Study On The Effects of Polyculture of the Sterlet (*Acipenser Ruthenus*) Fingerlings and European Catfish (*Silurus Glanis*) on Bioproductive Performances of These Species in Recirculating Aquaculture Systems

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Abstract
The aim of this study was to evaluate the effects of polyculture of the sterlet (*Acipenser ruthenus*) fingerlings with european catfish (*Silurus glanis*) (20 – 30%) into recirculating aquaculture system on growth dynamic of the fish and tank's bioproductivity. Two variants of polyculture have been tested during a period of 42 days in duplicate: V1-sterlet with 20% catfish (600 sterlets and 120 catfish); V2-sterlet with 30% catfish (600 sterlets and 180 catfish). The control group (C) contains sterlet in monoculture (600 sterlets). After 42 days of polyculture of the sterlet fingerlings with catfish 20% (V1) or 30% (V2) there were no significant differences ($p>0.05$) in sterlets' growth dynamic among the three variants. The bioproductive indices were better in the polyculture variant where sterlets were farmed with 30% catfish. Polyculture of catfish and sterlet could be a good way to positively influence the fingerling sterlet farming in RAS, having a beneficial impact on tank's bioproductivity. A significant plus of fish biomass (catfish) resulted by means of valorisation of the unconsumed food by the sterlet, was obtained in both polyculture variants.

Keywords: European catfish, polyculture, RAS, sterlet

1. Introduction

Intensively indoors sturgeon farming in recirculating aquaculture systems (RAS) represents an activity of growing interest due to the increased demand for sturgeon meat and caviar. Because recirculating aquaculture systems are relatively new for sturgeon farming, growing technologies need to be improved in order to achieve maximum bioproductive and economic efficiency.

The sterlet (*Acipenser ruthenus*) is very popular among sturgeon species farmed for caviar or meat. It is a freshwater species with many useful characteristics that recommends it as a very good candidate for intensive aquaculture in RAS because this species is relatively small and reaches sexual maturity faster than other sturgeon species [1-5]. The sterlet prefers to eat the food especially from the bottom of the tanks, so that the polyculture of this species with one with a gregarious instinct (such as the European catfish intensively reared) could ensure a better use of the available water volume and food.

European catfish (*Silurus glanis*) can lead to obtaining of a much faster income for meat production in monoculture and as auxiliary species as well. This species could reveal interesting characteristics useful for sturgeon farmers who are rearing fish in recirculating aquaculture systems. This has a high growth rate and an efficient use rate of granulated food. The possibility of using

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granulated food in the farming of the catfish and the sturgeon make these species suitable for polyculture in an intensive system [6]. Anyway, the impact of polyculture on growing, on survival rate and the potential competition for food of these two species is still unknown.

The aim of this study is to assess whether the European catfish (*Silurus glanis*) as an additional species grown in polyculture (20-30%) with the sterlet (*Acipenser ruthenus*) in the recirculating aquaculture system could have a beneficial impact on bioproductivity and growth dynamics of the sterlet.

2. Materials and methods

The trials were started using 114-days-old sterlet and 47-day-old European catfish. Both species were obtained by means of artificial reproduction in recirculating aquaculture systems, in the spring of 2019. Until the beginning of the experiment, both species grew in monoculture and were fed with different types and sizes of granulated food (Advance, Star Alevin and SUPREME-10; Alltech - Coppens, The Netherlands), according with the age and the size of the fish.

The study was carried out at the NIMB Sturgeon Farm (Giarmata, Romania). The hall with recirculating aquaculture systems (RAS) where the study was carried out contains 16 growth tanks with a total capacity of 12 m^3, 2 settling-tanks of 5 m^3 each, 2 moving bed biological filters of 5 m^3 each and recirculation pumps. Oxygenation was made by aeration with air blowers and ceramic stones.

