A comparative study on the evaluation of cyprinids growth performance in IMTA systems

[1]Stefan M. Petrea, [1]Alina Mogodan, [1]Isabelle Metaxa, [1]Sănduţa Plăcintă, [2]Mihaela A. Vasile, [3]Gheorghe Huian

[1] Department of Aquaculture, Environmental Science and Cadastre, „Dunărea de Jos" University of Galati, Galati, Romania; [2] Department of Food Science, Food Engineering and Applied Biotechnology, „Dunărea de Jos" University of Galati, Galati, Romania; [3] S.C. Piscicola Iasi, Iasi, Romania. Corresponding author: S. M. Petrea, stefan.petrea@ugal.ro

Abstract. The aim of this paper was to evaluate the cyprinids growth performance in condition of two integrated multi-trophic aquaculture (IMTA) systems. For our study, two fishponds with an area of 0.45 ha each and an average water depth of 1.5 m, were used. The first pond (PCP) was used for rearing polyculture common carp (*Cyprinus carpio*) with grass carp (*Ctenopharyngodon idella*), bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*). The second pond was divided by using a net, as follows: first part with an area of 0.15 ha CP (carp pond – common carp) and the second part with an area of 0.30 ha PP (polyculture pond – common carp, grass carp, bighead carp and silver carp). The experimental research has lasted for 83 days from 15 June to 5 September 2016. During this experimental period, three intermediary biometric and biomass measurements were made, respectively intermediary 1 (6 July 2016), intermediary 2 (25 July 2016) and intermediary 3 (5 August 2016), except initial (15 June 2016) and harvesting (5 September 2016) biometric measurements. The best feed conversion ratio (FCR) value was recorded in case of CP-PP experimental variant (0.59), while CP registered the highest FCR value (1.35). In case of CP, the FCR evolution had an upward tendency until final harvesting, starting from 0.48; 1.61 and ending to 1.99, while in case of PCP, the upward tendency of FCR from 0.53 to 1.44 is followed by a decrease to 1.07, registered at intermediary 3. Specific growth rate (SGR) had a downward tendency during the experimental period in case of common carp and grass carp, while the small upward tendency was observed in certain experimental stages, in case of silver carp and bighead carp. The average of protein efficiency ratio (PER) during the experimental period registered a value of 2.56 in case of PCP, 2.64 for CP and 6.06 for CP-PP. Our study had demonstrated that an IMTA cyprinides pond production system, were common carp is considered as main essential species, can be more sustainable, comparing with a classical polyculture cyprinides pond production system. In terms of common carp growth performance and total cyprinides biomass production, PCP production system registered the best results, compared with the IMTA system (CP-PP).
Key Words: cyprinids, *Cyprinus carpio*, fishponds, growth performance, IMTA.

Introduction. Integrated multi-trophic aquaculture (IMTA) is both conceptually a simple idea and also highly appealing to regulators: the waste products from one food production process (in this case, carps production) is acquired and assimilated by other organisms and converted into valuable products. This process both eliminates waste and increases the productivity of the food production system (Troell et al 2003; Neori et al 2004; Chopin et al 2004). While the term of polyculture is based on the principle that each species stocked has its own feeding niche that does not completely overlap with the feeding niches of other species. Therefore, a more complete use is made of the food resources and space available in polyculture than in monoculture. In some cases, one species enhances the food availability for other species and thus increases the total fish yield per unit area (Hepher et al 1989; Miah et al 1993; Azad et al 2004; Rahman et al 2008).

Recent country reviews of FAO (Hasan et al 2007) support that the characteristics of pond fish culture make it very suitable to produce fish in an inexpensive integrated way. Carp polyculture was dramatically improved in the 1960s when Chinese major carps were widely introduced to most countries of Europe and Asia. Today, it is a widely practiced pond fish culture technique, not only in temperate but also in subtropical and tropical climates (Woynarovich et al 2010).

Cyprinids form the most important group of teleost fish cultivated worldwide (reviewed by Kaushik 1995). According to the Fish Global Information System (FIGIS, FAO), the world production of the common carp (*Cyprinus carpio*) and the three Chinese carps used in Brazilian polycultures (*Ctenopharyngodon idella*, *Hypophtalmichthys molitrix*, *Hypophtalmichthys nobilis*) was more than 12.6 million metric tons in 2003, representing about 55% of the total production of freshwater fish in that year (Da Silva et al 2006).

Common carp, the most common cyprinid species that generates a significant part of inland freshwater fish production, is introduced to inland waters such as lakes, dam lakes and streams in different regions (Vilizzi et al 2015) and is the third most important farmed freshwater species in the world and the most important in Eastern Europe (Ljubojevic et al 2015). This fish is very much favored for cultivation in ponds in Asia, Near and Far East, alone or in combination with other fishes, because of its excellent growth rate, omnivorous habit, breeding in confined waters (unlike the Indian and Chinese major carps), hardy nature and easy adaptation to artificial feeds. Consequently, common carp has been introduced into many water bodies throughout the world, including Europe, Australia and North America (Khan et al 2016).

Central European fishponds represent unique, man-made aquatic ecosystems that are important and integral parts of the landscape (Korınek et al 1987; Adámek et al 2012). Currently, the main function of most fishponds is the production of fish based on utilisation of the natural production potential of the pond ecosystem. Since the early twentieth century, however, common carp production in ponds has been systematically increased through a variety of management improvements. Current carp pond management practice (which includes fertilisation and supplementary feeding), together with the influence of agriculture and human settlements, has led to a state in which the majority of ponds in Central Europe are considered as eutrophic to hypertrophic aquatic ecosystems (Pechar 2000; Potuzak et al 2007; Vsetickova et al 2012; Hlavac 2014).

Semi-intensive carp culture is an ancient popular practice in Romania, representing the most applied aquaculture technology. The main reason of carp production intensification is represented by cereals replacement with pelleted and extruded feeds (Ciric et al 2015; Mocanu et al 2015). Cereal grains provide the majority of carbohydrate in feeds used in carp nutrition, the proportion amounting to 35–45% of the diet on average (Przybyl & Mazurkiewicz 2004). The larger part, however, consists of starch (60–70%), of which the carp is able to digest around 60–80% in the raw state, depending predominantly on the cereal species (Medale et al 1999; Cirkovic et al 2002; Krogdahl et al 2005).

Romania has great possibilities to ensure low cost vegetal nutrients such cereals, cakes rich in oil and other raw ingredients for common carp nutrition, while producing “live food” is a matter of specific technology and even local resources when a limited small farms demand. One major challenge for a good quality of carp meat production is therefore to optimize a feeding technology which ensures that (Coroian et al 2015).

Culturing different carp species in the same pond optimizes the utilization of the food available in the ecological niches of the pond ecosystem (Kestemont 1995). In addition, the polyculture aims to increase productivity by a more efficient utilization of the ecological resources in the aquatic environment (Lutz 2003). Thus, stocking two or more complementary species can increase the maximum standing crop of a pond by allowing a wider range of available foods and ecological niches.

Taking into consideration the present situation of the global energetic and economic depression and the disorders that unfold on its fund, it is necessary to use any resource that can be capitalized with minimum effort and the lowest price. Fish nutrition is one of the most important elements that determine the meat production in a controlled environment (Dobrotă et al 2012). Although the economic and/or ecological importance in some countries of many cyprinid fish is debatable (Mills et al 1993; Ricciardi & MacIsaac 2000; Montchowui et al 2009; Ozcan & Balık 2009), in Romania, and also in several countries from Europe, they have a quite important role in both aquatic biodiversity and human alimentation (Balon 1995; Cioboiu & Brezeanu 2009; Luca et al 2010; Gheorghe et al 2011; Györe et al 2011), being by tradition very appreciated and therefore the cyprinid group is a component of fish polyculture in Europe and also in Asia (Sharma & Leung 2000; Terziyski et al 2009).

