AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 13, No 1, pp 47-51, 2021
Published by Faculty of Agriculture, Trakia University, Bulgaria
ISSN 1313-8820 (print)
ISSN 1314-412X (online)
http://www.agriscitech.eu
DOI: 10.15547/ast.2021.01.009

Length-weight relationship of European catfish (*Silurus glanis* L.) fry reared at different stocking densities under controlled conditions

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(Manuscript received 14 October 2020; accepted for publication 18 January 2021)

Abstract. *The present paper investigates the body length and weight, and the size-weight variations of one-month-old European catfish reared at 4 variants of stocking density: Variant 1 - 5 spec/l; Variant 2 - 10 spec/l; Variant 3 - 15 spec/l and Variant 4 - 28 spec/l. The experiment is carried out at the Institute of Fisheries and Aquaculture, Plovdiv for a period of 16 days, using a production system consisting of tubs with continuous water flow (0.7 l/min). At the end of the experiment, the fish from each variant are sorted in three size-weight groups: A - large, B - medium and C - small. The number of fish in each group is established. From the group of the medium- and small-sized fish, 150 speciments are measured, while from the group of the large specimens, which are the smallest in number, all specimens are measured for the biometric parameters body weight (BW, g) and total body length (TL, cm). The results from the study show small variations in the length and weight of the fish reared at the lowest stocking density (Variant 1). As the density increase, the size-weight differences between the specimens from Group A also increased, while of those from Group B they decrease. The number of the medium-sized fish decrease ($p \leq 0.001$) while the number of large specimens ($p \leq 0.01$) and small fish increase ($p \leq 0.001$).*

Keywords: body length, body weight, density, size, specimens, variations

Introduction

One of the issues in fish farming is the uneven growth of fish reared under the same conditions and production facilities. The variations in the body weight and body length between the specimens from one fish population, usually have a negative effect on the growth performance indicators, especially if the percentage of specimens with lower growth rate is higher (Zaikov et al., 2008). The variations of the biometric features, such as weight and length of the body, is common for all fish species and especially for predators (Hubenova et al., 2017). Differences in the weight and the length of the body are observed even in specimens received from the same female brood stock and reared under the same conditions (Huss et al., 2007). Factors, such as stocking density, feeding regime, food type and composition, hydro-chemical regime, can affect fish growth, but the individual growth potential of each specimen also plays an important role.

The size-weight differences are also determined by the social hierarchy, protection of territories, cannibalism, etc. (Hecht and Appelbaum, 1988; Smith and Reay, 1991; Hecht and Pienaar, 1993; Kaiser et al*.,* 1995a,b; Folkvord, 1997).

The European catfish is among the largest freshwater fish worldwide, reaching up to 4-5 m total length and body weight more than 300 kg (Copp et al., 2009; Bouletrau and Santoul, 2016). This species has an economic importance in aquaculture, due to its positive characteristics, such as high growth rate and high tolerance to different hydro-chemical conditions (Brzuska and Adamek, 1999) and its delicious meat with little bones. Currently in Bulgaria the rearing of European catfish for consumption is carried out mainly in dam lakes and earthen ponds in polyculture with carp fish, and the production of stocking material is often carried out in controlled conditions. Body length and weight variations are pronounced in this period of cultivation. In order to limit these manifestations, that lead to losses, more comprehensive research is needed.

Body length and weight relationship of European catfish, in its natural habitat or aquaculture systems, has been an object of few scientific studies (Zaikov et al., 2008; Alp et al., 2011; Kuzishchin et al., 2018). Zaikov et al. (2008) investigate the body length and weight characteristics of one-summer-old catfish, reared in earthen ponds.

Until now, there is no data for conducted research on the length and weight composition of European catfish, regardless of the stage of development, reared in an intensive production system. Body weight and length are elements of some studies, where they are considered as part of the growth performance. Such research has been conducted by Haffray et al. (1998), Beckan et al. (2006), Carol et al. (2009), Placinta et al. (2012) and Florczyk et al. (2014) for European catfish, by Gaylord et al. (2001), Rezk et al. (2003), Luo et al. (2009), Tan et al. (2009)

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and Bosworth et al. (2020) for Channel catfish and by Bake et al. (2015), Omodu et al. (2017) and Fazazi et al. (2019) for African catfish. Related to the current study is the research conducted by Ebonwu et al. (2009) in which the authors evaluate the body and weight variations of African catfish fry reared in circular plastic tanks.

The aim of the present study is to establish the body length and weight composition and the corresponding size-weight variations of European catfish fry, reared at different stocking densities in plastic tubs with continuous water flow.

