Arch. Biol. Sci., Belgrade, 61 (1), 113-121, 2009 DOI:10.2298/ABS0901113M

INFLUENCE OF ABIOTIC AND BIOTIC ENVIRONMENTAL FACTORS ON WEIGHT GAIN OF CULTURED CARP ON A CARP FARM

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Abstract — During the period from April to October in the production season of the year 2000, seven chemical parameters of the aquatic environment were analyzed twice a month for the amount of natural food (zooplankton and bottom fauna) on pond No. 4 at the Dubica Carp Farm in Banatska Dubica (Vojvodina, Serbia). Correlation between natural food and carp growth was analyzed as well. The investigations revealed negative correlation between the amount of natural food per kilogram of ichthyomass and pH ($p < 0.001$, $r = -0.875$), electroconductivity ($p = 0.0294$, $r = -0.673$), COD ($p = 0.0052$, $r = -0.782$), total water hardness ($p = 0.0186$, $r = -0.709$), and carbonate water hardness ($p = 0.0087$, $r = -0.758$). However, statistically significant positive correlation was found between the biomass of natural food (g/kg of ichthyomass) and concentration of nitrates ($p < 0.01$, $r = 0.841$) and phosphates ($p = 0.0427$, $r = 0.640$). Concerning components of natural food (zooplankton and bottom fauna), bottom fauna biomass had a very low production and showed no statistically significant correlation ($p = 0.137$, $r = 0.491$) with total natural food biomass whereas zooplankton biomass was very significantly correlated ($p<0.001$, $r = 0.830$) with the total amount of natural food, indicating that zooplankton was the dominant component of natural food at the investigated fish pond. The daily weight gain (%) of cultured fish was greatest at the beginning of the carp farming season, i.e., in April, when it comprised a value of 2.3%. After negative growth at the end of May (-0.2%), a gradual increase of weight gain was recorded until the beginning of September. By comparing the biomass of natural food with the daily weight gain (%) of carp, it was observed that the weight gain had a trend similar to biomass of natural food with a 15 day interval. This relationship was justified by positive statistical correlation ($p = 0.006$, $R = 0.960$). As zooplankton was the major component of natural food, fish relayed on it as the main protein source showed by a significant positive correlation ($p = 0.034$, $r = 0.907$).

Key words: Carp farm, carp, natural food, water chemistry

UDC 639.31(497.113):597.551.2:574.2

INTRODUCTION

The relationship between the cultivated fish species and the pond environment are largely dependent on the degree of intensification of the culture. The intensity of a system is measured in terms of inputs, including the intensity of management required to sustain the system, as well as the level of output products (Milstain, 1992).

In semi-intensive fish production, natural input factors are complemented by supplementary feeding and the application of manure and fertilizers, thus being the main factors for enhancing fish production (Biro, 1995). Supplementary feed usually consists of cheap and locally available raw ingredients (Ghosh et al., 1984), in Serbia mainly cereals (wheat, corn, barley). Similar to fish production in natural waters, in this type of aquaculture, productivity is considerably influenced by abiotic and biotic factors of the environment. Some negative effects of these factors can be overcome only by application of different technical measures (e.g. liming, fertilizing). Used appropriately, these interventions are expected to provide higher fish yields on a small area. The disadvantage of applied measures is that they can induce rapid and extensive changes in the water environment, making it unsuitable for fish and leading to metabolic disturbances, disease, and even fish death (Marković and Mitrović–Tutundžić, 2000). Therefore, for good maintenance of fish and better yields in semi-intensive culture, it is necessary to have good knowledge of the conditions prevailing in the aquatic ecosystem.

In general, the basis of semi-intensive carp (*Cyprinus carpio* L.) rearing is maintaining a balance between environmental factors, natural sources of proteins (natural food) and addition of supplementary food in a form of carbohydrates. However, carp growth depends on the level of development of natural food and to a lesser extent on the amount of added carbohydrates. Zooplankton and macrozoobenthos are the main protein sources for common carp. Additionally, they are also valuable source of amino acids, lipids, fatty acids and enzymes (Millamena et al. 1990; Pillay, 1990). Preferences of different carp age groups towards different kinds of prey change during their life and, in general, fish have been observed to consume increasingly larger prey as they grow. Several studies have documented the size-selectivity of fish for their invertebrate prey (Brooks and Dodson 1965; Dodson 1974; Zaret 1980; O'Brien 1987). Natural food for two year old carp are apparently larger forms of zooplankton (>500µm) (Spataru et al., 1983, Kormendi and Hancs, 2000), mostly from the group Cladocera, primarily some species of *Daphnia* (*D. magna, D. pulex*), but also organisms of bottom fauna as Chironomidae. The availability of natural food depends on their population dynamics and natural decrease in some critical periods of the fish production season can have negative consequences on the weight gain of fish. Low productivity often comes forward during the end of carp rearing season (end of August and September), being the critical point in economical production.