The aim of this study was to evaluate the cyprinids growth performance in condition of two IMTA systems, by using different techniques and technologies.

Material and Method

Description of the study sites. The research were conducted at the "S.C. Piscicola Iasi" fish farm, which is situated in the Larga Jijia village, 24 km north-west from Iasi city, Romania. The total fish farm surface area is 1,000 hectares, partitioned in 24 ponds (Figure 1). Both inlet and outlet are made gravitationaly, by using monk hydraulic constructions. The water source is represented by Jijia river.

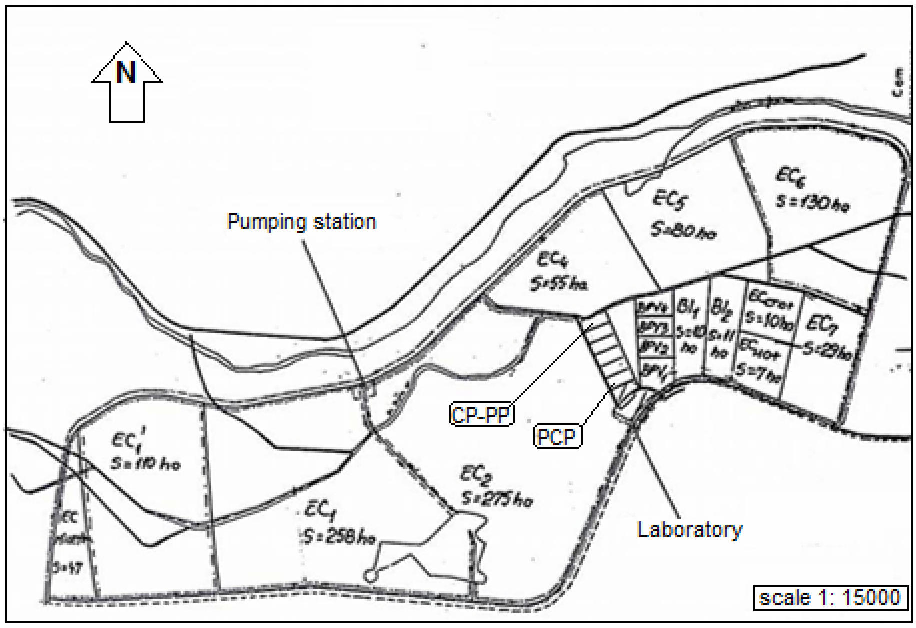

Figure 1. Piscicola Iasi farm hydrotechnical design.

Experimental design. For our research, two ponds with an area of 0.45 ha each and an average water depth of 1.5 m, were used. The experimental design and sampling areas are presented in Figure 2.

The first pond (PCP) was used for rearing polyculture common carp (*Cyprinus carpio*) with grass carp (*Ctenopharyngodon idella*), bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*Hypophthalmichthys molitrix*). Initial stocking consisted in:

- 2500 common carp specimens with an individual average of biomass weight of 63.0±7.80 g and an individual average lenght of 8.7±0.40 cm;
- 40 silver carp specimens with an individual average of biomass weight of 2006.3±213.80 g and an individual average lenght of 37.9±1.40 cm;
- 40 bighead carp specimens with an individual average of biomass weight of 1937.0±191.48 g and an individual average lenght of 35.5±1.70 cm;
- 100 grass carp specimens with an individual average of biomass weight of 200.4±20.01 g and an individual average lenght of 17.2±0.99 cm.

The second pond was divided by using a net (Figure 3 a, b), as follows: first part with an area of 0.15 ha CP (carp pond) and the second part with an area of 0.30 ha PP (polyculture pond). The CP pond was stocked with 2000 common carp specimens with an individual average biomass weight of 61.2±11.60 g and an individual average lenght of 8.5±0.90 cm.

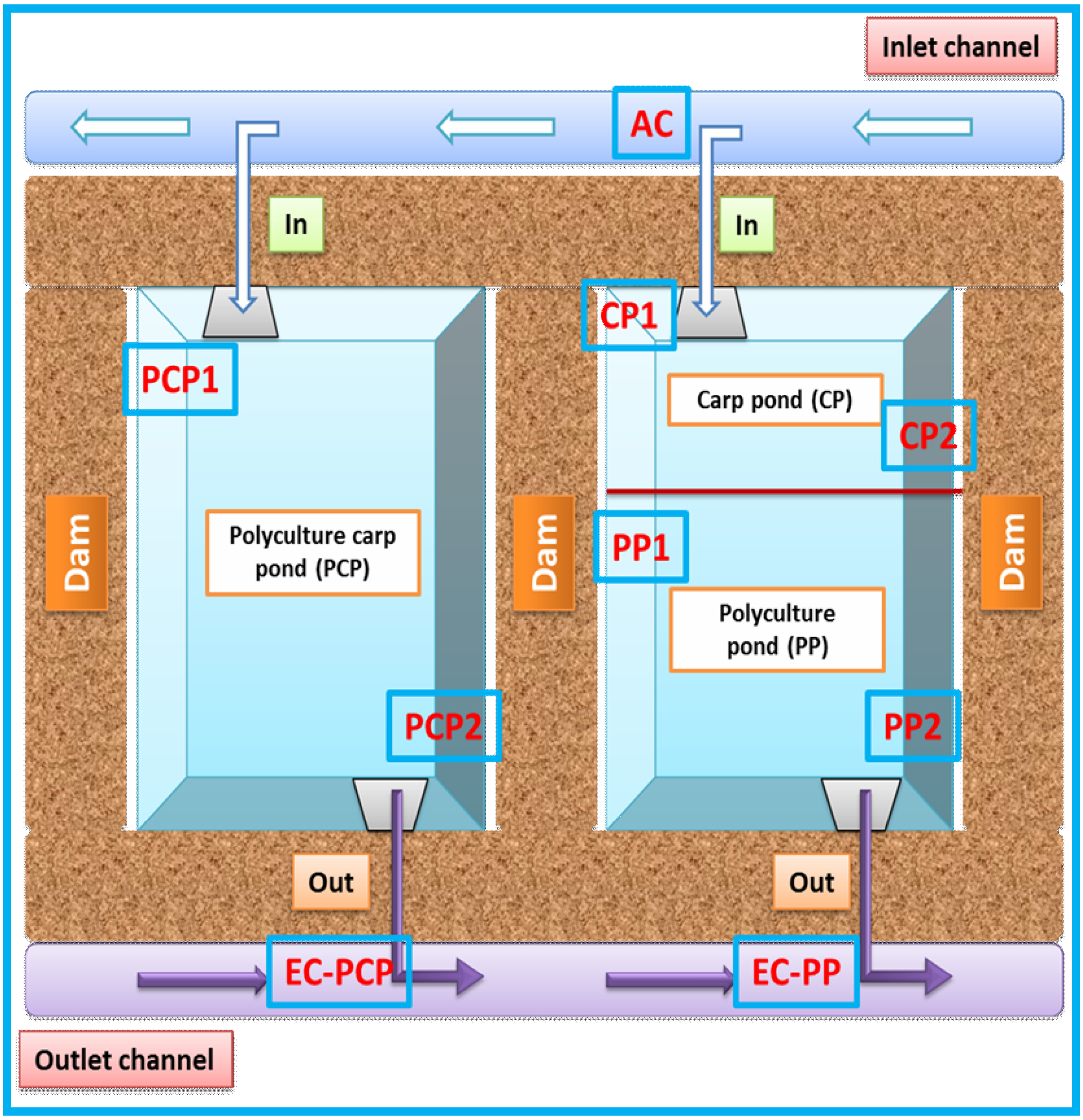

Figure 2. Experimental design and sampling areas (Sampling areas: AC – inlet channel; EC-PCP – outlet channel from polyculture carp pond; EC-PP – outlet channel from polyculture pond; PCP1 – polyculture carp pond 1; PCP2 – polyculture carp pond 2; CP1 – carp pond 1; CP2 – carp pond 2; PP1 – polyculture pond 1; PP2 – polyculture pond 2.