Material and methods

The experiment is conducted at the Institute of Fisheries and Aquaculture, Plovdiv for a period of 16 days. For the purpose of the study, a production system consisting of 40 L tubs with continuous water flow is used. The amount of the water supplied is 0.7 l/min. Complete water exchange is carried out every 57.1 min. Four variants of experimental stocking densities are applied – three variants with three repetitions and the fourth - with two repetitions. The different experimental variants, the number of fish and their initial body weight and length are presented in Table 1.

Table 1. Experimental variants with corresponding stocking densities and body measurements of the fish

Parameter	Unit of measure	Variant 1	Variant 2	Variant 3	Variant 4
Stocking density					
- litre		5	10	15	28
- total	count	600	1200	1800	2240
Initial body weight	g	0.20±0.07	0.18±0.06	0.19±0.05	0.17±0.04
Initial total length	cm	2.70±0.37	2.65±0.27	2.79±0.39	2.65±0.25

The object of the experiment is 1-month-old European catfish fry, obtained from semi-artificial propagation and reared in tubs with continuous flow. At the start of the experiment 90 specimens are measured for each variant for the biometric parameters body weight (BW, g) and total body length (TL, cm). The measurements are performed after treatment with solution of clove oil with concentration of 0.01-0.02 ml/l for sedative effect. The purpose of this methodology is to insure the animals' welfare according to the national laws and requirements. An electronic balance "Kern AEJ" (readability 0.001 g) is used to measure the body weight and an electronic caliper "Digital Caliper" (readability 0.01 mm) is used to measure the length. The total number of fry used in the research is 5840.

The main physical-chemical parameters of the water, dissolved oxygen (mg/l), temperature (°C) and pH, are measured daily using a digital water checker type WTW 315. To maintain the appropriate temperature and oxygen regime of the water, heaters and microcompressors are installed in the tubs. During the experimental period, the temperature was within the acceptable range of 22.4-26.3°C (e.g. Hilge, 2007). The average dissolved oxygen was 5.5±1.2 mg/l. According to Zaikov and Staikov (2013), its value should not fall below 4 mg/l. The pH ranged from 7.5 to 8.4 for all variants, which was within the admissible range. Similar pH values are reported in the study of Placinta et al. (2012). The number of dead fry is established daily.

Throughout the study, all fish are fed with commercial food "Ocean nutrition" – Canada with pellet size 0.8-1.0 mm and protein content 55%. The daily feeding rate is equal to 30% of the fish biomass and it is given three times per day.

At the end of the experiment, the fish from each variant are sorted in three size-weight groups: A- large, B- medium and C- small. The number of fish in each group is established. The percentage of each group, from the total number of fish, is calculated using the following formula:

Group, % = (NFG*100)/TNF,

Where: NFG is Number of fish in the group;

TNF - Total number of fish.

From size groups B and C, 150 specimens are measured, while from group A, which is the smallest in number, all fish are measured.

All established data are analyzed via Data Analysis (MS Office Excel 2010) and presented as mean±standard deviation (x±SD), coefficient of variation (CV, %) and limited values (lim). To find the influence of different stocking densities on the number of fish in each size-weight group T-test (Paired two sample for means) is used at significance level of $p<0.05$. Correlation and regression analysis are expressed by scatter plot. Pearson coefficient and regression function are used to determine the connection between the percentage distribution of each size-weight group and each variant of stocking density.

Results and discussion

The length-weight relationship of European catfish (*Silurus glanis* L.) fry is presented in Table 2. The coefficient of variation (CV, %) for the body weight of all variants is the highest in Group A, followed by Group B and Group C. An exception is the 4^{th} variant, where the second position is occupied by group C. Thus, the individual differences between the fish in this group are the largest. The individual variations between the fry in Group C are within the narrowest range; therefore the coefficient of variation is the lowest of all experimental variants, except for Variant 4.

