $\pm$ 0.42 <sup>a</sup>
	Net-cage	8.7 $\pm$ 0.60 <sup>a</sup>	8.9 $\pm$ 0.26 <sup>a</sup>	8.4 $\pm$ 0.22 <sup>a</sup>	9.0 $\pm$ 0.37 <sup>a</sup>
MCV ( $\mu^3$ )	Pond	291.3 $\pm$ 15.3 <sup>a</sup>	289.5 $\pm$ 19.2 <sup>a</sup>	284.1 $\pm$ 14.7 <sup>a</sup>	301.2 $\pm$ 20.9 <sup>a</sup>
	Net-cage	268.1 $\pm$ 13.9 <sup>a</sup>	307.4 $\pm$ 17.8 <sup>a</sup>	290.5 $\pm$ 16.9 <sup>a</sup>	214.3 $\pm$ 14.8 <sup>b</sup>
MCH (pg)	Pond	102.7 $\pm$ 5.9 <sup>a</sup>	96.5 $\pm$ 7.1 <sup>a</sup>	92.3 $\pm$ 5.5 <sup>a</sup>	105.4 $\pm$ 8.3 <sup>a</sup>
	Net-cage	90.8 $\pm$ 6.5 <sup>a</sup>	97.8 $\pm$ 8.5 <sup>a</sup>	88.9 $\pm$ 4.7 <sup>a</sup>	74.2 $\pm$ 4.1 <sup>b</sup>
MCHC (%)	Pond	33.5 $\pm$ 3.19 <sup>a</sup>	35.1 $\pm$ 2.64 <sup>a</sup>	32.9 $\pm$ 3.68 <sup>a</sup>	34.4 $\pm$ 3.75 <sup>a</sup>
	Net-cage	31.7 $\pm$ 4.21 <sup>a</sup>	31.2 $\pm$ 3.51 <sup>a</sup>	30.4 $\pm$ 2.56 <sup>a</sup>	35.1 $\pm$ 5.18 <sup>a</sup>
WBC ( $\times 10^3/\text{mm}^3$ )	Pond	9.31 $\pm$ 0.14 <sup>a</sup>	8.79 $\pm$ 0.12 <sup>a</sup>	9.67 $\pm$ 0.23 <sup>a</sup>	10.35 $\pm$ 0.51 <sup>a</sup>
	Net-cage	8.93 $\pm$ 0.22 <sup>a</sup>	9.16 $\pm$ 0.35 <sup>a</sup>	9.51 $\pm$ 0.14 <sup>a</sup>	13.62 $\pm$ 0.43 <sup>b</sup>
Lymphocyte (%)	Pond	82.45 $\pm$ 4.22 <sup>a</sup>	79.95 $\pm$ 5.18 <sup>a</sup>	80.75 $\pm$ 4.41 <sup>a</sup>	83.92 $\pm$ 5.11 <sup>a</sup>
	Net-cage	83.18 $\pm$ 3.97 <sup>a</sup>	81.93 $\pm$ 3.96 <sup>a</sup>	77.61 $\pm$ 3.86 <sup>a</sup>	78.29 $\pm$ 4.58 <sup>a</sup>
Monocyte (%)	Pond	9.76 $\pm$ 1.25 <sup>a</sup>	10.02 $\pm$ 1.64 <sup>a</sup>	9.25 $\pm$ 2.17 <sup>a</sup>	11.14 $\pm$ 1.06 <sup>a</sup>
	Net-cage	10.62 $\pm$ 1.97 <sup>a</sup>	7.96 $\pm$ 2.13 <sup>a</sup>	8.36 $\pm$ 1.22 <sup>a</sup>	9.85 $\pm$ 1.33 <sup>a</sup>
Neutrophil (%)	Pond	6.13 $\pm$ 0.56 <sup>a</sup>	5.50 $\pm$ 2.34 <sup>a</sup>	6.69 $\pm$ 1.15 <sup>a</sup>	7.21 $\pm$ 1.52 <sup>a</sup>
	Net-cage	6.87 $\pm$ 0.91 <sup>a</sup>	7.11 $\pm$ 1.92 <sup>a</sup>	9.44 $\pm$ 1.76 <sup>a</sup>	8.77 $\pm$ 1.39 <sup>a</sup>
Eosinophil (%)	Pond	1.3 $\pm$ 0.11 <sup>a</sup>	1.1 $\pm$ 0.17 <sup>a</sup>	1.3 $\pm$ 0.20 <sup>a</sup>	1.1 $\pm$ 0.32 <sup>a</sup>
	Net-cage	1.1 $\pm$ 0.16 <sup>a</sup>	1.6 $\pm$ 0.13 <sup>a</sup>	1.2 $\pm$ 0.15 <sup>a</sup>	1.4 $\pm$ 0.13 <sup>a</sup>

