THE USE OF RIVER HOPPER BARGES AS FACILITIES FOR AQUACULTURE: THE GROWTH CHARACTERISTICS OF CARP (Cyprinus carpio) DEPENDING ON STOCKING DENSITY

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Abstract: Carps (Cyprinus carpio) were farmed on a river hopper barge at two stocking densities, 10 and 20 individuals per m³. A comparison of average weights, specific growth rates and weight distributions was performed. The obtained results show that there was no statistically significant difference in any of the parameters studied with regard to stocking density.

Key words: carp (Cyprinus carpio), hopper barge, stocking density, growth.

Introduction

In Serbia, the dominant type of farming marketable carp is semi-intensive farming in ponds, based on a combination of natural and supplemental feed (Marković et al., 2009). Intensive farming of carps that are in the marketable category is sporadic and mostly conducted in cage systems, but the functioning of these systems is irregular and often of a short-term nature (Ćirković et al., 2002). Cage systems have a harmful effect on the surrounding environment in several ways: they take up relatively large areas, they cause changes in the flow regime, the possibility of waste treatment is very limited, there are problems related to escaping of farmed fish, the negative effect on the aesthetic qualities of the surrounding environment (Beveridge, 1984). The proposed type of intensive farming of marketable carp by using river hopper barges as aquaculture facilities is new in Serbia. Proposals for new technological processes need to be followed up with experimental research to determine farming conditions. The aim of the study conducted was to determine the effect of stocking density on the growth characteristics of carps under concrete farming conditions.

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Materials and Methods

The hopper barge used for the experiment measures 59.9 x 6.65 meters and is located on the left bank of the Danube in Kranjača, on the kilometre 1168 + 800. The total volume of the compartment intended for fish farming is 350 m³; the space is 40 m long, 4 m wide and 2 m deep, and it can be divided into separate compartments at every 1.5 m along the length of the barge. The water was supplied directly from the Danube, using two pumps, each with a power of 0.5 kW. The flow of water varied in the range of 324.4-514.4 m³/day, or in theory, 1-1.5 water exchanges/day. Two air compressors were used for additional aeration, each with a capacity of 170 l/min. One more compressor, with identical technical characteristics, was added during the middle phase of the experiment.

The experiment lasted 153 days (beginning of June – beginning of November, 2009). Two compartments were formed (hereinafter C1 and C2), each with a volume of 40 m³, and they were stocked with carps, with an average weight of 420 g, obtained from a commercial fish pond. The stocking density in the first chamber was 800 individuals (20 individuals/m³); in the second chamber 400 individuals were stocked (10 individuals/m³). The acclimatisation of the fish to their new conditions was monitored for 15 days and during this period they were not fed. The period of adjustment to the pellet feed lasted 9 days (the fish were given amounts of feed equalling 0.4% of the initial stock weight), followed by an experimental phase of more intensive feeding. The feed consisted of an extruded complete mixture for intensive farming of two-year-old and marketable carps, SOPROFISH 38/12, of 6 mm granulation, produced by the Veterinary Institute Subotica (38% proteins, 12% fats, 10% water, 4% cellulose, 10% ashes, vitamins: A 15 000 IU/kg, D₃ 2 500 IU/kg, E 90 mg/kg and C 200 mg/kg). The fish were hand-fed twice a day, in the morning and afternoon (the feed portions were six hours apart), and the daily dose of feed during the experiment varied within the range of 1.2-2.7% of the stock’s weight. This amount of food was determined using feeding tables, depending on temperature conditions and the average weight of individual fish in the stock. Three control samplings were performed (on days 25, 89 and 124 of the experiment; N + 21 - 110) and based on the obtained data, average weight was calculated and feed amounts were adjusted. At the end of the experiment total harvesting was performed and a sample of fish was taken for measurement of each compartment (C1, N = 117; C2, N = 80). Once a month control sampling was performed, and based on the data obtained, feed amounts were adjusted. Measurements were taken of weight to the nearest gram, and of total, fork and standard lengths to the nearest mm. Fish were anaesthetised for measuring purposes, and were returned to their respective compartments upon measurement and recovery. Mortality rates were monitored daily.
Statistical testing of pairs of average weights was performed using ANOVA. The growth rate was estimated using the equation for exponential growth (Ricker, 1958): 

\[ W_t = W_i \times e^{gt} \]

where \( W_t \) is the weight of fish after \( t \) days; \( W_i \) is the initial weight; \( g \) is the growth coefficient; \( t \) is time. The specific rate of weight growth \( G_w \), expressed as the average specific rate of weight increase (\( G_w \% \text{ d}^{-1} \)), is calculated using exponent \( b \) (\( G_w = 100 b \)), the value of which is determined using regression analysis. The comparison of specific growth rates was performed using the relation for comparing the slopes of two regression lines (Zar, 1984). Based on the samples collected from total harvest, the fish were grouped into 100 g intervals. The \( \chi^2 \) test was used to perform statistical testing of the obtained distributions.