Table 2. Length-weight relationship of three size-weight groups of European catfish fry

Group	A (large)		B (medium)		C (small)	
stat. value	BW (g)	TL (cm)	BW (g)	TL (cm)	BW (g)	TL (cm)
			Variant 1 (5 spec/l)			
x±SD	1.63±0.45	6.13±0.48	0.83±0.20	4.92±0.53	0.52±0.12	4.15±0.45
CV, %	27.80	7.88	24.06	10.68	23.81	10.94
lim	1.18÷3.27	5.53÷7.56	0.47÷1.44	3.55÷5.96	0.27÷0.47	3.10÷4.98
			Variant 2 (10 spec/l)			
x±SD	2.17±0.80	6.71±0.80	0.79±0.18	4.80±0.39	0.46±0.09	4.14±0.36
CV, %	36.38	11.86	23.15	8.03	20.66	8.60
lim	1.37÷4.18	5.45÷8.36	0.66÷1.20	4.05÷5.74	0.29÷0.46	3.44÷4.93
			Variant 3 (15 spec/l)			
x±SD	2.43±0.93	6.77±0.79	0.72±0.16	4.73±0.40	0.43±0.07	4.10±0.28
CV, %	38.15	11.24	21.80	8.48	16.89	6.90
lim	1.34÷4.04	5.65÷8.26	0.56÷1.22	3.67÷5.78	0.26÷0.48	3.50÷4.97
			Variant 4 (28 spec/l)			
x±SD	2.09±0.64	6.36±0.79	0.74±0.13	4.79±0.29	0.43±0.09	3.91±0.38
CV, %	30.44	12.47	17.27	5.99	20.65	9.60
lim	1.12÷3.41	4.82÷7.62	0.58÷1.09	4.17÷5.36	0.24÷0.50	3.30÷4.97

The body weight varies more than the body length. The individual variations between the fish of the three size-weight groups in terms of body weight are visible, while the body length is within narrower range for all experimental variants of stocking density. The specimens from Group A show lower values of the studied parameters in lower stocking densities (Variant 1 and Variant 2) and higher values at higher densities (Variant 3 and Variant 4). In contrast to Group A, in Group B and Group C it is found that with the increasing stocking density the average body weight of the fish decreases. Therefore, rearing in variants with different stocking densities affects the body length-weight composition and contributes to size differences in the three size-weight groups.

It is worth mentioning the study of Ebonwu et al. (2009) regarding body weight variations and population ratio of two-week-old fry of African catfish, *Clarias gariepinus*. Initial body weight and length are 15 mg and 80-90 mm, respectively, the experimental unit is a closed system consisting of plastic tanks. The applied stocking density is 200 fry/liter and the period of rearing is 4 weeks. Fish are divided into three size-weight groups. The authors found that the body weight of the fish, from the group of the large specimens, varies in the widest range (2.1-8.3 g) and the individual differences between the fry are the largest. The group of the medium-sized fry has weight variation within the range of 0.7-2.0 g and in the group of the small-sized fish - the weight differences vary in the narrowest range (0.1-0.7 g). The present results fully confirm those established by Ebonwu et al. (2009).

Zaikov et al. (2008) conducted research with European catfish divided into two main size-weight groups: up to 50 g and above 50 g. The first group is divided into five subgroups and the second one - into four subgroups, with all fish being measured. The results are presented in two ways: by subgroups and summarized for the two main groups. The comparison of the statistical values from both studies shows that the coefficient of variation in our study is the highest in fish from Group A (large), with all fish being measured, and the lowest in fry from Group C (small), where 150 specimens are measured. In the research of Zaikov et al. (2008) the highest coefficient of variation is established in the main group (up to 50 g), where 707 are measured. When the same specimens are divided into 5 subgroups, the values obtained for the coefficient of variation are lower.

When analyzing our results and those of Zaikov et al. (2008), we can summarize that the length-weight relationship depends on several factors: size differences, weight-size groups, number of fish measured from each group and rearing conditions.

In the present study, Group B has the highest percentage distribution in the length-weight relationship of all experimental variants, followed by Group C and Group A (Table 3).

Zaikov et al. (2008) established that the largest share of the first main group (up to 50 g) is taken by the subgroup of the smallest fish. As the weight increases, the percentage share of each of the subgroups decreases. The same pattern is observed in percentage distribution from the second main group although the studied fish have higher weight than those used in our experiment. In contrast to these results, in our study the group of medium-sized fish occupies the largest percentage share. It can be concluded that in both studies the group of the large specimens occupies the smallest percentage share of all size-weight groups of European catfish and of all experimental variants of stocking density.

Ebonwu et al. (2009) established population ratio of 1:8:10 for the group of the large-, medium- and small-sized fish, respectively. Thus, the group of the small specimens occupies the largest share of the population of African catfish fry, while in our study the largest share has the group of the medium-sized fish.

In the present study, with the increasing stocking density, the number of fish in Group B decreases ($p \leq 0.001$), while the number of fish in Group A ($p \leq 0.01$) and group C increases ($p \leq 0.001$). The most homogenous, based on the length-weight composition, are the fry reared at the lowest stocking density – Variant 1. In Variant 3, the largest size-weight differences are recorded in Group A. At higher stocking densities, the size-weight variations between the fish from Group A increase, while those of Group B - decrease. The percentage distribution of the different size-weight groups changes towards decrease in the number of medium-sized specimens and increase in the number of the large and small fish. This is due to the fact that some specimens have rapid development and suppress other fish.