Two variants of polyculture and one variant of monoculture were tested in duplicate over a period of 42 days as follows:

- Control (M): sterlet grown in monoculture (600 specimens with an average weight of 11 grams);
- Variant 1 (V1): sterlet (600 specimens with an average weight of 11 grams) plus 20% catfish (120 specimens with an average weight of 3.98 g); The catfish total weight in this trial represents 7.23% of total sterlet biomass.
- Variant 2 (V2): sterlet (600 specimens with an average weight of 11 grams) plus 30% catfish (180 specimens with an average weight of 3.91 g). The catfish total weight in this trial represents 10.63% of the total biomass of the sterlet.

At the beginning of the experimental period, the fish were fed with 1.2-1.5 mm pellets (Advance; Alltech - Coppens, The Netherlands), and then the food size was increased to 2 mm (Star Alevin; Alltech - Coppens, The Netherlands). After a period of 42 days (experimental period: July 8 - August 19), the amount of food was calculated as 4% of the sterlet biomass in the first 2 weeks, then increasing to 5%. Feeding was done manually every 4 hours.

The main physical-chemical parameters of the water were determined using the DR3900 spectrophotometer (Hach Lange, Germany) and the multiparameter Hanna (Hanna Instruments, Romania). Throughout the experimental period, these values were: temperature: 21^{o}C; ammonium (NH_4): 0.45 mg/l; nitrites (NO_2): 2.9 mg/l; nitrates (NO_3) 104.8 mg/l; phosphates (PO_4): 9.51 mg/l; pH: 7.9; conductivity 1090 µS/cm. Two m^3 of water from RAS were daily replaced with fresh water.

To assess the growth dynamics of both species, 180 sterlets from 6 tanks (30 sterlets/tank) and 120 catfish from 4 tanks (30 catfish/tank) were randomly measured weekly [7, 8].

The biometric study consisted of measuring total length (L), standard length (Sl), maximum body height (H), and body mass (G). During the biometric measurements, the fish were anesthetized with clove oil (0.05 ml/500 ml water) in order to avoid the stress of the fish and reactions during the handling [9].

For each biometric character, the mean, standard deviation (SD), standard error of the mean (SE) and coefficient of variation (CV) were calculated.

Based on the data obtained after the body measurements were carried out, the main bio-productive indices (the Specific Growth Rate (SGR) the Body Weight (SGR_{BW}) and Total Length (SGR_{TL}), the Daily Growth Rate (DGR) and Feed Conversion Rate (FCR)), were calculated using the following formulas:

Specific growth rate (% day^{-1});

SGR_{BW}=[(ln final BW-ln initial BW)/ΔT]x100

SGR_{TL}=[(ln final TL-ln initial TL)/ΔT]x100

Daily growth rate (g d^{-1});

DGR=(final BW-initial BW)/ΔT

Feed conversion rate;

FCR=Feed distributed/(final Biomass-initial Biomass)

where: ΔT is the duration of the experiment, the other being described above.

The data was analysed using STATISTICA10 software. Kruskal-Wallis test was used to assess the significance of differences. The data statistically processed are presented into the paper as Mean±SD.

3. Results and discussion

After the 42 experimental days it was observed that the total length and body mass of the studied sterlet fingerlings had a significant increase but the differences between the three experimental variants were very small (p>0.05) (Figure 1 and 2).
The total length of the sterlet fingerlings registered the highest value in V1 (23.74±1.93 cm), and the smallest value in control group C (23.40±1.58 cm) (Table 1). The sterlets in the experimental variant V1 (53.73 g±13.59 g) were with 1.83 g heavier than those in group C (51.90±11.48 g) and with 1.1 g heavier compared to the fingerlings from the experimental variant V2 (52.63±11.10 g) (Table 2). However, the differences between the body weight of the juvenile sterlets in the experimental variants remained not significant (p>0.05) after 42 days. This means that an additional species did not have a better or weaker influence on the sterlet's growth.

