Bulgarian Journal of Agricultural Science, 26 (No 1) 2020, 248–253

Influence of initial stocking density on growth performance and survival of European catfish (*Silurus glanis* L.) larvae under controlled conditions

Vasilka Krasteva

Agricultural Academy, Institute of Fisheries and Aquaculture, 4003 Plovdiv, Bulgaria
E- mail: vasilka_mitrova@abv.bg

Abstract

Krasteva, V. (2020). Influence of initial stocking density on growth performance and survival of European catfish (*Silurus glanis* L.) larvae under controlled conditions. *Bulg. J. of Agric. Sci., 26 (1)* 248–253

This paper presents the influence of initial stocking density on European catfish (*Silurus glanis* L.) larvae growth performance indicators. The experimental unit was a flow-through system with complete water turnover every 43 min. The research was carried out at the Institute of fisheries and aquaculture, Plovdiv in two consecutive years (2017-Experiment I and 2018-Experiment II). The experimental design includes the evaluation of three variants of stocking densities: variant A-10 ind.l^{-1}, variant B-20 ind.l^{-1} and variant C-40 ind.l^{-1}. The results from the study demonstrated that the weight gain (IWG, mg) was strongly affected by the stocking density. It is the highest in the lowest stocking density (Variant A) in both experiments. The survival rate was the highest in variant B, respectively 70.9% in 2017 and 89.9% in 2018. The specific growth rate (SGR, %.day^{-1}) and the daily growth rate (DGR, mg.day^{-1}) were the highest in variant A in Experiment I and Experiment II. The recorded values of food conversion ratio (FCR) were the highest in variant C (1.2) in both years.

Keywords: European catfish; *Silurus glanis*; larvae; initial density; rearing; growth; survival

Introduction

In fish farming European catfish is preferred predatory species. The positive aspects of the European catfish as a breeding stock are its rapid increase of weight gain; adaptability towards wide range of ecological conditions; high market price and exceptional tasty bone-free meat (Zaikov, 2006).

For the rearing of *S. glanis* it is essential to find the balance between stocking density and obtaining optimal growth performance and survival rate. This is much easier to achieve when successfully managing the external factors that influence the technological process (predators, insufficient food, poor water quality, sustaining optimal temperature, etc.). These factors largely affects fish farming production in earthen ponds, whereas controlled conditions used in the initial culturing of the larvae, significantly enhance the survival rate compared to traditional pond rearing (Krol et al., 2014).

The intensive fish growth in controlled conditions involves inevitably the practice of higher stocking densities compared to those in the natural environment of the fish. Therefore, the scientific, social and governmental attention had focused on the stocking density being considered as a key factor that may affect fish physiology in intensive systems (Bhakta et al., 2009; Jamroz et al., 2008; Kroletal., 2014; Opiyo et al., 2014; Placinta et al., 2012; Placinta et al., 2014).

The stocking density is one of the most important factors influencing the growth performance of European catfish. In many studies different low (3-10 ind.l^{-1}) (Nwipieetal., 2015; Szlamińska, 1986) and high densities are applied (100 ind.l^{-1}) (Kozłowski et al., 1995; Mares & Kouril, 1988; Offem et al., 2013; Wioeniewolski, 1989). According to Ulikowski & Borkowska (1999) the results obtained by different authors depend to large extent on several main factors: age, size, feeding intensity, water quality, type of growing units, determining the relation between density and growth of a certain species.

In Bulgaria the first published data for rearing of European catfish larvae in controlled conditions, without focusing on the initial stocking density, was presented by Zaikov & Basamakov (1987), Zaikov & Hubenova (1998) and Grozev et al. (2000). The mentioned studies are conducted at too various conditions and the final results are contradictory, which makes it difficult to conclude the definite advantage of one stocking density over another.

The purpose of the present study is to assess the optimal stocking density by determining the growth performance and survival rate at specific environmental conditions, used feed and the feeding technique.