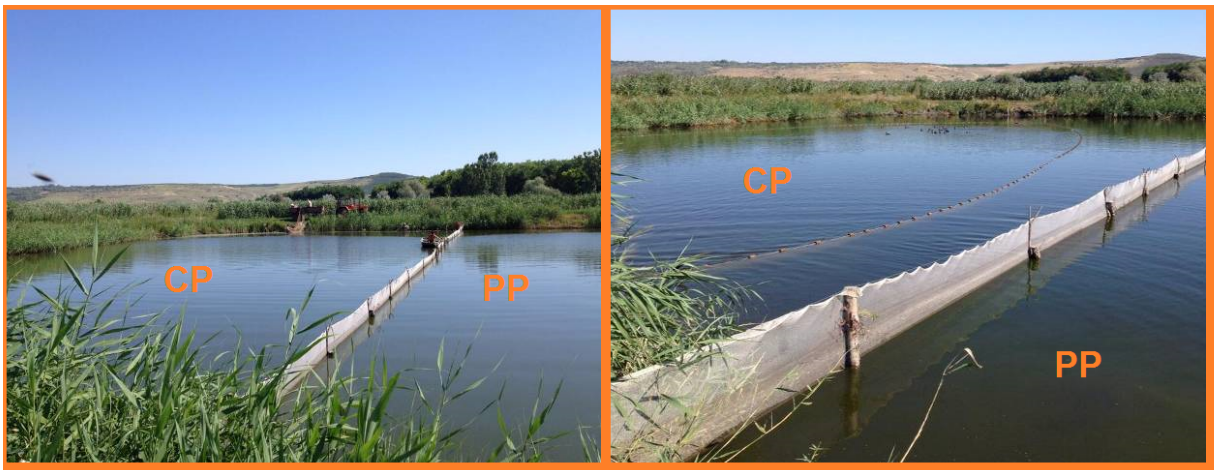

Figure 3. The second pond divided by using a net (CP and PP).

In the PP pond were stocked 500 common carp specimens (60.0±10.45 g fish^{-1}, respectively 8.3±0.7 cm fish^{-1}), 40 silver carp specimens (2044.0±289.80 g fish^{-1}, respectively 38.7±1.80 cm fish^{-1}), 40 bighead specimens (1824.1±182.59 g fish^{-1}, respectively 34.7±1.20 cm fish^{-1}) and 100 grass carp specimens (199.4±20.00 g fish^{-1}, respectively 17.1±1.00 cm fish^{-1}).

The experimental research has lasted for 83 days from 15 June to 5 September 2016. During this experimental period, three intermediary biometric and biomass measurements were made, respectively intermediary 1 (6 July 2016), intermediary 2 (25 July 2016) and intermediary 3 (5 August 2016), except initial (15 June 2016) and harvesting (5 September 2016) biometric measurements (Figure 4).

Figure 4. Biometric measurements.

The administered feed had a crude protein content of 28% and was represented by a mix of cereals (wheat lees, dry maize dregs, sunflower groats) in equal amounts and flour protein. Feed was manually administered twice/day, only in PCP and CP, for five days/week, that makes a total of 59 days of feeding during the entire experimental period. The quantity of administered food was adjusted after each fishing control. Two daily feeding ratio were used: 3% of biomass weight (BW) and 1.5% BW.

Technological indicators. The analysed technological indicators were as follows: individual biomass gain (IBG - g fish^{-1}), relative grow rate (RGR g g^{-1} day^{-1}), specific grow rate (SGR %fish biomass day^{-1}), feed conversion ratio (FCR) and protein efficiency ratio (PER). These technological indicators were determined by using the following formulas:

Individual biomass gain: IBG = (Bf) - (Bi)/ fish number [g/fish]

where: Bf – final fish biomass; Bi – initial fish biomass;

Relative growth rate: RGR = ((Bf- Bi)/t)/Bi [g/g/day]

where: Bf – final fish biomass; Bi – initial fish biomass, t - duration of the experiment;

Specific growth rate: SGR = 100 * (ln Bf - ln Bi)/t [% fish biomass day^{-1}]

where: Bf – final fish biomass, Bi – initial fish biomass, t - duration of the experiment;

Feed conversion ratio: FCR = F/IBG

where: F – feed intake, FBG – individual biomass gain;

Protein efficiency ratio: PER = IBG/(F * CP/100)

where: FBG – individual biomass gain, F – feed intake, CP - crude protein.

Water quality assessment. From each pond, water samples were collected daily, from nine prelevation stations and the following analysis were made: temperature, dissolved oxygen (DO), oxygen saturation and pH measurements. The concentration of nitrate N-

NO_3 (mg L^{-1}), nitrite N-NO_2 (mg L^{-1}), ammonium N-NH_4 (mg L^{-1}) and phosphate P_2O_5 (mg L^{-1}) in water were determined monthly. The instruments used were the HQ40d Portable pH, Dissolved Oxygen, Multi-Parameter (HACH), respectively Spectroquant photometer, Nova 400 for nitrate, nitrite, ammonium and phosphate determination, with Merck kits. The analysis of some water quality parameters were determined at the Research Laboratory of Aquaculture, Environmental Science and Cadastre Department from "Dunarea de Jos" University of Galati, while the other parameters were determined at the fish farm laboratory.

Statistical analysis. The results, of growth performance parameters, of the experimental research were statistically analyzed using descriptive statistics and ANOVA test. Programs used were Microsoft Excell 2010 and IBM SPSS Statistics 20.0. The results were presented as minimum, maximum and mean±standard deviation.

Results and Discusion

Water quality parameters. The water quality parameters were within the optimum range for rearing cyprinides in pond extensive systems. Thus, the maximum value of DO was registered in PP1 (24.96 mg L^{-1}), while minimum values were recorded at EC-PP (0.12 mg L^{-1}) and EC-PCP (0.18 mg L^{-1}) (Figure 5a). The oxygen saturation (Figure 5c) had registered a similar dynamics with that of the DO. Therefore, it can be observed that the outlet channel, which is the same for both experimental ponds (PCP and CP-PP), has the lowest concentration of DO, fact probably due to the high organic matter concentration, as there are not any mechanical or biological filters at the outlet of the ponds. Mocanu et al (2015) and Oprea et al (2015) reported values of DO between 5.9-8.6 mg L^{-1}, for rearing common carp at first summer age in ponds aquaculture systems, during June-October. Dobrotă et al (2012) reported values of DO between 5.5-9.6 mgL^{-1}, for rearing common carp in polyculture with paddlefish, during June-August.