Every day, at five points along the barge (the beginning and end of each compartment, and water at the exit) water quality parameters were measured (temperature, pH, dissolved oxygen, concentrations of ammonia, nitrites, nitrates and phosphates). Measurements were performed using a Windaus field laboratory.

**Results and Discussion**

Measurements of physical and chemical characteristics indicated uniform water quality along the entire barge. The variation ranges of the monitored parameters were: 

- \( T = 11.9-25.2^\circ\text{C} \); 
- \( O_2 = 1.6-9.24 \text{ mg/l} \); 
- \( O_2 = 18.7-104\% \) saturation; 
- \( pH = 7.44-9.12 \); 
- \( NH_3-N + NH_4^+ = 0.417-1.084 \text{ mg/l} \); 
- \( NO_2 = 0.03-0.134 \text{ mg/l} \); 
- \( NO_3 = 1.97-4.64 \text{ mg/l} \); 
- \( PO_4 = 0.2-0.49 \text{ mg/l} \).

The mortality rate was low, a total of 28 individuals died, of which 15 in C1 and 13 in C2. As indicators of growth characteristics in relation to stocking density, we monitored changes in average weight, the weight growth rate, and the distribution of defined weight classes at the end of the farming period. Table 1 contains data on the growth of farmed carps. At the end of the experimental period, the absolute weight gain was 424.41 g and 425.64 g, for C1 and C2, respectively. After testing pairs of average weights for each control period, a statistically significant difference was found only for the sample collected on day 89 (\( F = 4.132; P < 0.05 \)).

Table 1. Average weight (g; ± SD) of farmed carps. The data given are based on control samples for the entire farming period and per compartment. Values in the same row that are marked with asterisks statistically differ (ANOVA, \( P = 0.05 \)).

<table>
<thead>
<tr>
<th>Day</th>
<th>Compartment 1</th>
<th>Compartment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>420</td>
<td>420</td>
</tr>
<tr>
<td>25</td>
<td>501.89 ± 92.21</td>
<td>499.0 ± 128.35</td>
</tr>
<tr>
<td>89</td>
<td>660.68 ± 132.85*</td>
<td>585.76 ± 113.68*</td>
</tr>
<tr>
<td>124</td>
<td>769.24 ±151.03</td>
<td>778.69 ± 151.17</td>
</tr>
<tr>
<td>153</td>
<td>844.41 ±168.22</td>
<td>845.64 ± 135.73</td>
</tr>
</tbody>
</table>
The specific weight growth rates were $G_w = 0.41\% \text{d}^{-1}$ and $G_w = 0.43\% \text{d}^{-1}$, for carps from C1 and C2 (Figure 1). Equations for the regression lines obtained, ln of the transformed $W_t/W_i$ ratio as a function of time, and the appropriate correlation coefficients are given in Figure 1. Statistical testing showed that there was no statistically significant difference of carp growth rates in C1 and C2 ($t = 0.8628; P > 0.05$).

At the end of the farming period, the body weight in representative samples (C1 - $N = 117$; C2 - $N = 80$) varied within the following ranges: 502-1780 g for C1, and 538-1300 g for C2. Based on 13 defined weight classes, weight frequencies per sample were obtained (Figure 2). Both samples were unimodal. Both distributions showed asymmetricity to the left (Skewness = 2.22 for C1 and 0.7 for C1).

Classes in the 700 - 999 g range made up 74.36% and 78.75%, for C1 and C2, respectively. Statistical testing showed that there was no statistically significant difference in the distribution of weight classes between samples ($\chi^2 = 3.28; df = 6; P > 0.05$).
Growth characteristics of carp (*Cyprinus carpio*) depending on stocking density

The high survival rate of carps in both groups indicates high tolerance for given experimental conditions. General farming conditions (temperature and quality of water, duration of farming and number of feeding days, relative amount of feed and its distribution) were identical for both experimental groups. The aim of the experiment was to determine the growth characteristics of carps in relation to stocking density and in this way, to estimate the capacities of the given farming system.

The entire farming period was characterised by significant variations in dissolved oxygen content, with concentrations that often dropped below 3 mg/l. According to Boyd (1982), concentrations of dissolved oxygen < 3 mg/l have a negative effect on fish growth. For the intensive production of marketable carp using complete fodder mixtures, Ćirković et al. (2005) state that the concentration of oxygen must not be below 3 mg/l, even in the morning. The farming period lasted 153 days, but due to pronounced fluctuations and breaks in feeding during low oxygen concentrations, there was a total of 87 feeding days. The relatively small number of feeding days and breaks in feeding during the production cycle are

![Figure 2. Distribution of weight classes within experimental groups at the end of the farming period.](image-url)
certain to have had a suppressive effect on growth processes, which is reflected in the final results. By increasing flow and/or stronger additional aeration (constant or sporadic) the problem of adverse oxygen regimes can be overcome relatively easily.

Generally speaking, gregarious species can be farmed at high stocking densities. Optimal stocking densities depend on the species and age of individuals on one hand, and on the production characteristics and environmental conditions of the production system on the other hand. Furthermore, especially in intensive aquaculture systems, potential overload is closely correlated to the technical and functional characteristics of the given aquaculture facility.