Data are represented as mean  $\pm$  SE. The values in the same line with different superscripts are significantly different ( $P < 0.05$ ).

period. The initial and final mean body weights were determined as 279.5  $\pm$  31.27 g and 1112.8  $\pm$  234.77 g in the first group and 271.1  $\pm$  28.21 g and 1140.5  $\pm$  213.31 g in the second group, respectively. The SGR was determined between 3.47% and 2.35% in the high-density group, and between 3.49% and 2.38% in the low-density group. CF was found to be 0.45  $\pm$  0.05 in both groups. The mean FCR and mortality were determined as 5.7 and 5.6, 7.3% and 3.9% in both groups for the total experiment period. In another study, specimens of the Amur sturgeon (*Acipenser schrenckii*) were placed in the Three Gorges Reservoir in cages (15, 30, 45, and 60 fish  $\text{m}^{-2}$ ). At the beginning of the trial, the weight of all fish ranged from 48.7 to 51.6 g and the water temperature was between 14.8–21.7 °C [31]. After 75 days of growth, the survival rate of the group of 15 fish  $\text{m}^{-2}$  was highest at 97.5%. At the end of the trial, the FCR, SGR, and final mean weight of the sturgeons in the group of 15 fish  $\text{m}^{-2}$  was 1.4, 1.01, and 110.3  $\pm$  11.2 g, respectively. In another study, Vaccaro et al. [32] examined the growth

performance of two sturgeon hybrids in floating cages in a lake in Sicily, Southern Italy, between December 2000 and July 2001 (water temperature 9.8–26.4 °C). The first group (AL-hybrid) consisted of 1000 fish with an initial weight of 49.5  $\pm$  19.4 g, and the second group (LA-hybrid) consisted of 1000 fish with an initial weight of 45.5  $\pm$  10.5 g. The final weight at the end of the trial was 820.8  $\pm$  210.1 and 707.8  $\pm$  145.4 g for the AL-hybrid and LA-hybrid, respectively. In addition, the mortality rate was 3.9% and 3.4% for AL and LA, respectively. The mean values of SGR, FCR, and CF for the AL and LA hybrids were 1.39–1.24, 1.69–1.55, and 0.44–0.42 for the total period, respectively. The type, size, and shape of culture systems, the weight and age of the fish, stock density, flow rate of water, feed content, and feeding period also affected the factors for the sturgeon such as growth rate, body weight increase, condition factor, food conversion ratio, and survival rate. Therefore, it is difficult to compare our results with other resources or experiments.