The average value of the water temperature (Figure 5b), during the experimental period, was 21.01^{o}C. At the beginning of September the water temperature decreased significantly to a value of 14.50^{o}C. Mocanu et al (2015) and Oprea et al (2015) reported values of water temperatures between 12.5-25.8^{o}C, Dobrotă et al (2012) reported a water temperature variation between 22-27^{o}C, during June-August and 17-21^{o}C on May and September, in the same technological conditions mentioned above. In another study, Gheorghe et al (2008) reported a water temperature variation between 18.8-20.8^{o}C, for rearing common carp at second summer age, in ponds aquaculture systems, during May-September.

The lowest values of pH were recorded in the inlet channel (6.5 pH units) (Figure 5d), while in both ponds (PCP and CP-PP) the pH dynamics were similar, with the average value between 8.90–9.14 pH units. Mocanu et al (2015) and Oprea et al (2015) reported values of pH between 7.19-8.52, Gheorghe et al (2008) values of pH between 7.6-8.2 and Dobrotă et al (2012) between 7.2-8.5, in the same technological conditions mentioned above.

Regarding the N compounds, the N-NO_3 highest concentration in water, was registered at the outlet channel (18.60 mg L^{-1}) (Figure5e), fact similar for both N-NO_2 (0.26 mg L^{-1}, Figure 5f) and N-NH_4 (1.50 mg L^{-1}, Figure 5g). The correlations between N compounds registered concentrations, indicates a higher nitrification process in case of PP1 sampling area, PCP1 sampling area and EC-PP sampling area.

Highest P_2O_5 concentrations were registered in PCP2 and EC-PCP2 (7.73 mg L^{-1}, respectively 8.34 mg L^{-1}, Figure 5h), as a result of feed administration. As such, in case of PCP the feed was administered among the entire surface of the pond, while in the case of the second pond (CP-PP) the feed was administered only on the CP surface, fact that justified the higher concentration P_2O_5 found in the sampling area mentioned above.

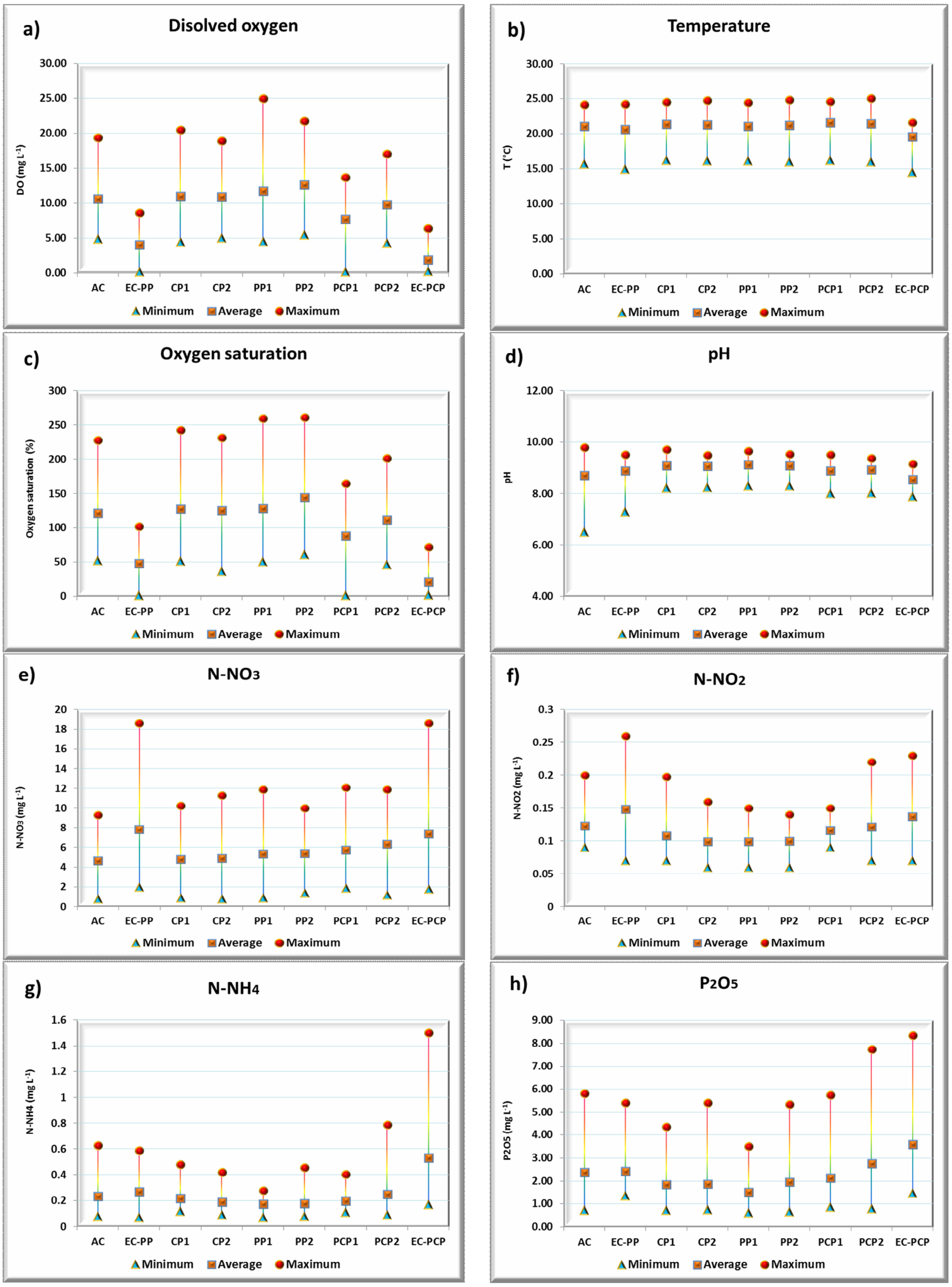

Figure 5. Water quality parameters during the experimental period, in PCP, CP and PP.

Also, the feed amount administered in PCP was almost double than the one in CP-PP, fact sustained by the total biomass, which was superior in case of PCP, compared with CP (the only surface where feed was administrated from CP-PP) (Table 1). Therefore, this situation can be the cause of better values of water quality parameters recorded in PP compared with CP and PCP (Figure 5).

The technological indicators. The synthetic table for the evaluation of growth performance indicators (Table 1) indicates higher survival rates in case of PCP, compared with CP-PP. The common carp reared in CP registered a lower survival rate, most probably because of the higher stocking densities that were applied (Table 1), comparing with PCP carp. However, the specimens of common carp stocked in PP registered the highest survival rate, while the rest of fish species from PP had a lower survival rate, comparing with their PCP homologues.

Common carp reared at CP-PP registered better values regarding individual average biomass, comparing with the specimens reared at PCP (Table 1). However, grass carp, bighead carp and silver carp individual average biomass was higher at PCP, compared to PP.

Applying polyculture technologies for rearing common carp (PCP) generates better individual biomass gain results, than the monoculture technologies (CP) (Table 1). Those results are confirmed also by Woynarovich et al (2010).

Mocanu et al (2015) studied the effect of supplementary feeds quality on growth performance and production of 10 g fish^{-1} common carp, in ponds aquaculture systems. Therefore, during a 120 days experimental period, two types of feeding regimes were tested, first with feed containing 48% and 30% protein and second with 48% and 35% protein. The results in terms of individual weight gain were between 167-204 g fish^{-1}, closed to those obtained in our present study (113.93-150.6 g fish^{-1}). Also, regarding the survival rates, Mocanu et al (2015) reported lower survival percentage 67-70%, compare with the one registered our present study (73-80%).

