original research paper

Acta Agriculturae Serbica, Vol. XV, 30 (2010) 107-115

The Possibility of Using River Hopper Barges as Aquaculture Facilities

Slobodan Regner, Branislav Mićković, Stefan Skorić, Željka Višnjić-Jeftić, Aleksandar Hegediš
Institute for Multidisciplinary Research, Belgrade, Serbia

Abstract: The aim of this study is to explore the possibilities of introducing the new technology of intensive carp (*Cyprinus carpio*) farming in a floating vessel. The experiment was conducted on an out-of-use hopper barge on the Danube. Water was pumped in from the Danube using two pumps with a total power of 1 kW. The farming was conducted in two barge compartments with volumes of 40 m^3, from June 5^{th} to November 5^{th} 2009. The first compartment was stocked with 800 (20 ind./m^3), and the second one with 400 individuals (10 ind./m^3) of juvenile carp, with an average weight of 420 g. The fish were fed 6 mm granulation pellet feed containing 38% proteins. The daily amount of feed varied during the experiment in the range of 1.2-2.7% of the stock weight. Indicators of water quality were measured daily (temperature, pH, dissolved oxygen, concentrations of ammonia, nitrites, nitrates and phosphates) both within the barge and in the Danube. It was determined that amounts of dissolved oxygen were bellow optimal values for intensive carp farming and often dropped bellow 3 mg/l. During periods of low oxygen concentrations the fish were not fed, and thus the number of feeding days (87) was lower than the duration of the experiment (153 days). Despite this, weight gain values were 97.23% for the first, and 94.8% for the second compartment, while feed conversion ratios were 1.89 in the first, and 1.95 in the second compartment. Mortality was low, 1.88% in the first, and 3.25% in the second compartment. These values are considerably better than those from fish farming in ponds and cages. Furthermore, a comparison of fish meat quality between carps raised in the experiment and those raised in a classic fish pond system has revealed no difference in quality. The obtained results, although preliminary, indicate that it is possible, with certain technical improvements, to achieve high yields from barges, with significantly lower expenditure on feed and negligible negative effects on the environment.

Key words: *Cyprinus carpio*, hopper barge, intensive farming, weight gain, feed conversion ratio.

Received: 2 March 2010 / *Accepted*: 11 May 2010

Introduction

In Serbia, aquaculture is almost exclusively carried out in warm-water (carp) and cold-water (trout) fish ponds. In addition to these, there is a small number of cage systems, as well as some smaller surfaces that are fenced-off or partitioned-off parts of natural or man-made water bodies that are used for farming purposes (Ćirković 2002, Marković *et al.* 2007). The dominant form of production in carp fish ponds is the semi-intensive system, with production ranging from several hundred to over 2000 kg/ha (Marković and Mitrović-Tutundžić 2005). Trout fish ponds are located in highland areas, their estimated total surface is around 13-14 ha, farming is intensive, and production is rather variable, commonly ranging from 15 to over 50 kg/m^3 (Marković and Mitrović-Tutundžić 2005). Around 210 t of fish are produced in cage systems, of which there are about 10, but the functioning of these systems is irregular and often of a short-term nature (Ćirković *et al.* 2002). The prospects of the future development of warm-water aquaculture in Serbia are largely associated with increasing areas under fish ponds, which would be constructed in the immediate proximity of watercourses and river channel networks (Marković *et al.* 2007). However, with the construction of new fish ponds in salt marshes and swamps, there is a danger of losing these unique habitats and ecosystems, which would have a harmful effect on ecosystem and species diversity. Furthermore, due to the high usage of their natural potentials, as well as an evident need for protecting the fragile ecosystems of small and clear highland streams, the options for building new trout ponds are quite limited. In recent years, based on international experiences, there has been indication of a need for introducing new technologies into the aquaculture sector in Serbia (Hegediš 2005, Ćirković *et al.* 2005, Marković *et al.* 2009).

This study is a pilot experiment conducted in an attempt to point out to the possibility of utilizing out-of-use hopper barges as aquaculture facilities. This method is among the most recently developed, and was patented only in 1992 (Bourg 1992, US Patent 5095851).