Material and Methods

The research was carried out at the Institute of Fisheries and Aquaculture, Plovdiv in two consecutive years (2017 – experiment I and 2018 – experiment II).

Experiment I had duration of 16 days. The experimental individuals were European catfish larvae with initial body weight 8.3±0.9 mg and initial age of 4 days. The number of the individuals used in the experiment was 4200. The larvae were obtained from semi-artificial propagation. Three variants of experimental stocking densities, each with one repetition, were applied: 10 ind.l^{-1}(variant A), 20 ind.l^{-1} (variant B) and 40 ind.l^{-1}(variant C).

Experiment II also had duration of 16 days. The experimental individuals were European catfish larvae with initial body weight 18.8 ± 1.4 mg and initial ages of 10 days. The number of the individuals used in the experiment was 6300. The experimental stocking densities were the same as in Experiment 2, but with two repetitions each for better statistical analysis.

Weight assessments were performed with 50 randomly selected individuals at the beginning and at the end of the experiment. The individuals were anesthetized with 0.02 ml.l^{-1} clove oil and weighed with analytical balance „Kern AEJ".

The experimental unit was a flow-through production system consisting of 9 tanks 60×40×40 cm in size and volume of 30 l (Figure 1). Water flow rate was 0.7 l.min^{-1} and complete water cycle took 43 min. The water for the experimental system was supplied from drill with average temperature of 12ºC and warmed up by heaters installed in the collecting reservoir. In each tank micro compressors for continuous air supply were installed. For the sterilization of the water UV lamp was used. The tanks were cleaned twice a day and the dead fish were counted and removed.

The daily feeding rate was equal to 50% of the fish weight at the beginning of the experiment and at the 6th day of the study it was decreased to 30%. The larvae were fed with commercial dry pellet food "Ocean nutrition" with pellet size 0.5 mm and protein content 58%, during the whole duration of the experiment. The physicochemical parameters of water (dissolved oxygen (O_2), temperature (T˚C), hydro-

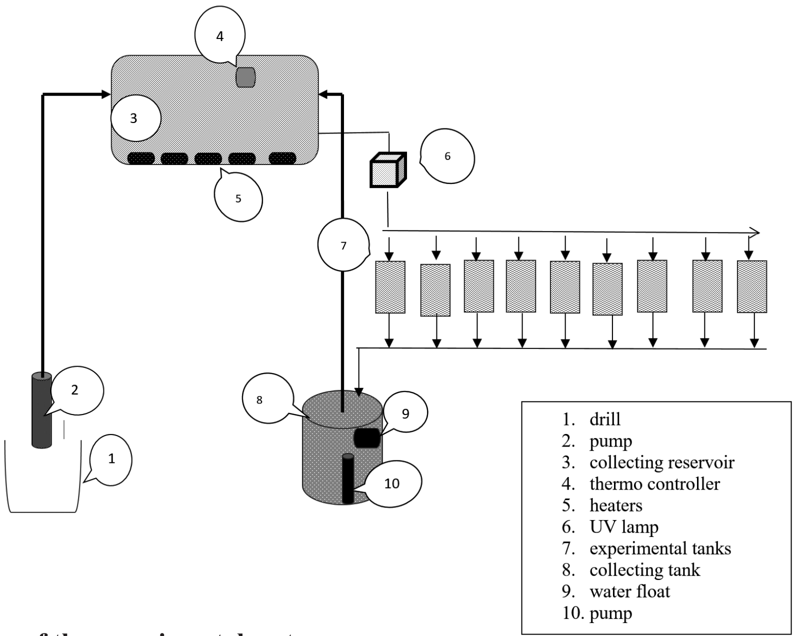

Figure 1. Configuration of the experimental system

gen indicator (pH)) were measured daily, while nitrogen compounds were monitored once a week.