Oprea et al (2015) studied the influence of stocking density on growth performance, feed intake and production of 10 g fish^{-1} common carp in ponds aquaculture systems, during a 150 days experimental period. Therefore, he obtained a survival range between 44 to 58% for common carp reared at a stocking density of 15 kg ha^{-1} and 30 kg ha^{-1}. The results in terms of individual weight gain were between 250-345 g fish^{-1}, higher than those obtained in our present study (113.93-150.6 g fish^{-1}).

Gheorghe et al (2008) tested two type of feed (30% protein and 25% protein) used for the intensive common carp rearing, in the second summer, during a 4 months experimental period. The results shows an individual weight gain ranged between 315-333.6 g in May-June, 437.6-696.9 g in June-July, 375.5-538.3 g in July-August and 450.2–645.3 g in August-September.

Dobrotă et al (2012) made a comparative study on rearing common carp (101-106 g initial individual biomass) in polyculture, together with paddlefish, in an intensive pond system, using nonconventional fodders. He reported a superior individual weight gain (1036–1210 g fish^{-1}), compared to our study and also superior survival rates (92-93%).

Coroian et al (2015) study the growth performance of common carp fingerlings fed with various protein levels (feed 30% protein; live food mixture and live food grains mixture 30.1% protein) and registered a total weight gain between 0.54-7.68 g fish^{-1}, lower compared with the one registered in our present study.

Table 1

Growth performance indicators for each of the experimental variants

Crt. No.	*Technological indicator*	*Experimental period*	*Experimental variants*								
			PCP				*CP*	*PP*			
			CC	*HN*	*HM*	*CI*	*CC*	*CC*	*HN*	*HM*	*CI*
1.	No. of fish	Initial	2500	40	40	100	2000	500	40	40	100
		Harvesting	2000	35	36	88	1460	430	33	32	84
2.	Experimental period (days)	Initial - Int. 1	22	22	22	22	22	22	22	22	22
		Int. 1 - Int. 2	19	19	19	19	19	19	19	19	19
		Int. 2 - Int. 3	11	11	11	11	11	11	11	11	11
		Int. 3 - Harvesting	31	31	31	31	31	31	31	31	31
3.	Survival (%)	During the experimental period	80	87.5	90	88	73	86	82	80	84
4.	Total biomass (kg)	Initial	157.5	77.5	80.3	20	122.4	30	60.2	65.4	19.9
		Int. 1	325	107.5	-	87.8	243.9	34.1	-	-	52.6
		Int. 2	416.7	127	117.3	114.9	302.6	59.2	82.5	-	45.1
		Int. 3	491.5	134.7	136	152.8	288	49	111.9	-	-
		Harvesting	427.1	111.6	106.5	126.2	255.7	79.5	119	89.6	103
5.	Individual average biomass (g $fish^{-1}$)	Initial	63	1937	2006.3	200.4	61.2	60	1824.1	2044	199.4
		St. dev. Initial	7.8	191.5	213.8	20	11.6	10.5	182.6	289.8	20.5
		Int. 1	130	2688.6	-	877.5	121.9	68.2	-	-	526.8
		St. dev. Int. 1	20.4	507.1	-	293.1	38.8	6.3	-	-	103.8
		Int. 2	166.67	3175	2932	1149	151.3	118.4	2500.4	-	451.2
		St. dev. Int. 2	47.44	354.82	146.18	251.19	51.2	37.7	162.8	-	176.5
		Int. 3	196.61	3368	3400	1528	144	98	3391.3	-	-
		St. dev. Int. 3	42.8	455.8	157.1	386.6	60.7	14.8	317.4	-	-
		Final	213.55	3187.2	2958.8	1434.5	175.1	184.9	3248.3	2801	1226.5
		St. dev. Final	57.3	412.7	417.5	624.8	63.9	65.5	406.1	250.1	489.5
6.	Individual average length (cm $fish^{-1}$)	Initial	8.7	35.5	37.9	17.2	8.5	8.3	34.7	38.7	17.1
		St. dev. Initial	0.4	1.7	1.4	1	0.9	0.7	1.5	1.8	1
		Int. 1	20.2	52.3	-	38	15.9	14	-	-	24.7
		St. dev. Int. 1	1.5	5.9	-	3.8	1.8	0.8	-	-	3.4
		Int. 2	17.2	56.4	56.2	41.2	16.1	14.6	48.4	-	30.3
		St. dev. Int. 2	1.6	1.8	0.8	2.8	1.8	2.3	4.3	-	4.3
		Int. 3	18.1	56.8	58	45.9	16.6	14.8	58.7	-	-
		St. dev. Int. 3	1.6	2	0.5	4.6	3.2	0.6	1.5	-	-
		Final	18.9	56.7	56	45.7	18.2	17.6	59.4	47.3	40.9
		St. dev. Final	2.5	2.9	2.5	6.7	2.8	2.9	2.5	5.5	7.1

7.	Fish stocking density (kg ha^{-1})	Initial	350	172.2	178.3	44.5	816	100	200.7	218	66.5
		Int. 1	722.2	239	-	195	1625.3	113.7	-	-	175.5
		Int. 2	925.9	282.2	260.6	255.3	2017.3	197.3	275	-	150.4
		Int. 3	1092.3	299.4	302.2	339,6	1920	163.3	373.1	-	-
		Harvesting	949.1	247.9	236.7	280.5	1704.6	265.0	396.7	298.8	343.4
8.	Total biomass gain (kg)	Initial - Int. 1	167.5	30	37.1	67.7	121.4	4.1	-	-	32.7
		Int. 1 - Int. 2	91.7	19.5	18.7	10.9	58.8	25.1	27	-	-7.6
		Int. 2 - Int. 3	74.9	7.7	-	15.2	-14.6	-10.2	35.6	-	-
		Int. 3 - Harvesting	33.9	-6.3	-15.9	-8.2	45.5	37.4	7.1	-	65.1
		Initial - Harvesting	368	50.9	39.9	85.5	211.1	56.4	69.8	57	90.3
9.	Individual biomass gain (g $fish^{-1}$)	Initial - Int. 1	67	751.6	925.7	677.1	60.7	8.2	-	-	327.4
		Int. 1 - Int. 2	36.7	486.4	468	271.5	29.4	50.2	676	-	-75.6
		Int. 2 - Int. 3	29.9	193	-	379	-7.3	-20.4	891	-	-
		Int. 3 - Harvesting	16.9	-180.9	-441.3	-93.5	31.13	86.9	215	-	775.3
		Initial - Harvesting	150.6	1250.2	952.5	1234.1	113.93	124.9	1782	1782	1027.1
10.	Relative growth rate (g g^{-1} day^{-1})	Initial - Int. 1	0.048	0.018	0.021	0.154	0.0045	0.006	-	-	0.075
		Int. 1 - Int. 2	0.015	0.01	-	0.007	0.0013	0.039	-	-	-0.008
		Int. 2 - Int. 3	0.016	0.006	-	0.012	-0.004	-0.016	0.039	-	-
		Int. 3 - Harvesting	0.002	-0.002	-	-0.002	0.005	0.025	0.002	-	-
		Initial - Harvesting	0.01	0.005	0.005	0.008	0.01	0.009	0.007	0.008	0.011
11.	Feed protein (%)	Initial - Harvesting	28	28	28	28	28	28	28	28	28
12.	Daily feeding ratio (% BW)	Initial - Int. 1	3	3	3	3	3	3	3	3	3
		Int. 1 - Int. 2	3	3	3	3	3	3	3	3	3
		Int. 2 - Int. 3	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
		Int. 3 - Harvesting	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5

Note: CC - *Cyprinus carpio*, HN - *Hypophthalmichthys nobilis*, HM - *Hypophthalmichthys molitrix*, CI - *Ctenopharyngodon idella*; Int - intermediary; PCP - polyculture carp pond; CP - carp pond; PP - polyculture pond.