Our aim was to point out to the aquaculture potentials of our large lowland and highland rivers for fish farming on small surfaces with minimal environmental impact exerted.

Compared to traditional types of farming, the advantages of this technology should include better control of the technological process, increased stocking density, better feed utilization, decreased environmental pollution, optimal usage of hydrological conditions, and if necessary, the possibility of easily relocating facilities to locations with optimal conditions.

Material and methods

The hopper barge used for the experiment is owned by the ”Projekt Pro” company from Belgrade, measures 59.9 x 6.65 meters, and is located on the left bank of the Danube in Krnjača, at km 1168 + 800. The total volume of the compartment that could be used for fish farming is 350 m^3; the space is 40 m long, 2 m deep, and 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, and the flow varied in the range of 1-1.5 water exchanges/day

(324.4-514.4 m^3/day). At the beginning of July (on July 2nd) two air compressors were installed, each with a capacity of 170 l/min.

The experiment lasted 5 months, from June 5th to November 5th, 2009. Two compartments were formed, each with a volume of 40 m^3, and were stocked with juvenile carps obtained from a commercial fish pond. The stocking was done on June 4th 2009. The average weight of the stocked individuals was 420 g. The stocking density in the first chamber was 800 individuals (20 ind./m^3); in the second chamber 400 individuals were stocked (10 ind./m^3). The acclimatisation of the fish was monitored for 15 days. During this period the fish were not fed. After the period of acclimatization we started getting the carp accustomed to pellet feed, the amounts of feed equalling 0.4% of the initial stock weight. 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, D_3 2 500 IU/kg, E 90 mg/kg, C 200 mg/kg). The period of adjustment to the feed lasted for nine days, followed by an experimental phase of more intensive feeding. The fish was 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 weight. This amount of food was determined using feeding tables, depending on temperature conditions and the average weight of individual fish in the stock. Control sampling was performed on a monthly basis, and the data obtained were used to adjust feed amounts. Measurements were taken of weight to the nearest gram, and three body lengths, total, fork and standard length, to the nearest mm. Fish were anaesthetized for measuring purposes, and were returned to their respective compartments upon measurement and recovery. Mortality rates were monitored daily. The specific growth rate was calculated according to the following formula:

$$SGR = ((\ln W_f - \ln W_i)/t) \times 100;$$

where W_f and W_i are the final and initial average weights of carps, respectively; t is the farming time. Specific growth rates were calculated for the entire experimental period, as well as for the number of feeding days.

The feed conversion ratio (FCR) was calculated based on the consumed feed/weight gain ratio. When calculating the feed conversion ratio, individuals that had died were not taken into consideration.

Every day, at five points along the barge (the beginning and end of each compartment, and water at 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.

Upon completion of the farming period, a comparative chemical analysis was performed of the meat quality of the farmed carp and of carps from ponds. As a control group, carps from the same generation were obtained from the same producer that provided the experimental stock. The protein, water, fat and ash contents, as well as the energy value were analyzed. Analyses were performed at the Institute of Meat Hygiene and Technology, Belgrade, on five individuals each from the experimental and the control groups, using standard methods. The non-parametric Mann-Whitney U test was used for statistical testing of the data obtained.

Results

Measurements of the temperature and chemical quality of the water indicated uniform water quality along the entire length of the farming area. Table 1 shows data, given by month, on the average values and ranges of variation of measured indicators. During June, July, August and September, average temperatures were above 20^{o}C and below 25^{o}C, i.e. within a temperature range favourable for farming marketable carp. However, based on the registered ranges with the exception of August, substantial temperature variations were observed, being a consequence of meteorological conditions and the Danube's hydrological regime during 2009. Among the monitored indicators of the chemical quality of water, the most pronounced fluctuations were observed for dissolved oxygen concentrations. In June, following the stocking and without additional aeration, there was a sudden decrease in oxygen concentrations. At the beginning of July, when feeding started, air compressors were installed and aeration of the water began. Overall, dissolved oxygen concentrations were below optimal values for intensive carp farming. Values often dropped to levels below 3 mg/l and the lowest recorded value (1.6 mg/; 18.7% saturation), which coincided with elevated temperatures, was recorded in August. Throughout the observed period pH values were above 7. The values of all the other indicators of chemical water quality, did not reach concentrations that would be considered threatening.