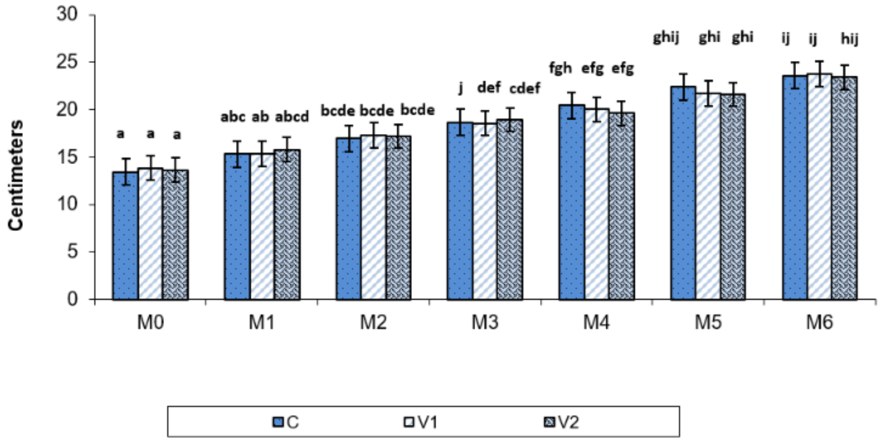

Figure 1. The weekly dynamic of the total length and the significance of the differences in sterlet M0-M6-weekly measurements. Same letter indicates not significant differences (p>0.05)

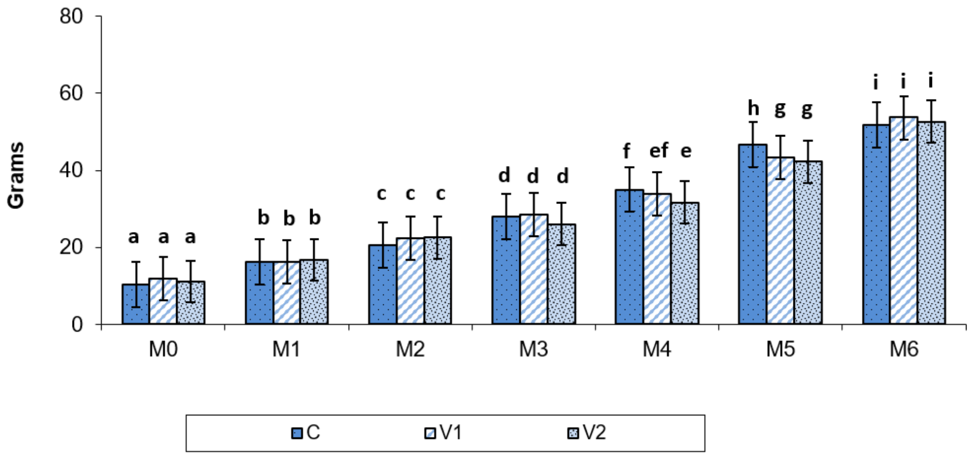

Figure 2. The weekly dynamic of the body weight and the significance of the differences in sterlet M0-M6-weekly measurements. Same letter indicates not significant differences (p>0.05)

Table 1. Dynamics of the total length-TL (cm) of the sterlet during the 42 days (n=60)

Specification	M0			M2			M4			M6		
	C	V1	V2	C	V1	V2	C	V1	V2	C	V1	V2
Mean (cm)	13.43	13.84	13.64	16.96	17.31	17.18	20.42	20.02	19.62	23.40	23.74	23.57
SD	0.67	1.05	0.77	1.11	1.22	1.18	1.40	1.34	1.42	1.58	1.93	1.69
SE	0.09	0.14	0.10	0.14	0.16	0.15	0.18	0.17	0.18	0.20	0.25	0.22
CV	4.96	7.60	5.66	6.54	7.03	6.84	6.86	6.68	7.23	6.77	8.13	7.17

M0- M6 - the weekly measurements; SD-standard deviation; SE- standard error; CV- coefficient of variation; C-control; V1 and V2- trials

Table 2. Dynamics of the body weight-BW (g) of the sterlet during the 42 days (n = 60)