Hassan & Mahmoud (2011) studied the effect of stockig density on growth performance in semi-intensive and extensive fish culture methods in earthen ponds. They tested a polyculture system including Nile tilapia (*Oreochromis niloticus*), common carp, silver carp, mullet (*Mugel cephalus*) and African catfish (*Clarias gariepinus*), during a 5 months experimental period. The stocking densities varied between 1–15 fish m^{-3} and the individual weight gain ranged between 875–1700 g $fish^{-1}$ in case of common carp and 500–1400 g/fish for silver carp.

The values of FCR (Figure 6), PER (Figure 6) and SGR (Figure 7) give a clear overview of the growth performance of each of the tested variants (PCP, CP and PP).

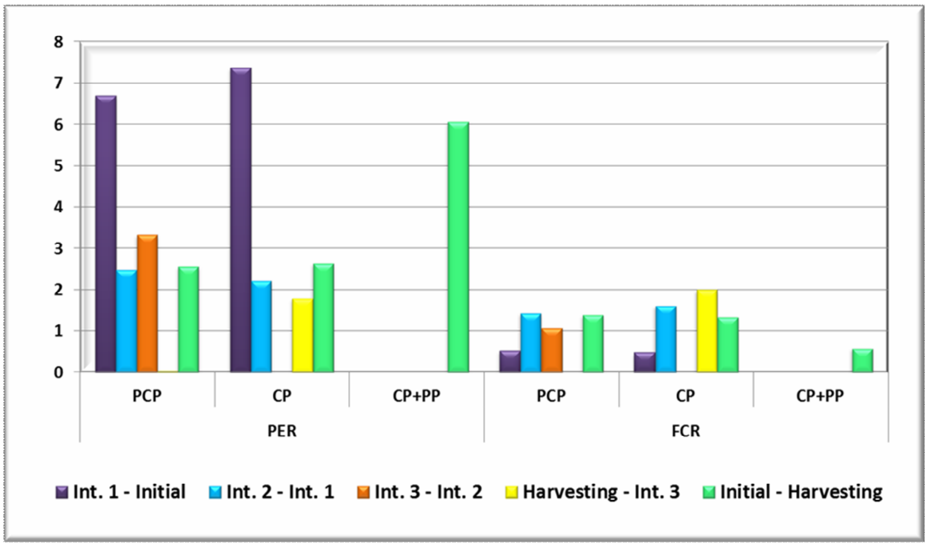

Figure 6. The evolution of feed conversion ratio (FCR) and protein efficiency ratio (PER) for each of the tested variants, during the experimental period.

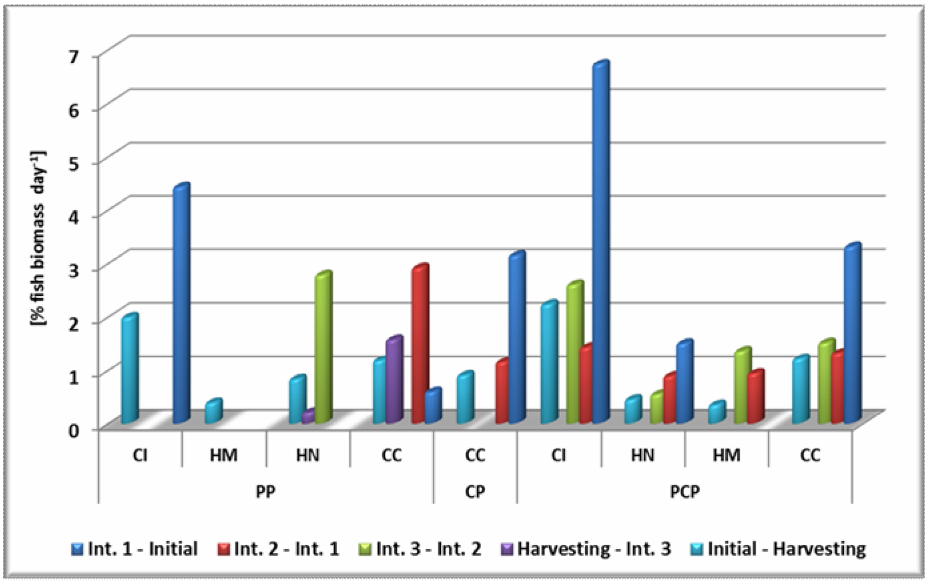

Figure 7. The evolution of specific growth rate (SGR) for each of the tested variants, during the experimental period.

The best FCR value was recorded in case of CP-PP experimental variant (0.59), while CP registered the highest FCR value (1.35) (Figure 6). This can be due to low survival rate (Table 1), registered for CP experimental variant. Also, it must be mentioned that in case of PCP and CP-PP the FCR covers the entire production, since a polyculture and IMTA systems is used, while in case of CP, a common carp monoculture FCR is mentioned. It can be observed that in case of CP, the FCR evolution had a upward tendency until final harvesting, starting from 0.48; 1.61 and ending to 1.99 (Figure 6), while in case of PCP, the upward tendency of FCR from 0.53 to 1.44 is followed by a decrease to 1.07, registered at Int. 3 (Figure 6).

Regarding PER, a continuous downward tendency can be observed in case of both PCP and CP (Figure 6). However, the average PER during the experimental period registered a value of 2.56 in case of PCP, 2.64 for CP and 6.06 for CP-PP (Figure 6). The results confirm the fact stated by Aderolu et al (2010) that the ability of an organism to utilize the nutrients, especially proteins, positively affects growth rate.

The highest SGR is registered in case of grass carp reared at PCP (Figure 7). Also, common carp reared at PCP registered a nearly similar value of SGR (1.2% day^{-1}), compared with common carp stocked at PP (Figure 7). However, both of the SGR values are considerable higher, comparing with CP common carp (0.89% day^{-1}) (Figure 7). Also, regarding silver carp and bighead carp SGR values, it can be observed that the specimens reared at PCP registered lower values, compared with those stocked at PP (Figure 7).

Also, SGR had a downward tendency during the experimental period in case of common carp and grass carp, while the small upward tendency was observed in certain experimental stages, in case of silver carp and bighead carp (Figure 7).

Mocanu et al (2015) registered, for common carp, a FCR variation between 1.25-1.4 and a SGR variation between 2.35-2.6% day^{-1}, in the previously described technological conditions.

Oprea et al (2015) reported, for common carp, FCR values between 1.33–1.41 and a SGR between 3.31–3.35% day^{-1} in the previously described technological conditions.

Gheorghe et al (2008) reported a FCR between 0.54–4, a SGR between 5.59-5.76% day^{-1} and PER values range between 0.83–3.05, for common carp, in the previously described technological conditions. Also, in the same study, Gheorghe et al (2008) observed the highest FCR values during August–September (3.81–4), situation similar with the one encountered in our present study.

Coroian et al (2015) had registered a FCR ranged between 2.16–3.77, for common carp, in the previously described technological conditions, but he also pointed out that higher values of FCR (53.79) can be achieved if 30% protein feed is used for rearing common carp fingerlings.

Másílko et al (2014) conducted a 111 days experiment with common carp with the purpose to improve the production efficiency by mechanical processing of cereal diet and reported a SGR value of 0.54% day^{-1}.

Afzal et al (2008) analized the growth performance of bighead carp in monoculture systems, with and without supplementary feeding. He obtained a FCR average value of 4.24±1.17 after a 12 months experimental period.