Acquaintance with mutual influences between abiotic and biotic factors and determination of optimal values in aquaculture constitute the basis for realization of an adequate technology of production and thereby for attaining maximal production at minimal cost. With this as our goal, in the present work we examine the effects of abiotic environmental conditions on secondary production (production of natural food) and consider the influence of natural food itself on the weight gain of cultured carp on a carp farm.

MATERIAL AND METHODS

The study was carried out during one production season at pond No. 4 on the Dubica Carp Farm in Banatska Dubica, Serbia, that has a surface area of 112 ha and volume of 1,747,685 m^3. The fish pond was stocked with approximately 44000 two-year old carp, average weight of 800 g. The quantity of supplementary food was determined by correcting the accustomed percentage per kg of ichthyomass for carp fish farms (Marković i Mitrović-Tutundžić, 2003) according to the biomass of available natural food (g/kg of ichthyomass).

Chemical characteristics of the water (pH, electroconductivity, COD, total water hardness, carbonate water hardness, nitrate levels, and phosphate content) were monitored, together with production of zooplankton and bottom fauna (as the natural food of carp) and the dynamics of carp growth (through the daily weight gain in %). Sampling was carried out fortnightly at five profiles of the pond. Two profiles were located near shore (about 50 m from the place where water is let into the pond and about 50 m from the opposite shore). Three profiles were in the middle of the fish pond, one in the central part and one each between it and the offshore profiles.

Samples for chemical analysis were collected in 1-liter plastic bottles in the central part of the fish pond at a depth of 30 cm below the surface of the water. Winkler bottles were used for determination of oxygen and COD. Chemical analyses were performed according to current regulations using American standard methods (APHA, 1998) in the chemical laboratory of the Health Protection Institute of Serbia.

Sampling of zooplankton was performed using a slender transparent plastic tube, 2 m in length and 1 liter in volume. After taking, the water sample was filtered using a No. 20 plankton net, mesh size of 76 µm (Tonolli, 1971; APHA, 1998). Filtered samples were transferred to 100-ml glass bottles and conserved with a 4% formaldehyde solution. Since zooplankton is unevenly distributed in water and has a strong vertical gradient in abundance (Wetzel, 1983), this sampling method is used to obtain average values of zooplankton abundance and biomass in the entire water column. By applying this method we also obtain more reliable data on the water volume of the whole fish pond (lake). Moreover, a transparent tube is also used for zooplankton sampling on account of the similar refraction index of transparent plastic and water, which prevents planktonic organisms with good vision (for example, *Daphnia* sp.) from avoiding the tube.

Samples of zooplankton were processed in the Laboratory of Zoology and Fisheries of Belgrade University's Faculty of Agriculture in Zemun, Serbia using a Carl Zeiss (Jena) microscope with maximal magnification of 160x. Zooplankton was identified to the level of species, variety, and form. Where this was impossible due to the use of formalin as a fixative, identification was to the genus level. Identification of zooplankton was conducted using appropriate keys (Rudescu, 1960; Harding and Smith, 1960; Collins et al., 1961; Šramek-Hrušek et al., 1962; ScourfIeld and Harding, 1966); Dussart, 1969; Koste, 1978; Živković, 1987).

The quantitative composition of zooplankton was determined by direct counting of zooplanktonic individuals from a Sedgewick-Rafter chamber with a volume of 1 ml. The 100 ml samples were concentrated up to 20 ml by pouring off liquid. Followed by mixing and homogenization, every sample was examined with three repetitions, using a subsampling technique, after which the number of identified species was recalculated for the whole sample or 1 liter. The biomass of zooplankton in the sample was determined using tables of average values for different zooplanktonic species (Morduhai-Boltiviskoi, 1954; Ulomski, 1958) multiplied by the number of individuals of each species.

On the basis of the obtained values of zooplankton biomass per 1 liter of water (recalculated per cubic meter) and total volume of the fish pond (lake), the total biomass of zooplankton of the pond was calculated in order to determine the amount of food consisting of zooplankton.