Tab. 1. Average values (± SD) and ranges of variation of basic physico-chemical parameters of water quality

Indicator	June	July	August	September	October
T (^{o}C)	20.67 ± 1.48 (17.6-23.3)	22.17 ± 1.44 (19.4-24.4)	23.97 ± 0.67 (23-25.2)	20.3 ± 1.16 (19.1-23.3)	16.76 ± 3.22 (11.9-19.6)
O_2 (mg/l)	4.28 ± 1.66 (2.3-9.24)	4.98 ± 1.21 (3.38-8.27)	3.82 ± 1.04 (1.6-5.37)	3.84 ± 0.85 (2.4-5.24)	4.94 ± 1.95 (2.67-8.38)
O_2 (%)	48.4 ± 18.49 (25.9-104)	57.13 ± 14.84 (38.3-98.5)	45.45 ± 12.25 (18.7-62.5)	42.26 ± 10.01 (26-59.6)	49.78 ± 16.44 (29-78)
pH	7.91 ± 0.14 (7.66-8.14)	8.07 ± 0.14 (7.83-8.47)	8.23 ± 0.086 (8.13-8.47)	7.77 ± 0.43 (7.33-9.12)	7.49 ± 0.06 (7.44-7.57)
$NH_3 + NH_4^+$ (mg/l)	0.72 ± 0.2 (0.417-0.948)	0.65 ± 0.085 (0.54-0.76)	0.86 ± 0.16 (0.637-0.984)	0.77 ± 0.17 (0.477-0.98)	0.88 ± 0.22 (0.526-1.084)
NO_2 (mg/l)	0.057 ± 0.028 (0.031-0.097)	0.087 ± 0.014 (0.075-0.108)	0.087 ± 0.01 (0.074-0.099)	0.082 ± 0.01 (0.066-0.1)	0.09 ± 0.02 (0.074-0.134)
NO_3 (mg/l)	3.02 ± 0.19 (2.78-3.21)	3.55 ± 1.03 (2.44-4.64)	3.16 ± 1.01 (2.14-4.16)	2.68 ± 0.51 (1.97-3.51)	1.92 ± 0.25 (1.73-2.35)
PO_4 (mg/l)				0.32 ± 0.13 (0.2-0.49)	0.23 ± 0.02 (0.2-0.26)

Table 2 shows the initial data of the experimental setup (initial values for numbers of stocked individuals, stocking densities, biomass, average weight) as well as the basic farming outcomes (final values for numbers of stocked individuals, stocking densities, biomass, average weight, numbers of farming and feeding days and corresponding specific growth rates, feed conversion ratios and mortality rates).

Tab. 2. Farming results: N_i – initial number of stocked individuals; SD_i – initial stocking density; W_i – initial average weight; B_i – initial biomass; N_f – final stock; W_f – final average weight; B_f – final biomass; SD_f – final stocking density; SGR – specific growth rate for the entire farming period; SGR_1 – specific growth rate with regard to the number of feeding days; FCR – feed conversion ratio; M – mortality.

Indicator	Compartment 1	Compartment 2	Total
N_i	800	400	1200
SD_i (ind/m^3)	20	10	
SD_i (kg/m^3)	8.4	4.2	
W_i (g)	420	420	
B_i (kg)	336	168	504
No. of farming days	153	153	
No. of feeding days	87	87	
N_f	785	387	1172
W_f (g)	844.41 ± 168.225	845.64 ± 135.732	844.91 ± 155.483
B_f (kg)	662.86	327.26	989.26
SD_f (ind/m^3)	19.63	9.68	
SD_f (kg/m^3)	16.57	8.18	
Weight gain (kg)	326.86	159.26	485.26
SGR (%W d^{-1})	0.445	0.458	
SGR_1 (%W d^{-1})	0.803	0.805	
Amount of feed	617.75	311.15	928.9
FCR	1.89	1.95	1.91
M	15	13	28

Low mortality rates were observed: 1.88% in the first compartment, 3.25% in the second compartment and 2.33% for the total fish stock. When compared to initial values, the final average weights were doubled, with coefficients of variation of 19.92% and 16.05%, for the fish stocks of the first and second compartments, respectively. Weight gain values amounted to 97.23% and 94.8% for the first and second compartments respectively, and 96.23% in total. Specific growth rates were calculated, both with regard to the total number of farming days, as well as with regard to the number of feeding days. The corresponding values were 0.445 %W d^{-1} and 0.803 %W d^{-1} for the first, and 0.458 %W d^{-1} and 0.805 %W d^{-1} for the second compartment. Feed conversion ratio values were bellow 2, both in the individual treatments, as well as in total.