Du et al (2005) studied the influence of feeding rate on growth, feed efficiency and body composition of juvenile grass carp. After 56 days of experiment, they obtained a FCR average value of 0.74±0.04 when applying a 1.5% BW feeding rate and 0.37±0.03 for a 3% BW feeding rate. Also, SGR average value reported for 3% BW feeding rate was 1.03±0.09% day^{-1}, while for 1.5% BW feeding rate, the SGR average value was 0.94±0.06% day^{-1}. The average PER values ranged between 2.28±0.12 at 1.5% BW feeding rate and 1.14±0.10 at 3% BW feeding rate.

Conclusions. The results of present research have a high applicability degree for aquaculture industrial production. The main argument of this affirmation is related to real production conditions that were used, in order to put into practice the IMTA concept. Therefore, firstly it was proved that IMTA can be a solution for improving aquaculture sustainability, its economic, social and especially environmental impact.

Our study has demonstrated that an IMTA cyprinides pond production system, where common carp is considered as main essential species, can be more sustainable, comparing with a classical polyculture cyprinides pond production system.

Also, rearing common carp in monoculture generates a lower productivity of the production system, than rearing it by using polyculture technologies. However, rearing common carp as primary production species, like CP experimental variant, generates better results in terms of productivity, that rearing it was secondary production branch, like PP experimental variant. This fact confirms the intense synergistic effects of food availability.

Therefore, both in terms of common carp growth performance and total cyprinides biomass production, PCP production system registered the best results, compared with the IMTA system (CP-PP). However, by analysing the economical sustainability of the two tested production systems, it can be said that IMTA (CP-PP) is by far, the best option, as it generates a certain fish biomass gain by using less resources. Thus, the considerable lower value of IMTA total feed conversion ratio, compared with classical polyculture cyprinides pond production system, stands up for those mentioned above.

Future researches are recommended to be made in order to determine the environmental impact of IMTA, compared with a classical pond cyprinides polyculture production system and also, for identify the phytoplankton dynamics, fact that can contribute to a better understanding of IMTA concept.

Acknowledgements. This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CCCDI – UEFISCDI, project number 46/2016, within PNCDI III – project cod: COFASP-IMTA-EFFECT.

References

Adámek Z., Linhart O., Kratochvíl M., Flajšhans M., Randák T., Policar T., Masojídek J., Kozák P., 2012 Aquaculture in the Czech Republic in 2012: modern European prosperous sector based on thousand-year history of pond culture. Aquaculture Europe 37(2):5-14.

Aderolu A. Z., Seriki B. M., Apatira A. L., Ajaegbo C. U., 2010 Effects of feeding frequency on growth, feed efficiency and economic viability of rearing African catfish (*Clarias gariepinus*, Burchell 1822) fingerlings and juveniles. African Journal of Food Science 4(5):286-290.

Afzal M., Rab A., Akhtar N., Ahmed I., Khan M. F., Qayyum M., 2008 Growth performance of bighead carp *Aristichthys nobilis* (Richardson) in monoculture system with and without supplementary feeding. Pakistan Veterinary Journal 28(2):57-62.

Azad M. A. K., Rahman M. R., Rahman Z., Kader M. A., Haque M. M., Alam M. J., 2004 Polyculture of carp, tilapia and pangas using low cost inputs. Pakistan Journal of Biological Sciences 7(11):1918–1926.

Balon E. K., 1995 Origin and domestication of the wild carp, *Cyprinus carpio*: from Roman gourmets to the swimming flowers. Aquaculture 129:3–48.

Chopin T., Robinson S., Sawhney M., Bastarache S., Belyea E., Shea R., Armstrong W., Stewart I., Fitzgerald P., 2004 The AquaNet integrated multi-trophic aquaculture project: rationale of the project and development of kelp cultivation as the inorganic extractive component of the system. Bulletin of the Aquaculture Association of Canada 104(3):11–18.

Cioboiu O., Brezeanu G., 2009 Hydrobiological and piscicultural features of certain small basins within the Oltenia Plain. AACL Bioflux 2(2):133-136.

Ciric M., Subakov-Simic G., Dulic Z., Bjelanovic K., Cicovacki S., Markovic Z., 2015 Effect of supplemental feed type on water quality, plankton and benthos availability and carp (*Cyprinus carpio* L.) growth in semi-intensive monoculture ponds. Aquaculture Research 46(4):777-788.

Cirkovic M., Jovanovic B., Maletin S., 2002 [Fisheries]. Univerzitet u Novom Sadu, Poljoprivredni Fakultet, pp. 106-121. [in Serbian]

Coroian C. O., Miresan V., Cocan D. I., Vatu R. D., Raducu C. M., Coroian A., 2015 Growth performance of common carp (*Cyprinus carpio* L.) fingerlings fed with various protein levels. AACL Bioflux 8(6):1038-1047.

Dobrota N., Dobrota G., Costache M., Marica N., 2012 Comparative study on rearing some valuable species in intensive system using non-conventional fodders. AACL Bioflux 5(5):361-368.

Du Z. Y., Liu Y. J., Tian L. X., He J. G., Cao J. M., Liang G. Y., 2006 The influence of feeding rate on growth, feed efficiency and body composition of juvenile grass carp (*Ctenopharyngodon idella*). Aquaculture International 14:247–257.

Gheorghe C. E., Radu D., Costache M., Bucur C., 2008 Testing some protein feed used for the intensive carp raising (*Cyprinus carpio* L., 1758), during summer II. Analele IBNA 24:16-24.

Gheorghe D. C., Razlog G. P., Cristea V., Enache I., 2011 The growth characteristics of common carp (*Cyprinus carpio*) in the northern part of the Small Island of Braila Natural Park. AACL Bioflux **4**(2):154-158.

Györe K., Józsa V., Wilhelm S., 2011 Monitoring of the fish community in the Hungarian reach of River Tisza in 2009. Studia Universitatis "Vasile Goldiş" Seria Ştiinţele Vieţii 21(4):793-801.

Hasan M. R., Hecht T., De Silva S. S., Tacon A. G. J. (eds), 2007 Study and analysis of feeds and fertilizers for sustainable aquaculture development. FAO Fisheries Technical Paper, No. 497, FAO, Rome, 510 pp.

Hassan A. A. R., Mahmoud A. A. F., 2011 Effect of stockig density on growth performance and economic retern in semi-intensive and extensive fish culture methods in earthen ponds. Journal of the Arabian Aquaculture Society 6(1):13-32.

Hepher B., Milstein A., Leventer H., Teltsch B., 1989 The effect of fish density and species combination on growth and utilization of natural food in ponds. Aquaculture Research 20:59–71.

Hlavac D., Adámek Z., Hartman P., Masilko J., 2014 Effects of supplementary feeding in carp ponds on discharge water quality: a review. Aquaculture International 22:299–320.

Kaushik S. J., 1995 Nutrient requirements, supply and utilization in the context of carp culture. Aquaculture 129:225–241.

Kestemont P., 1995 Different systems of carp production and their impacts on the environment. Aquaculture 129:347–372.

Khan M. N., Shahzad K., Chatta A., Sohail M., Piria M., Treer T., 2016 A review of introduction of common carp *Cyprinus carpio* in Pakistan: origin, purpose, impact and management. Croatian Journal of Fisheries 74:71–80.

Korınek V., Fott J., Fuksa J., Lellak J., Prazakova M., 1987 Carp ponds of central Europe. In: Managed aquatic ecosystems. Michael R. G. (ed), Elsevier Science, Amsterdam, pp. 29-62.