Samples of bottom fauna organisms were taken with Eckmann dredge modified for use on carp farms. The dredge had a grab area of 87.55 cm^2. Substrate grabbed by the dredge was passed through a sieve to remove the mud, and macrozoobenthic organisms were housed in plastic jars and conserved with a 4% formaldehyde solution. Bottom fauna biomass was determined by direct weighing of moist biomass on a Sartorius AC IS technical balance (with accuracy of 10^{-4}g). Biomass of macrozoobenthos has been calculated for the total surface of the fish lake to define the whole amount of natural food from the bottom fauna.

Samples of fish were taken at the feeding sites. The fish were captured with nets. The least number of sampled fish was 100. Individual specimens of carp were weighed with a digital technical weighing device (with accuracy of 1 g). Average fish mass was determined on the basis of a test catch. To calculate the total ichthyomass in the fish pond the average weight of fish was multiplied by the total number of stocked individuals and by subtracting fish loss.

Growth was studied in terms of daily weight gain (GBW %) that was calculated after Brown (1957) as follows:

$$GBW = \frac{W_2 - W_1}{t \times W_1} \times 100$$

where W_2 is the average fish mass (g) in the given time period, W_1 is average fish weight (g) in the previous time period, and t is the time period (in days) between the two measurements.

In order to determine the amount of natural food present in the fish pond, i.e., available to cultured fish, the amount of natural food was expressed per kilogram of ichthyomass. The amount of natural food per kilogram of ichthyomass was determined from the quotient of the total biomass of natural food (the biomass of zooplankton and bottom fauna) and total ichthyomass.

Statistical analysis was performed with the aid of the Sigma Stat program (Version 2) and STATISTICA

6.0. Statistical correlations were used to study the relationship between abiotic and biotic parameters.

RESULTS AND DISCUSSION

During the production season pH of water ranged between 7.03 (April 27) and 8.34 (September 18) and was optimal for carp rearing (Svobodova et al., 1993). Electroconductivity was in the range from 392 (May 13) to 632 (September 5) µS/cm. The recorded values of COD fluctuated from a minimum of 11.7 (June 20) to a maximum of 21.3 (August 1) mg/L and were within acceptable ranges for fish culture as reported by Alabaster and Lloyd (1980) and Boyd (1982). Moderate values of COD are an indication good water quality, in general lower organic load, that has a positive effect on carp growth and better yields (Chakrabarti and Jana, 1991). Water hardness (total and carbonate) tended to increase from the outset of the rearing season to the beginning of September (total hardness from 7.2 to 13.6, carbonate hardness from 5.2 to 9.76°dH). The concentration of nitrates in the water varied in the range of from 1.5 (September 5) to 2.5 (June 20) mg/L, while that of phosphates varied from 0.100 (May 13) to 0.289 (August 18) mg/L.

The total biomass of zooplankton had an trend of increasing from the end of May to beginning of July (Fig. 1A) and in the second half of August, while a decrease of biomass was recorded in the second half of July, at the beginning of August, and in September (Fig. 1A). However, zooplankton biomass ranged from 167.72 g/kg in the second half of September up to 1074.46 g/kg in the second half of May that was on average 569.8 g/kg. Such high zooplankton biomass, comprising up to 75% of Cladocera reported by Dulić (2006), is a very good source of protein for reared fish (Delbare and Dhert, 1996; Kibria et al., 1997), specially in traditional semi-intensive production where usually no supplementary proteins are given to fish (Marković, 2003). The effect of good zooplankton production was observed through the increase of fish weight gain that followed up the increase of zooplankton biomass during end of April, second half of June and August with a 15 day lag (Fig.3).

The highest values of bottom fauna biomass were recorded at the beginning of May (32.00 g/kg, Fig. 1B), the lowest in the second half of September (1.70 g/kg). According to these results, even though there was two bottom fauna maxima recorded, the production were very low throughout the whole season and could not have had any significant influence on the weight gain of fish in the lake(Zur, 1979). Production of natural food under 100 g/kg