A comparative analysis was performed of the chemical composition of the experimental fishes and of a control group comprising carps of the same generation and origin that were raised in a pond using semi-intensive farming methods (Table 3). Statistical tests (the Mann-Whitney U-test) confirmed that, according to all the measured parameters, there is no statistically significant difference ($P>0.05$) between our carps and the pond-raised carps.

Tab. 3. Comparative analysis of fish meat quality of carp farmed on the barge and carp farmed in a pond

Parameter	Barge	Pond
Proteins (%)	17.078 ± 0.858	17.132 ± 0.753
Water (%)	71.864 ± 1.262	72.17 ± 2.039
Fats (%)	9.62 ± 2.278	8.696 ± 3.25
Ashes (%)	0.958 ± 0.061	1.014 ± 0.112
kJ/100 g	648.068 ± 74.004	614.176 ± 110.639

Discussion

The dissolved oxygen content during most of the farming process, was, with some fluctuations, bellow the optimal range for carp farming (Mitrović-Tutundžić *et al.* 1997). There are multiple reasons for this. During the summer of 2009, especially in July, the water level of the Danube was high and it was characterized by large amounts of suspended solids, accompanied by relatively low oxygen content (the dissolved oxygen concentration ranged from 3.6-9.28 mg/l, the average value was 5.75 mg/l). The large amount of suspended solids caused blockage of the pumps and of the distribution pipe system, which resulted in frequent variation of the flow. Furthermore, due to technical flaws, the barge did not have an installed sludge pump, and it was not possible to apply thorough hygienic measures. With the accumulation of Danube silt, unconsumed feed and fish faeces, favourable conditions arose for the massive development of microorganisms and increased oxygen consumption. When oxygen concentrations dropped bellow 3 mg/l, feeding was halted and this resulted in a significantly lower number of feeding days compared to the total duration of the experiment. In addition, in mid-August, due to pump malfunction and halted flow, the fish were not fed for seven days. Furthermore, a sudden drop in temperature in mid-October caused a sudden drop in water temperature, and the fish stopped feeding (for 5 days) until temperatures stabilized. All of the above affected the total number of 87 feeding days, which had significant consequences on the final results. Namely, the breaks in feeding during the production cycle are sure to have had a negative effect on growth processes.

In Serbia, the semi-intensive type of farming is the dominant form of carp production. In recent years, this type of farming has seen the replacement of grain, as additional feed, with complete feeds (pellet or extruded feed), which has intensified production, and it ranges from 1500 – 3000 kg/ha (Marković *et al.* 2009). If these values are expressed in relation to volume, with the assumption that the average depth is 1.5 m, or related to surface of 1 m^2, we come to values in ranges of 0.1 – 0.2 kg/m^3 and 0.15 – 0.3 kg/m^2. In intensive farming in ponds, yields reach 5 000 – 10 000 kg/ha, that is 0.5 – 1.0 kg/m^2 or 0.33 – 0.67 kg/m^3 (Marković *et al.* 2009).

Calculated per unit of area and per unit of volume, the production results obtained in our experiment were 27.62 kg/m^2 and 16.57 kg/m^3 for the fist compartment, and 13.64 kg/m^2 and 8.18 kg/m^3 for the second compartment. The presented results clearly indicate the potential for using barges as intensive aquaculture facilities, in comparison to the predominant forms of carp farming in Serbia.