The growth performance of the larvae in the three experimental variants was compared in terms of absolute weight gain (WG), specific growth rate (SGR), daily growth rate (DGR), feed conversion ratio (FCR) and survival rate (SR) using the following formulas:

Absolute weight gain (WG, mg): WG = Wt2 – Wt1

Specific growth rate (SGR, %.day^{-1}):

$$SGR = \frac{\ln Wt_2 - \ln Wt_1}{P} \times 100$$

Daily growth rate (DGR, mg.day^{-1}): $DGR = (Wt_2 - Wt_1)*p^{-1}$

where: Wt_1= initial weight; Wt_2=final weight; P = duration of the experiment (days);

Food conversion ratio (FCR): $(FCR) = \frac{FI}{WT}$,

where: FI = total feed intake (g); WT = total weight gain (g); (Total weight gain = mean individual weight gainnumber of survival fish);

Survival rate (SR, %): $SR = \frac{NF}{NI} \times 100$,

where: NF = final number of fish; NI = initial number of fish.

The results are presented as mean ± S.E.M. and were analyzed via Data Analysis (Excel 2010). T-test (Two Sample for Means), at significant level of $P < 0.05$, was used to compare the effect of the initial stocking density on growth performance of the larvae of European catfish. Correlation analysis (Pearson coefficient) was performed by applying scatter plot and linear regression in order to determine the correlation between tank stocking density and growth performance characteristics.

Results and Discussion

According to Cristea et al. (2002) high stocking density generates large amount of metabolic waste. Thus, the main technological requirement that must be achieved in different production systems is to ensure that environmental conditions largely correspond with the ecological and physiological characteristics of the cultured species.

The values of the physicochemical parameters of the water are presented in Figure 2 and Figure 3. During the period of rearing the temperature was within the optimal range of 23.7-26.6°C in both experiments, with an exception of fluctuation of 19.4°C in Experiment II. The values of the dissolved oxygen fluctuated within acceptable levels (5.6-7.5 mg.l^{-1}) and the pH was relatively constant, with values ranging from 7.7 to 8.2 in both experiments.

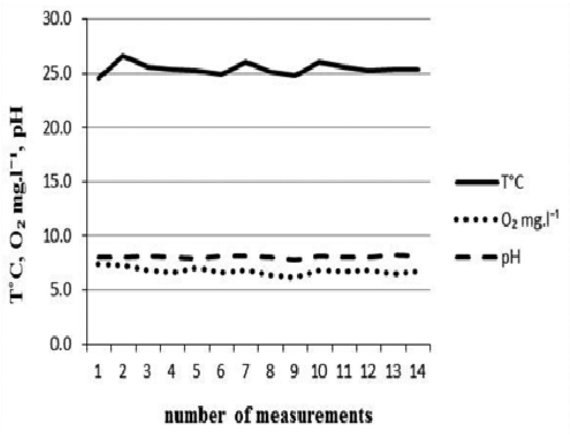

Figure 2. Values of dissolved oxygen, temperature and pH during Experiment I

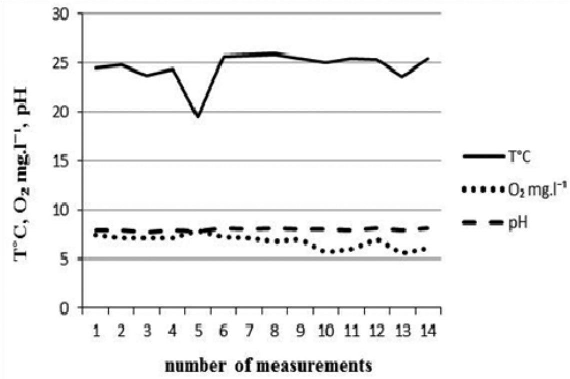

Figure 3. Values of dissolved oxygen, temperature and pH during Experiment II

Nitrogen compounds concentrations are presented in Table 1. During the experimental period the nitrogen compounds were within the acceptable range for catfish rearing. Nitrite nitrogen and ammonium nitrogen kept relatively constant values, while nitrate nitrogen varied from 11.7±3.43 to 20.7±4.14 mg.l^{-1}.