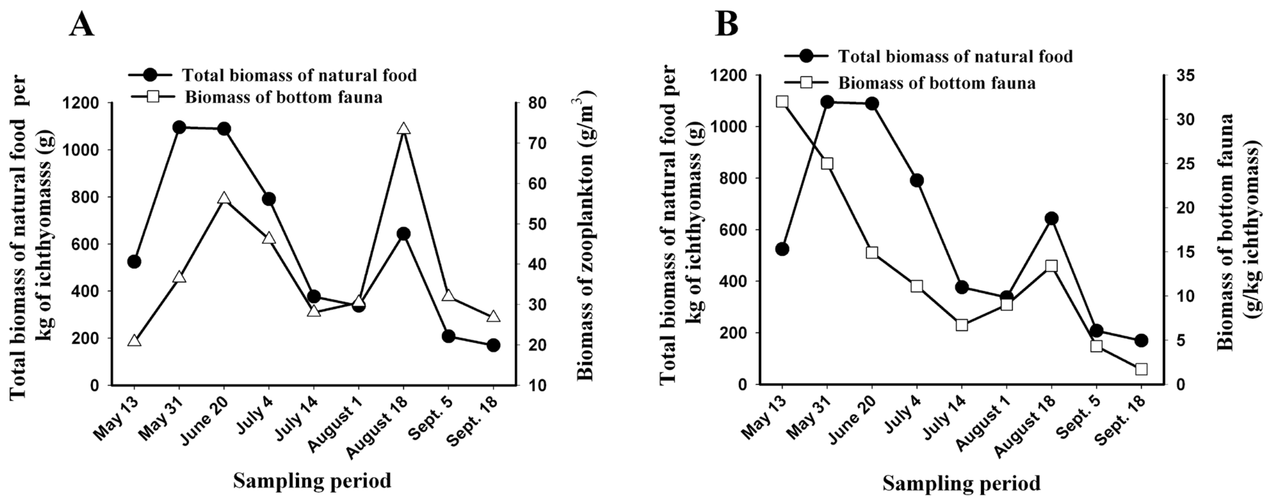

Fig. 1. A) Dynamics of total biomass of natural food and zooplankton biomass in fish lake No. 4. B) Dynamics of total biomass of natural food and bottom fauna biomass in fish lake No. 4.

ichthyomass is concerned as very low in terms of carp production (Marković, 2003).

In the course of the conducted investigation, correlation was observed between seven abiotic environmental factors (pH, electroconductivity, COD, total hardness, carbonate hardness, nitrate levels, and orthophosphate content) and production of zooplankton and bottom fauna (the natural food of carp) expressed through their biomass (Fig. 2), as well as correlation between components of natural food (zooplankton and bottom fauna) and the total biomass of available natural food.

The correlation was negative for pH ($p < 0.001$, $r = -0.875$), electroconductivity ($p = 0.0294$, $r = -0.673$), COD ($p = 0.0052$, $r = -0.782$), total water hardness ($p = 0.0186$, $r = -0.709$), and carbonate