Specification	M0			M2			M4			M6		
	C	V1	V2	C	V1	V2	C	V1	V2	C	V1	V2
Mean (cm)	10.277	11.83	11.08	20.67	22.38	22.55	35.03	33.94	31.69	51.90	53.73	52.63
SD	1.41	2.35	1.73	4.32	4.25	4.40	6.52	7.17	5.99	11.48	13.59	11.10
SE	0.18	0.30	0.22	0.56	0.55	0.57	0.84	0.93	0.77	1.48	1.75	1.43
CV	13.75	19.87	15.58	20.90	18.99	19.53	18.62	21.12	18.90	22.11	25.29	21.09

M0-M6- the weekly measurements; SD- standard deviation; SE- standard error; CV-coefficient of variation; C-control; V1 and V2- trials

At the end of the experimental period, the juvenile catfish from the experimental variant V1, used as an additional species in sterlet polyculture, had a significant increase in body mass ($p \leq 0.001$) (Figure 4), increasing from 3.984±0.45 g to 23.15±5.30 g in 42 days (Table 4). These values indicate that the body mass of the European catfish has increased almost 6 times in a relatively short period of time. The body weight of the catfish from V1 (23.15±5.30 g) was significantly higher ($p \leq 0.05$), with 1.45 g in comparison with the fish from V2 (21.70±5.39 g). It also had a very significant growth in total length ($p \leq 0.001$) (Figure 3), increasing from 7.74±0.33 cm to 14.35±1.10 cm in 42 days, doubling its length (Table 3).

Table 3. Dynamics of the total length - TL (cm) of the European catfish during the 42 days (n=60)

Specification	M0		M2		M4		M6	
	V1	V2	V1	V2	V1	V2	V1	V2
Mean (cm)	7.74	7.78	10.38	10.19	12.74	12.19	14.35	14.05
SD	0.33	0.27	0.45	0.45	0.8	0.74	1.10	1.21
SE	0.04	0.04	0.06	0.06	0.10	0.10	0.14	0.16
CV	4.31	3.49	4.30	4.47	6.28	6.07	7.66	8.65

M0-M6- the weekly measurements; SD-standard deviation; SE- standard error;CV-coefficient of variation; V1 and V2- trials

Table 4. Dynamics of the body weight - BW (g) of the European catfish during the 42 days (n=60)

Specification	M0		M2		M4		M6	
	V1	V2	V1	V2	V1	V2	V1	V2
Mean (g)	3.984	3.906	9.62	8.89	16.59	14.78	23.15	21.70
SD	0.45	0.43	1.21	1.33	3.15	2.52	5.30	5.39
SE	0.06	0.06	0.16	0.17	0.41	0.33	0.68	0.70
CV	11.32	10.96	12.61	15.01	18.99	17.04	22.88	24.83

M0-M6-the weekly measurements; SD-standard deviation; SE-standard error; CV-coefficient of variation; V1 and V2-trials

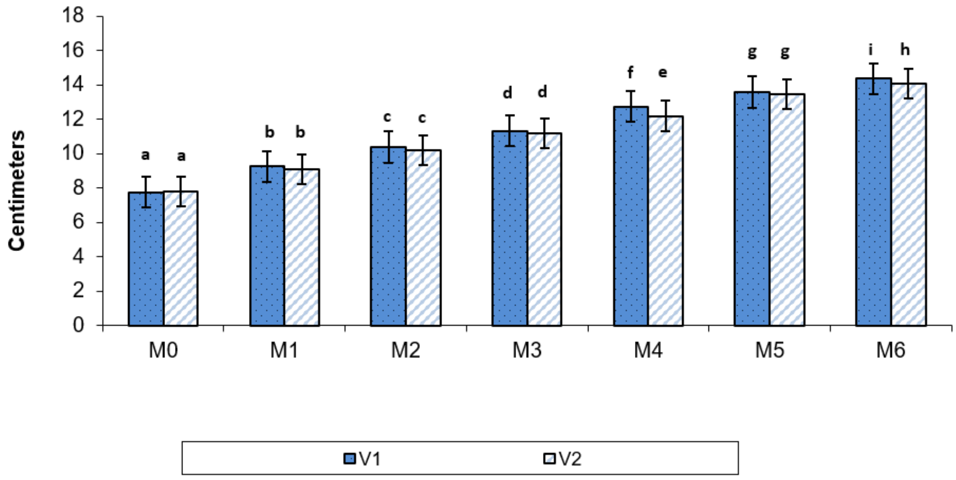

Figure 3. The weekly dynamic of the total length and the significance of the differences in european catfish M0-M6-weekly measurements. Same letter indicates not significant differences (p>0.05)