In intensive farming using cage systems, the yields that are obtained range from 10 kg/m^3 to over 40 kg/m^3 (Marković *et al.* 2007). Our results, despite the fact that the experiment was accompanied by certain limiting factors, fall into the given range. The basic requirements of farming using cage systems demand that water depth must be at least twice the depth of the submerged portion of the cage, and that the ratio of the working volume of the cage to the volume of the space where the cages are located must be at least 1:500 to 1:1 000 (Mitrović-Tutundžić *et al.* 1997). These conditions are necessary because of the substantial effect of cage systems on the eutrophication of the surrounding environment (Mitrović-Tutundžić *et al.* 1997, Hristić 2000). By positioning barges in large lowland rivers and owing to their construction, both of these standards are achieved in practice. In cage farming, losses in pellet feed amount to 10-30%, which is reflected in high feed conversion ratios (Mitrović-Tutundžić *et al.* 1997). Mikavica *et al.* (2007) have determined a 2.5 feed conversion ratio in cage farming of juvenile carp with an average weight of 140 g, which were fed feed containing 32% protein and 12% fat. Bogut *et al.* (2007), after farming carps with an average weight of 700-750 g, which they fed on feed of the same composition, reported that the feed conversion ratio varied between 3.67 and 4.13, representing high values. During our study, we obtained significantly lower feed conversion ratios (1.89 and 1.95, that is 1.91 on average).

The specific growth rate of carps in local fish ponds during the summer usually ranges between 0.4 and 0.7 (Marković 2003). Mikavica *et al.* (2007) state that, during their study, the value of this parameter varied between 0.97 and 1.12, pointing out that certain Hungarian authors have also observed similar results. These results refer to juvenile fish that were around three times smaller than the fish in our experiment, and it is a known fact that the intensity of growth decreases with age. Furthermore, as has been pointed out already, the breaks in feeding during our study have certainly had a negative effect on growth. The specific growth rate we have obtained based on the number of feeding days (Table 2) is a more realistic indicator of the potential for farming carp under the described conditions.

The analyses that were performed at the Institute of Meat Hygiene and Technology have shown no difference in the quality of meat of carps from the experiment and carps farmed in a classical fish pond system. Thus the widely adopted prejudices about the superior quality of fish that have been raised in a "more natural" way have been proven false.

Conclusions

The obtained results, although preliminary, indicate that certain technical improvements (installation of filtering units at the entrance and exit, installation of a sludge pump with a structural solution for depositing sludge outside the vessel without releasing it into the watercourse, improved aeration) can facilitate the realization of this type of warm-water fish farming. The fulfilment of these conditions, coupled with the accompanying controls and improvements, will help towards the completion of a technological process having the potential for developing a new type of highly productive aquaculture.

Acknowledgment: This project is financed by the Ministry of Science and Technological Development, Republic of Serbia, Contract No. TP 23034.

References

Bogut I., Magovac R., Sabo D., Bodakoš D., Galović D., Arežina M. Rajković V. (2007): Cage fattening results of common carp (*Cyprinus carpio*) in hydroaccumulation Grabovo near Vukovar. *Krmivo*, **4**: 207-214.

Bourg C. J. (1992): US Patent 5095851 - Method and apparatus for mariculture utilizing converted hopper barges or the like.
Available on: http://www.patentstorm.us/patents/5095851/description.html

Ćirković M., Jovanović B., Maletin S. (2002): *Ribarstvo*. Univerzitet u Novom Sadu, Poljoprivredni fakultet Novi Sad.

Ćirković M., Đorđrević V., Jurakić Ž., Milašinović M., Malović B., Maletin S., (2005): Using geotermal waters for rearing fish. *Conference Proceedings*, II International Conference "Fishery", 58-62.

Hegediš A. (2005): Possibilities for eel rearing in Serbia and Montenegro, *Conference Proceedings*, II International Conference "Fishery", 207-212.

Hristić Đ. (2000): Uticaj kaveznog gajenja riba na pojavu eutrofizacije vode u objektima gde se on sprovodi. *IV jugoslovenski simpozijum "Ribarstvo Jugoslavije"*. Vršac, Zbornik radova, 44-48.

Marković Z. (2003): Carp feeding in semi-intensive system of fish culture. *Seminar „Pastrmsko i šaransko ribarstvo*", Zbornik predavanja, 44-50.