The effect of stocking density is demonstrated in the behaviour of farmed fish, competition for food, its effect on water quality, and vulnerability to disease. Ultimately, all these factors have an effect on the growth and survival of farmed organisms. One of the manifestations of the effect of stocking density on the growth of farmed organisms is the effect of spatial limitation, which is still not sufficiently understood and explained, and which can reflect negatively on growth. Ruer et al. (1987) point out that during physiological studies on groups of fishes, one must take into consideration the great importance of available space per individual, seeing how its drastic decrease leads to stress. Overpopulation affects metabolism levels, and thus affects the appetite of the fish (Hastings and Dickie, 1972). Brown (1946, according to Hastings and Dickie, 1972) believes that there is an optimal density that allows the optimal consumption of food, while at higher and lower densities food consumption and growth rates decrease.

As indicators of growth characteristics, we monitored the increase in average weight, the growth rate, and weight distribution of individuals within farming groups. Differences in the average weight of fish from C1 and C2 were observed only for the sample taken on the 89th day. However, considering the late farming phase, these values were obtained based on relatively small samples (n = 25 and n = 21), which may have influenced their estimation. No differences were observed in this indicator – neither in the earlier phases of the experiment, when the weight distribution of the fish was more uniform nor in later phases when the sample size was 4-5 times larger. As a measure of growth intensity, specific growth rates were determined, as a function of stocking densities. Ordinary growth rates are calculated for shorter intervals of time, and one can apply this individually or collectively for a population of a certain age (Ricker, 1958). This is used as one of the most convenient ways of expressing growth, especially as a basis for comparing organisms from two or more populations (Weatherley and Gill, 1987).

The specific growth rate of carps in our ponds during the summer mostly varies within the range of 0.4% d\(^{-1}\) and 0.7% d\(^{-1}\) (Marković, 2003). Mikavica et al. (2007) state that under intensive cage farming of juvenile carps with an average weight in the range of 138.13-141.59 g and at stocking densities in the range of 15.8-20.9
individuals/m³, the value of this indicator for a period of 60 days varied within the range of 0.97-1.12% d⁻¹, and they point out that similar results were also obtained by Hungarian authors. Bogut et al. (2007), with intensive cage farming of carps during 109 feeding days (average weight in the range of 720-778 g; stocking density 6.22-7.04 individuals/m³), present far lower values of this indicator, which varied in the range of 0.093-0.168% d⁻¹. The authors explain that such low specific growth rates are due to an adverse oxygen regime. One of the aims of pond farming is to produce marketable fish of uniform body characteristics. Specific growth rates in our experiment (0.41 and 0.43% d⁻¹) are at the lower limit of the range given by Marković (2003) and Mikavica et al. (2007), but are significantly higher than those given by Bogut et al. (2007) for intensive cage farming. Even though it is difficult to compare the given growth rates due to differing initial weights and farming conditions, it is clear that the growth rates calculated in this experiment fall within the range given by Marković (2003). At the end of farming, absolute individual differences in weight were 1,278 g and 762 g for fish from C1 and C2, respectively. In addition, there was a slight tendency in the C1 group towards higher weight classes. However, for this indicator of growth characteristics as well, statistical testing showed that there was no significant difference in the distribution of defined weight classes. For both experimental groups, individuals in the 700-999 g weight interval made up around ¾ of the stock (C1-74.36% and C2-78.75%).

Based on the monitored indicators, the results obtained indicate that with regard to their effect on growth characteristics, there was no difference between the applied stocking densities. Certainly, further studies in this direction are needed, especially in the case of further technical and functional improvements of the farming facility, and the consequent improvement of water quality conditions.

Conclusion

Experimental use of river hopper barge as a rearing facility of carp, compared with the traditional way of rearing, showed that mortality rates in both stocking densities were considerably lower. Mean weights and growth rates estimated for both stocking densities (10 and 20 individuals/m³) did not significantly differ, which indicates that even higher stocking densities could be applied in the future experiments. Analysis of weight distributions also did not show significant differences, because more than 75% of individuals belonged to the weight interval from 700 g to 999 g. In general, results obtained showed that hopper barges might be used as a very efficient aquaculture facility.

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Growth characteristics of carp (Cyprinus carpio) depending on stocking density

UPOTREBA REČNIH BARŽI KAO OBJEKATA ZA AKVAKULTURU: KARAKTERISTIKE RASTA ŠARANA (Cyprinus carpio) U ZAVISNOSTI OD GUSTINE NASADA

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Rezime

U rečnoj barži je uzgajan šaran (Cyprinus carpio) u dve gustine nasada, 10 i 20 individua po m³. U poređenje su srednje težine, specifične stope rasta i težinska raspodela. Dobijeni rezultati pokazuju da ni kod jednog od ispitivanih parametara nije bilo statistički signifikantne razlike u odnosu na gustinu nasada.

Ključne reči: šaran (Cyprinus carpio), barža, gustina nasada, rast.

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