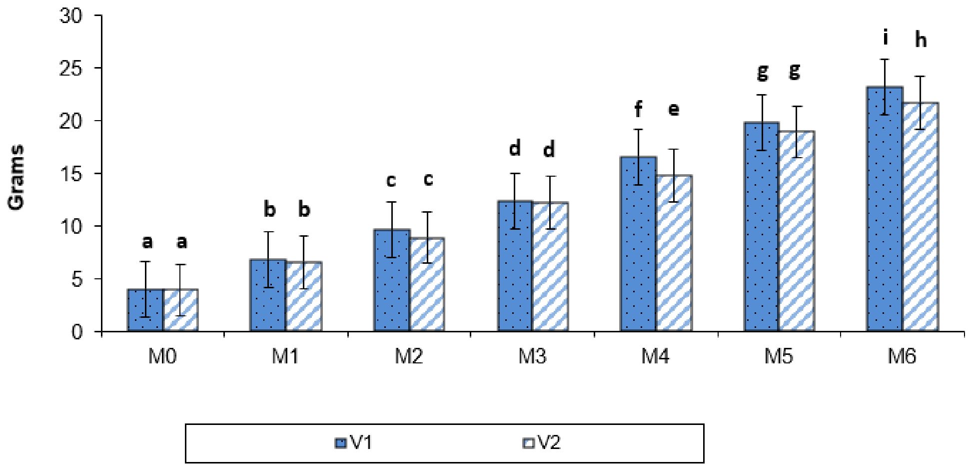

Figure 4. The weekly dynamic of the body weight and the significance of the differences in European catfish M0-M6-weekly measurements. Same letter indicates not significant differences (p>0.05)

During the experimental period, the highest increase in biomass was recorded in the sterlet polyculture variant with 30% catfish (70.97 kg), followed by an extremely small difference in biomass growth in polyculture with 20% catfish (70.03 kg) (Figure 5). Both polyculture variants have superior results to the sterlet monoculture, where only 62.28 kg of biomass were obtained, even the same amount of food was used.

According to Table 5, the specific growth rates of the body weight (SGR_{BW}) in sterlet indicates higher values in the experimental variant V2 and the specific growth rate of the total length (SGR_{TL}) indicates higher values in the control group. The daily growth rate (DGR) in sterlet was highest in the experimental variant V1. The food conversion rate for the sterlet is observed to reach the lowest values in the polyculture variant V1 (1.169), compared to the variant C (1.177) and the variant V2 (1.179). The best results of the food conversion rate on the polyculture basins were obtained at the end of the experimental period in variant V2 (1.044).