The highest individual weight gain (IWG) was recorded in Variant A (10 ind.l^{-1}) in both experiments (Table 2 and Table 3). The difference between Variant A and Variant C is statistically significant in Experiment I ($P < 0.05$).

The final biomass (FB) correlates to the initial biomass (IB), with the highest values registered in Variant C (40 ind.l^{-1}) in both experiments. The initial stocking density significantly affects the final biomass, with a high level of significance established between Variant A and Variant C in Experiment I and among the all of variants in Experiment II ($P < 0.01$)

Table 1. Mean values (±SD) of nitrogen compounds

	Experiment I			Experiment II		
	A	B	C	A	B	C
NO_2^- $mg.l^{-1}$	0.3±0.03	0.3±0.05	0.3±0.03	0.3±0.04	0.3±0.04	0.4±0.03
NO_3^- $mg.l^{-1}$	20.3±4.05	20.4±3.81	20.7±4.14	11.8±3.78	11.8±3.71	11.7±3.43
NH_4^+ $mg.l^{-1}$	0.2±0.03	0.2±0.01	0.2±0.03	0.2±0.07	0.2±0.10	0.2±0.10

Table 2. Technological performance indicators of growth of European catfish larvae rearing in different conditions of intensity – Experiment I

Growth performance indicators	Experiment I			Level of significance
	A	B	C	
ISD[1] ($ind.l^{-1}$)	10	20	40	
INF[2]	600	1200	2400	
MIW[3] ($mg.ind^{-1}$)	8.3±0.9	8.3±0.9	8.3±0.9	
IB[4] (mg)	4 980	9 960	19 920	
FB[5] (mg)	29 136^{a}	47 401^{ab}	80 714^{b}	**
FSD[6] ($ind.l^{-1}$)	5.6^{a}	14.2^{b}	26.5^{bc}	*
SR[7] (%)	56.3^{a}	70.9^{a}	66.3^{a}	NS
MFW[8] ($mg.ind^{-1}$)	86.2±20.1^{a}	55.7±13.7^{ab}	50.7±11.9^{b}	*
IWG[9] (mg)	77.9±8.8^{a}	47.4±6.6^{ab}	42.5±7.0^{b}	*
TWG[10] (mg)	26 330^{a}	40 337^{ab}	67 660^{b}	*
SGR[11] ($\%.day^{-1}$)	14.7±0.6^{a}	11.9±0.8^{ab}	11.3±0.8^{b}	*
DGR[12] ($mg.day^{-1}$)	4.9±0.6^{a}	3.0±0.4^{ab}	2.7±0.5^{b}	*
FCR[13]	1.1±0.2^{b}	1.0±0.1^{b}	1.2±0.1^{b}	NS

Values connected by different superscripts are significantly different ($P \leq 0.05$)
***$P \leq 0.001$; **$P \leq 0.01$; *$P \leq 0.05$; NS – non significant;
[1]ISD – initial stocking density, [2]INF – initial number of fish, [3]MIW – mean individual weight, [4]IB – initial biomass, [5]FB – final biomass, [6]FSD – final stocking density, [7]SR – survival rate, [8]MFW – mean final fish weight, [9]IWG – individual weight gain, [10]TWG – total weight gain, [11]SGR – specific growth rate, [12]DGR – daily growth rate, [13]FCR – feed conversion ratio

Table 3. Technological performance indicators of growth of European catfish larvae rearing in different conditions of intensity – Experiment II