Marković Z., Poleksić V., Mitrović-Tutundžić V. (2007): Akvakultura u Srbiji. *Conference Proceedings*, III International Conference "Fishery", 35-40.

Marković Z., Poleksić V., Živić I., Stanković M., Ćuk D., Spasić M., Dulić Z., Rašković B., Ćirić M., Bošković D., Vukojević, D. (2009): State of the art of fishery in Serbia..*Conference Proceedings*, IV International Conference "Fishery", 30-38.

Mikavica D., Kosorić Đ., Savić N., Torbica R. (2007): Effects of carp (*Cyprinus carpio* L., 1758) feeding in cage culture system of the farm Saničani-Prijedor. *Conference Proceedings*, III International Conference "Fishery", 147-153.

Mitrović-Tutundžić V., Hristić Đ., Marković Z. (1997): Proizvodnja ribe u kavezima: mogućnost i ograničenja. *Ribarstvo Jugoslavije*, III jugoslovenski simpozijum sa medjunarodnim učešćem 24.-27. septembar, Cetinje-Rijeka Crnojevića, 55-63.

Mitrović-Tutundžić V., Jovanović B., Matić A., Marković, Z. (1997): Akutni problemi klasičnih šaranskih ribnjaka u Srbiji i mogućnosti racionalnog gajenja konzumnog šarana u njima. *Ribarstvo Jugoslavije*, III jugoslovenski simpozijum sa medjunarodnim učešćem 24.-27. septembar, Cetinje-Rijeka Crnojevića, 67-80.

MOGUĆNOST KORIŠĆENJA REČNIH BARŽI KAO OBJEKATA ZA AKVAKULTURU

- originalni naučni rad -

Slobodan Regner, Branislav Mićković, Stefan Skorić, Željka Višnjić-Jeftić, Aleksandar Hegediš
Instutut za multidisciplinarna istraživanja, Beograd, Srbija

Rezime

Cilj ovog istraživanja je da se ispitaju mogućnsti uvođenja nove tehnoligije intenzivnog uzgoja šarana (*Cyprinus carpio*) u plovnom objektu. Eksperiment je vršen na rashodovanoj rečnoj barži na Dunavu. Voda je pumpana iz Dunava pomoću dve pumpe ukupne snage od 1 kW. Uzgoj je vršen u dve komore zapremine od 40 m^3, od 5. juna do 5. novembra 2009. godine. U prvoj komori nasađeno je 800 (20 ind./m^3), a u drugoj 400 jedinki (10 ind./m^3) juvenilnog šarana prosečne težine 420 g. Riba je hranjena peletiranom hranom granulacije 6 mm, koja je sadržavala 38% proteina. Dnevna količina hrane je tokom eksperimenta varirala u rasponu od 1,2-2,7% težine nasada. Pokazatelji kvaliteta vode (temperatura, pH, količina rastvorenog kiseonika, koncentracije amonijaka, nitrita, nitrata i fosfata) mereni su svakodnevno, kako u barži tako i u Dunavu. Utvđeno je da su koncentracije rastvorenog kiseonika bile su ispod optimalnih vrednosti za intenzivan uzgoj šarana i često su padale ispod 3 mg/l. U periodima niskih koncentracija kiseonika ribe nisu hranjene, tako da je broj hranidbenih dana (87) bio manji od trajanja eksperimenta (153 dana). Vrednosti masenog prirasta iznosile su 97,23% za prvu, 94,8% za drugu komoru, dok su faktori konverzije bili 1.89 u prvoj komori i 1.95 u drugoj. Mortalitet je bio nizak, u prvoj komori 1,88%, u drugoj 3,25%. Dobijene vrednosti su veće u odnosu na uzgoj u ribnjacima i kavezima. Upoređenje kvaliteta mesa šarana iz sprovedenog eksperimenta i šarana gajenog u matičnom klasičnom ribnjačkom sistemu pokazuje da ne postoje razlike u kvalitetu. Dobijeni rezultati, iako preliminarni, ukazuju da se u baržama, uz određena tehnička poboljšanja, mogu postići visoki prinosi, sa znatno manjim utroškom hrane i zanemarljivim negativnim uticajem na okolinu.