Table 3. Percentage distribution of the three size-weight groups at different stocking densities

Variant No	1 (5 spec/l)	2 (10 spec/l)	3 (15 spec/l)	4 (28 spec/l)	Level of significance
		A (large)			
x±SD	1.5±0.5[a]	2.4±0.1[b]	3.1±0.3[c]	3.8±0.2	**
CV, %	33.33	5.97	8.33	4.98	
lim	1.0÷2.0	2.3÷2.5	2.8÷3.3	3.6÷3.9	
		B (medium)			
x±SD	91.3±2.1[a]	81.3±3.5[b]	72.0±2.0[c]	65.0±2.8	***
CV, %	2.28	4.32	2.78	4.35	
lim	89.0÷93.0	78.0÷85.0	70.0÷74.0	63.0÷67.0	
		C (small)			
x±SD	7.2±2.6[a]	16.3±3.6[b]	24.9±2.3[c]	31.2±2.6	***
CV, %	35.80	22.35	9.02	8.45	
lim	5.0÷10.0	12.5÷19.8	22.7÷27.2	29.4÷33.1	

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

According to Smith and Reay (1991), Hecht and Pienaar (1993) and Ebonwu et al. (2009), the variations and differences in the body weight and in the body length of fish is due to the competition for food, territorial hierarchy, social dominance and aggression. Heterogeneous growth and size-weight differences are precondition for a stronger manifestation of cannibalism (Baras and Jobling, 2002; Naumowicz et al., 2017). In the present study, the survival rate decreases with the increasing stocking density, Variant 1 – 81.0%, Variant 2 – 74.4%, Variant 3 – 72.4%, Variant 4 – 66.6%, respectively.

The correlations between the three size-weight groups and the different stocking densities are presented in Figure 1. Pearson's coefficient determines very strong degree of correlation between the three size-weight groups and the stocking density. Higher stocking density determines decrease in the number of fish from Group B (r=0.92) and lower percentage distribution, while the number and percentage distribution of Group C (r=0.91) and Group A (r=0.90) increase. The regression function for Group B is negative, while for Groups A and C it is positive.

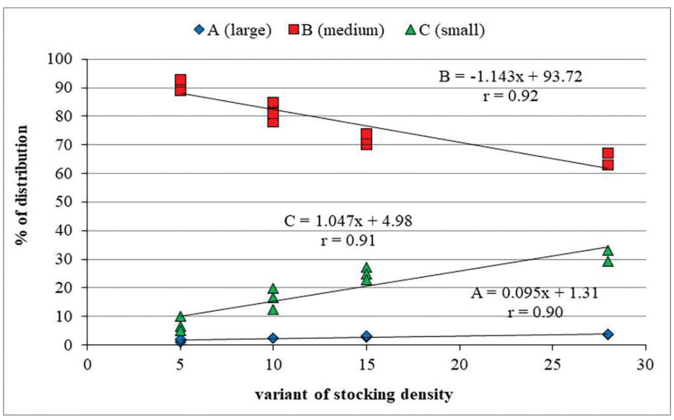

Figure 1. Correlation between the three size-weight groups and the different variants of stocking density

For the rearing of European catfish it is important to produce high quality stocking material, which can be subsequently reared in earthen ponds, dam lakes, cages or recirculation systems and tubs with continuous water flow. Most often, *S. glanis* fry are reared in controlled conditions, at high stocking densities, in order to maximize the capacity of the facilities and achieve high productivity. Placed under these conditions, the size-weight differences between the fish increase, which leads to losses due to cannibalism, malnutrition and slow growth. In order to prevent or reduce the size-weight variations, it is recommended to sort the fry by length and weight in order to narrow the differences in the size of the fish as much as possible.

Conclusion

The results from the present study revealed that the most homogenous body length-weight composition is achieved in the specimens reared at the lowest stocking density. Higher stocking densities lead to increase in the size-weight differences between the large-sized fry, while between those with medium size - they decrease. The percentage distribution between the different size-weight groups changes towards decrease in the number of the medium-sized fish ($p \leq 0.001$) and increase in the number of the large ($p \leq 0.01$) and the small fry ($p \leq 0.001$). In order to reduce size-weight differences, it is recommended to sort the fry by length and weight in order to narrow the differences in the size of the fish as much as possible.

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