Krogdahl A., Hemre G. I., Mommsen T. P., 2005 Carbohydrates in fish nutrition: digestion and absorption in postlarval stages. Aquaculture Nutrition 11:103–122.

Ljubojevic D., Radosavljevic V., Puvaca N., Balos M. Z., Đorpevic V., Jovanovic R., Cirkovic M., 2015 Interactive effects of dietary protein level and oil source on proximate composition and fatty acid composition in common carp (*Cyprinus carpio* L.). Journal of Food Composition and Analysis 37:44-50.

Luca C., Suciu R., Costache M., 2010 Comparative karyotype in different lineages of cyprinid fish (Teleostei: Cypriniformes: Cyprinidae). Studia Universitatis "Vasile Goldiş" Seria Ştiinţele Vieţii 20(1):37-41.

Lutz G. C., 2003 Polyculture: principles, practices, problems, and promises. Aquacultural Magazine (March/April), pp. 34-39.

Másílko J., Hartvich P., Rost M., Urbánek M., Hlaváč D., Dvořák P., 2014 Potential for improvement of common carp production efficiency by mechanical processing of cereal diet. Turkish Journal of Fisheries and Aquatic Sciences 14:143-153.

Medale F., Poli J. M., Vallee F., Blanc D., 1999 Utilisation of a carbohydrate-rich diet by common carp reared at 18 and 25 degrees C. Cybium 23:139–152.

Miah M. S., Uddin M. S., Shah M. S., 1993 Effects of artificial feed in carps polyculture system. Bangladesh Journal of Agricultural Sciences 20:359–364.

Mills E. L., Leach J. H., Carlton J. T., Secor C. L., 1993 Exotic species in the Great Lakes: a history of biotic crises and anthropogenic introductions. Journal of Great Lakes Research 19:1–54.

Mocanu M. C., Vanghelie T., Sandu P. G., Dediu L., Oprea L., 2015 The effect of supplementary feeds quality on growth performance and production of common carp (*Cyprinus carpio* L.) at one summer of age, in ponds aquaculture systems. AACL Bioflux 8(4):602-610.

Montchowui E., Laleye P., Moreau J., Philippart J. C., Poncin P., 2009 Population parameters of African carp: *Labeo parvus* Boulenger, 1902 (Pisces: Cyprinidae) in the Ouémé River in Bénin (West Africa). North-Western Journal of Zoology 5(1):26-33.

Neori A., Chopin T., Troell M., Buschmann A. H., Kraemer G. P., Hailing C., Shpigel M., Yarish C., 2004 Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. Aquaculture 231:361-391.

Oprea L., Mocanu M. C., Vanghelie T., Sandu P. G., Dediu L., 2015 The influence of stocking density on growth performance, feed intake and production of common carp, *Cyprinus carpio* L., at one summer of age, in ponds aquaculture systems. AACL Bioflux 8(5):632-639.

Ozcan G., Balık S., 2009 Some biological parameters of the bergamae barb, *Capoeta bergamae* Karaman, 1969 (Cyprinidae), in Kemer reservoir (Aydin, Turkey). North-Western Journal of Zoology 5(2):242-250.

Pechar L., 2000 Impacts of long-term changes in fishery management on the trophic level water quality in Czech fish ponds. Fisheries Management and Ecology 7(1–2):23–31.

Przybyl A., Mazurkiewicz J., 2004 Nutritive value of cereals in feeds for common carp (*Cyprinus carpio* L.). Czech Journal of Animal Science 49(7):307–314.

Potuzak J., Huda J., Pechar L., 2007 Changes in fish production effectivity in eutrophic fishponds – impact of zooplankton structure. Aquaculture International 15:201–210.

Rahman M. M., Nagelkerke L. A. J., Verdegem M. C. J., Wahab M. A., Verreth J. A. J., 2008 Relationships among water quality, food resources, fish diet and fish growth in polyculture ponds: a multivariate approach. Aquaculture 275:108-115.

Ricciardi I. I., MacIsaac H. J., 2000 Recent mass invasion of the North American Great Lakes by Ponto-Caspian species. Trend in Ecology and Evolution 15:62–65.

Sharma K. R., Leung P. S., 2000 Technical efficiency of carp pond culture in South Asia: an application of a stochastic meta-production frontier model. Aquaculture Economics and Management 4:169-189.

Da Silva B. L., Barcellos L. J. G., Quevedo R. M., de Souza S. M. G., Kreutz L. C., Ritter F., Finco J. A., Bedin A. C., 2006 Alternative species for traditional carp polyculture in southern South America: initial growing period. Aquaculture 255:417–428.

Terziyski D. I., Kalchev R. K., Vasileva P. L., Piskov I. A., Iliev I. Z., 2009 Fish abundance differences and relations to plankton primary production in two variants of pond stocking with common carp (*Cyprinus carpio* L.), grass carp (*Ctenopharyngodon idella* Val.) and bighead carp (*Aristichthys nobilis* Rich.) larvae. AACL Bioflux 2(3):251-260.

Troell M., Halling C., Neori A., Chopin T., Buschmann A. H., Kautsky N., Yarish C., 2003 Integrated mariculture: asking the right questions. Aquaculture 226:69-90.

Vilizzi L., Tarkan A. S., Copp G. H., 2015 Experimental evidence from causal criteria analysis for the effects of common carp *Cyprinus carpio* on freshwater ecosystems: a global perspective. Reviews in Fisheries Science and Aquaculture 23:253-290.

Vsetickova L., Adamek Z., Rozkosny M., Sedlacek P., 2012 Effects of semi-intensive carp pond farming on discharged water quality. Acta Ichthyologica et Piscatoria 42(3):223–231.

Woynarovich A., Moth-Poulsen T., Péteri A., 2010 Carp polyculture in Central and Eastern Europe, the Caucasus and Central Asia - a manual. Food and Agriculture Organization of the United Nations, Rome, 73 pp.

Received: 24 November 2016. Accepted: 28 December 2017. Published online: 09 February 2017.
Authors:
Ştefan-Mihai Petrea, „Dunărea de Jos" University of Galaţi, Department of Aquaculture, Environmental Science and Cadastre, Domnească Street, no. 47, 800008 Galaţi, Romania, e-mail: stefan.petrea@ugal.ro
Alina Mogodan, „Dunărea de Jos" University of Galaţi, Department of Aquaculture, Environmental Science and Cadastre, Domnească Street, no. 47, 800008 Galaţi, Romania, e-mail: alina.antache@ugal.ro
Isabelle Metaxa, „Dunărea de Jos" University of Galaţi, Department of Aquaculture, Environmental Science and Cadastre, Domnească Street, no. 47, 800008 Galaţi, Romania, e-mail: isabelle.metaxa@ugal.ro
Săndiţa Plăcintă, „Dunărea de Jos" University of Galaţi, Department of Aquaculture, Environmental Science and Cadastre, Domnească Street, no. 47, 800008 Galaţi, Romania, e-mail: sandita.placinta@ugal.ro
Aida Vasile, „Dunărea de Jos" University of Galaţi, Department of Food Science, Food Engineering and Applied Biotechnology, Domnească Street, no. 47, 800008 Galaţi, Romania, e-mail: aida.vasile@ugal.ro
Gheorghe Huian, S.C. Piscicola Iaşi, Păcurari Street, no. 130, 700522 Iaşi, Romania, e-mail: piscicolaiasi@yahoo.com

How to cite this article:
Petrea S. M., Mogodan A., Metaxa I., Plăcintă S., Vasile M. A., Huian G., 2017 A comparative study on the evaluation of cyprinids growth performance in IMTA systems. AACL Bioflux 10(1):87-102.