Bucur et al. [33] performed haematological examinations on North American sturgeon (*Polyodon spathula*) cultured in ponds. They detected the Hb, Hct, RBC, MCV, MCH, and MCHC values for fish weighing 777 g as  $8.0 \pm 0.95$ ,  $40.5 \pm 5.53$ ,  $2.252 \pm 0.25$ ,  $180.85 \pm 26.12$ ,  $35.88 \pm 4.66$ , and  $20.18 \pm 3.74$ , respectively. They also determined these values for fish weighing 1193.7 g as  $9.9 \pm 1.7$ ,  $39.3 \pm 8.0$ ,  $1.299 \pm 0.2$ ,  $300.8 \pm 24.0$ ,  $76.9 \pm 7.2$ , and  $25.7 \pm 3.7$ , respectively. They reported that the differences between some haematological values in the groups of different ages might be due to changing environmental factors or pathogenic activity. Bahmani et al. [34] comparatively examined the haematological values of the cultured *Huso huso* and *Acipenser persicus* sturgeons. Hb ( $\text{g L}^{-1}$ ), RBC ( $\times 10^3 \mu\text{L}^{-1}$ ), WBC ( $\times 10^3 \mu\text{L}^{-1}$ ), lymphocyte (%), monocyte (%), neutrophil (%), and eosinophil (%) values for *Acipenser persicus* (weight 1196.5 g) were found as 48.9, 360, 30.9, 78.25, 1.06, 17.99, and 2.7, respectively. For *Huso huso* (weight 741 g), these values were determined as 56.05, 623.45, 61.03, 55.08, 0.75, 32.09, and 12.08, respectively. Ghiasi et al. (35), in their study on the *Acipenser ruthenus* (698.6  $\pm$  8.9 g), determined these values as RBC ( $\times 10^5 \text{ mm}^{-3}$ )  $1.32 \pm 0.05$ , Hct (%)  $27.0 \pm 1.3$ , Hb ( $\text{g dL}^{-1}$ )  $6.3 \pm 0.3$ , MCH ( $\text{pg cell}^{-1}$ )  $49.1 \pm 3.6$ , MCHC ( $\text{g dL}^{-1}$ )  $24.2 \pm 1.9$ , MCV (fl)  $20.7 \pm 1.3$ , WBC ( $\times 10^3 \text{ mm}^{-3}$ )  $62.3 \pm 7.5$ , lymphocyte (%)  $91.7 \pm 1.4$ , neutrophil (%)  $6.8 \pm 1.2$ , eosinophil (%)  $0.8 \pm 0.3$ , and monocyte (%)  $0.3 \pm 0.1$ . In one study, RBC ( $\text{T}\cdot\text{L}^{-1}$ ), Hct ( $\text{L}\cdot\text{L}^{-1}$ ), Hb ( $\text{g}\cdot\text{L}^{-1}$ ), MCV (fl), MCH (pg), and MCHC ( $\text{L}\cdot\text{L}^{-1}$ ) values of the Siberian sturgeon (*Acipenser baerii*) control group, with an average body weight of 401 g, were found as  $0.87 \pm 0.02$ ,  $0.32 \pm 0.02$ ,  $72.75 \pm 1.69$ ,  $361.34 \pm 9.57$ ,  $83.46 \pm 1.51$ , and  $0.23 \pm 0.01$ , respectively [36]. Jahanbakhshi et al. [37] stated that the haematological values of the juvenile Great sturgeon

(*Huso huso*) in fiberglass tanks with a capacity of 400 L at  $22 \pm 1$  °C were  $6.8 \pm 0.23$  for Hb ( $\text{g/dL}$ ),  $22.1 \pm 00$  for Hct (%),  $12.5 \pm 1.52$  for WBC ( $\times 10^3/\text{mm}^3$ ),  $65.4 \pm 27.0$  for RBC ( $\times 10^4/\text{mm}^3$ ),  $29.6 \pm 3.00$  for MCHC ( $\text{g dL}^{-1}$ ),  $99.8 \pm 3.45$  for MCH (Pg),  $329.21 \pm 10.91$  for MCV (fl),  $6.00 \pm 00$  for neutrophil (%),  $93.3 \pm 0.57$  for lymphocyte (%), and  $0.667 \pm 0.57$  for eosinophil (%). Some of the haematological findings obtained in our study were lower than the previous research results mentioned above. However, some data was consistent with the values of previous research, and some data was higher than reported by other researchers. In the third sampling in our study, some differences in RBC, Hct, MCV, MCH, and WBC levels were found to be statistically significant between the net-cage and the pond. In natural environments, the increased metabolic activity of fish with the warming of the water in the spring and summer months, enhanced oxygen demand, and enhancement of microbial activity in the water are reported to be the main reasons for these changes [38]. Furthermore, many other factors, such as water temperature, age, changes in the physicochemical parameters of the water, sex, stress, stock density, content of feed, maturity, photoperiod, season, hypoxia, and disease may affect the haematological values in fish.

Cage farming has some advantages over other aquaculture systems. These advantages include efficient use of lakes and rivers that are not currently in use, easier feeding, easier stocking and harvesting, less cost related to treatment or prevention of diseases, and easier stock management compared to the pond culture [39]. Consequently, it can be concluded that the breeding of Siberian sturgeon in net-cages is more advantageous than in concrete pond conditions. In addition, more detailed research should be conducted on sturgeon in terms of environmental factors and breeding techniques.

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