Growth performance indicators	Experiment II			Level of significance
	A	B	C	
ISD[1] ($ind.l^{-1}$)	10	20	40	
INF[2]	900	1800	3600	
MIW[3] ($mg.ind^{-1}$)	18.8±1.4	18.8±1.4	18.8±1.4	
IB[4] (mg)	16 920	33 840	67 680	
FB[5] (mg)	159 440^{a}	295 285^{b}	596 197^{c}	**
FSD[6] ($ind.l^{-1}$)	8.9^{a}	18.0^{b}	35.7^{c}	***
SR[7] (%)	89.0^{a}	89.9^{a}	89.3^{a}	NS
MFW[8] ($mg.ind^{-1}$)	199.3±70.9^{a}	182.5±58.0^{a}	185.5±51.3^{a}	NS
IWG[9] (mg)	180.5±32.5^{a}	163.0±19.3^{a}	166.5±27.2^{a}	NS
TWG[10] (mg)	144 400^{a}	263 734^{b}	535 131^{c}	**
SGR[11] ($\%.day^{-1}$)	14.7±1.1^{a}	14.2±0.7^{a}	14.3±1.0^{a}	NS
DGR[12] ($mg.day^{-1}$)	11.3±2.0^{b}	10.2±1.2^{b}	10.4±1.7^{b}	NS
FCR[13]	1.0±0.1^{b}	1.1±0.3^{b}	1.2±0.3^{b}	NS

Values connected by different superscripts are significantly different ($P \leq 0.05$)
***$P \leq 0.001$; **$P \leq 0.01$; *$P \leq 0.05$; NS – non significant
Abbreviations are the same used in Table 2

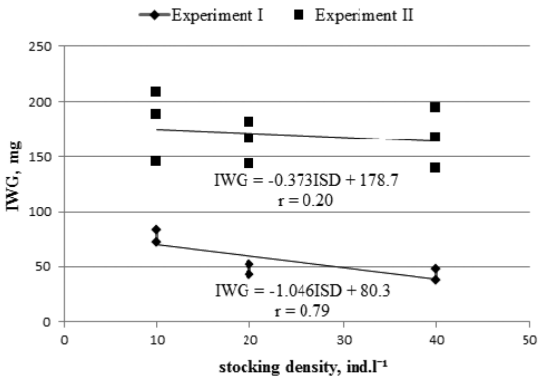

Figure 4. Correlation between individual weight gain (IWG, mg) and initial stocking density (ISD, ind.l^{-1})

The final stocking density (FSD) remains the highest in Variant C. The differences between variants A and B in Experiment I were statistically significant ($P < 0.05$) while in Experiment II the effect of the initial stocking density was significant in all variants ($P < 0.001$).

The highest survival rate (SR) was recorded in variant B in both experiments with no significant difference between the experimental groups ($P > 0.05$).

Opposite to the individual weight gain (IWG), total weight gain (TWG) was the highest in variant C due to the largest number of fish. The influence of the initial stocking density on the total weight gain was statistically significant between variant A and C ($P < 0.05$) in Experiment I, while in Experiment II high significance was established between all variants ($P < 0.01$).

Maximum values of the growth rates (SGR and DGR) were registered in variant A with statistically significant differences between variant A and C in Experiment I.

The recorded values of food conversion ratio (FCR) had similar values ranging from 1.0 to 1.2. The highest FCR was established in variant C with no significant difference among the variants in both experiments ($P > 0.05$).

The correlation between individual weight gain (IWG) and initial stocking density (ISD) is presented in Figure 4. Pearson coefficient determined a weak correlation between the studied factors in Experiment I ($r = 0.20$), while in Experiment II strong correlation was established between IWG and ISD ($r = 0.79$).

Conclusions

The results from the two-year experiments established that the European catfish larvae grow better at lower initial stocking densities, which is also mentioned by other authors (Ulikowski & Borkowska, 1999; Placinta et al., 2014). The stocking density did not significantly affect the survival rate which was the highest in variant B (20 ind.l^{-1}) in experiments, respectively 70.9% in Experiment I and 89.9% in Experiment II.

The highest growth performance indicators were registered at 10 ind.l^{-1}and 20 ind.l^{-1} which makes these stocking densities applicable in the fish farming industry.

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Received: January, 14, 2019; *Accepted:* July, 14, 2019; *Published:* February, 29, 2020