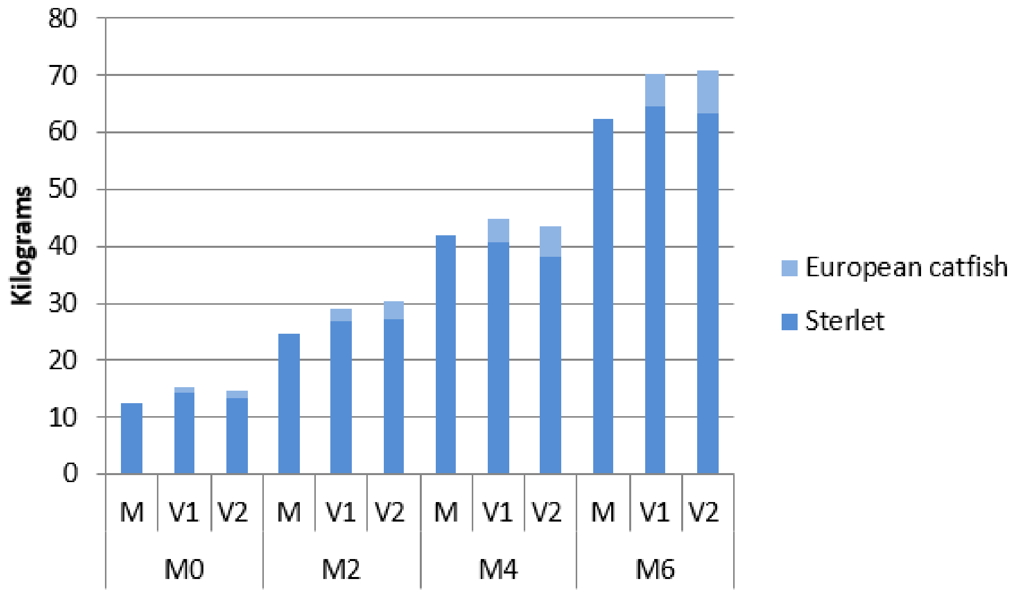

Figure 5. Graphical representation of fish biomass growth (kg/m^3) during experimental period

Table 5. Bio-productive parameters of the sterlet at the end of experimental period in the experimental variants

Specification	Control	V1	V2
SGR_{BW} (% day^{-1})	3.855	3.603	3.709
SGR_{TL} (% day^{-1})	1.339	1.284	1.285
DGR (g)	0.991	0.997	0.989
FCR (sterlet)	1.177	1.169	1.179
FCR (sterlet+European catfish)		1.071	1.044

The fish biomass of the additional species (catfish) was thought as a solution for the sterlet's uneaten food. Therefore, catfish appear to be an additional good species in sterlet polyculture. The real gain of the polyculture variant sterlet plus European catfish would be the fact that additional catfish biomass would be obtained based on the food uneaten by the sterlet in monoculture.

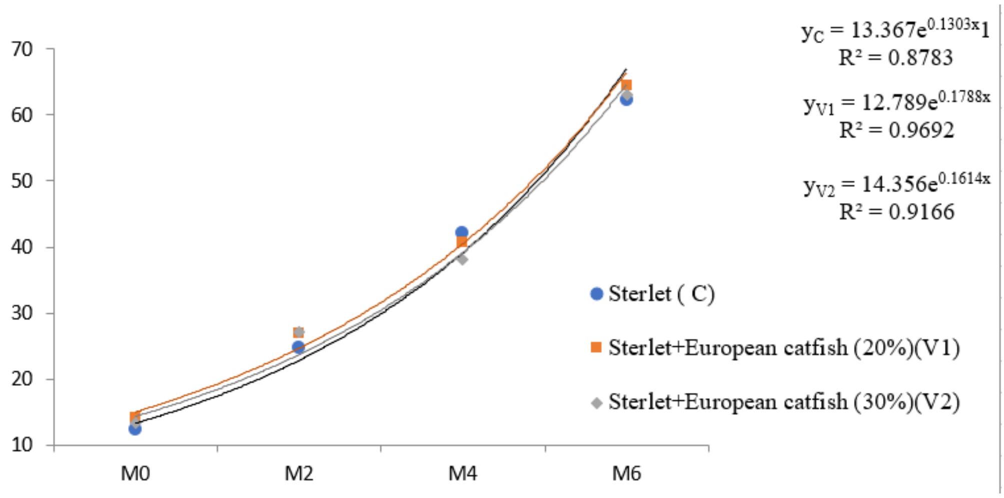

Figure 6. Fish biomass dynamic during 42 days, mathematically adjusted, in control and experimental variants

4. Conclusions

The polyculture of the sterlet fingerlings with European catfish 20% (V1) or 30% (V2) for 42 days did not significantly ($p>0.05$) influenced the sterlets' growth dynamic.

Anyway, a significant plus of fish biomass (European catfish) resulted by valorisation of the pellets unconsumed by the sterlet, was obtained in both polyculture variants (V1, V2).

European catfish appear to be an additional good species for sterlet polyculture in recirculating aquaculture systems.

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