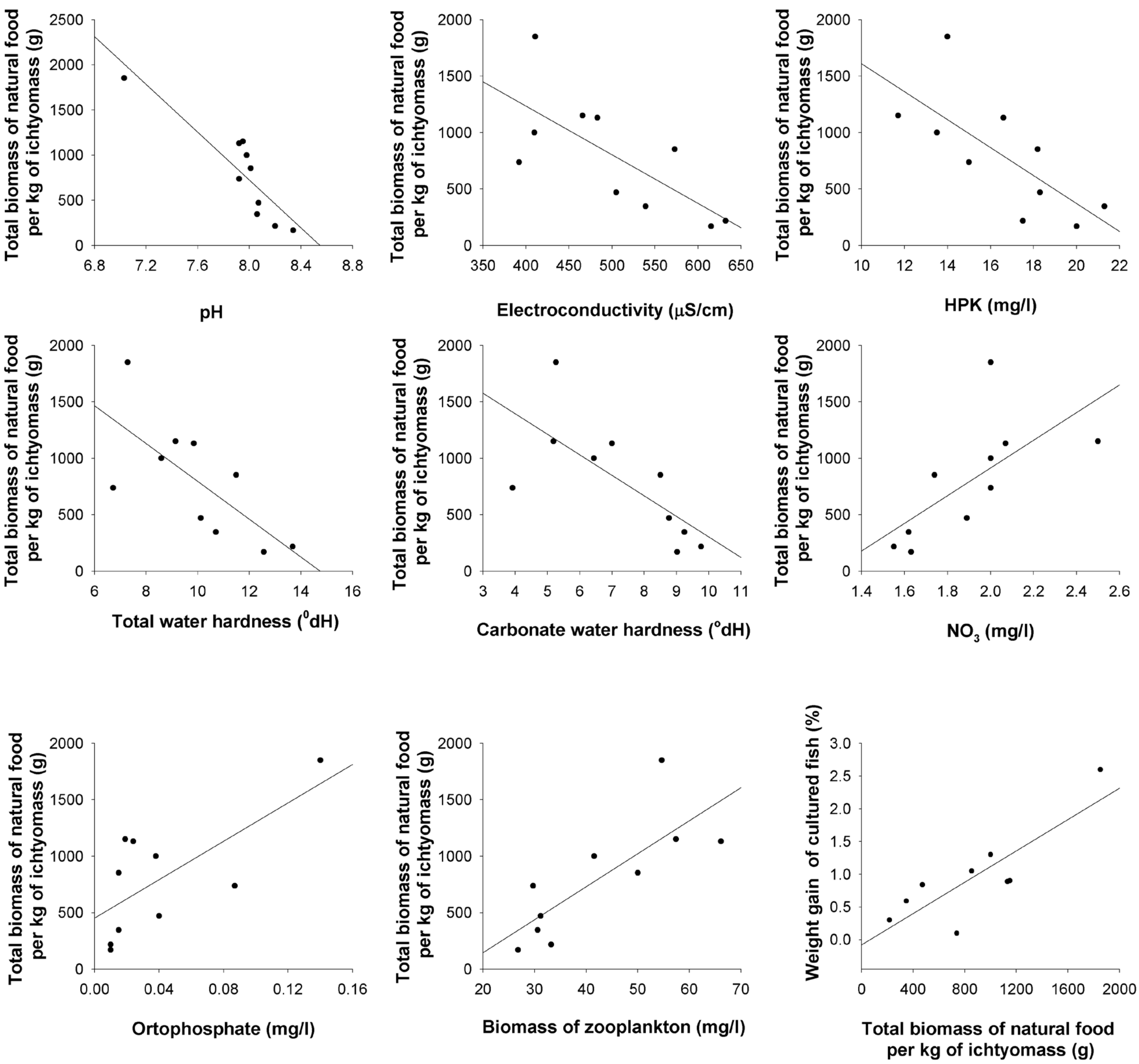

Fig. 2. Total biomass of natural food in relation to chemical and biological factors of the environment.

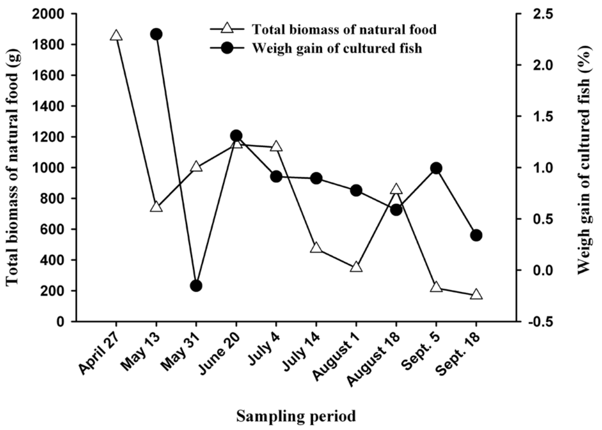

Fig. 3. Weight gain of cultured fish in correlation with the dynamics of total natural food biomass in fish pond No. 4.

water hardness ($p = 0.0087$, $r = -0.758$) (Fig. 1). The highest total biomass of natural food per kilogram of ichthyomass was observed in the case of soft and medium-hard water with neutral pH characterized by low electroconductivity and the lowest chemical oxygen demand. The obtained negative correlation was expected under conditions of the recorded pH values (Livojević et al., 1967; Kolaska-Jasminska, 1987; Marković and Mitrović-Tutundžić, 2003), values of electroconductivity and COD (Marković and Mitrović-Tutundžić, 2003). However, negative correlation between water hardness and production of natural food (zooplankton and bottom fauna) was not expected since harder water has a positive direct [facilitates osmoregulation and mineral absorption in fish (Klontz, 1995, Parker, 2002)] and indirect (growth of zooplankton) (Tessier and Horwitz; Hessen *et al.*, 2000) effect on fish growth.

A statistically significant positive correlation was observed during the investigation (Fig. 2) between biomass of natural food per kilogram of ichthyomass and nitrates ($p < 0.001$, $r = 0.841$) and phosphates concentration ($p = 0.0427$, $r = 0.640$). Positive correlation was expected in view of the fact that nitrate and phosphate values fluctuated within the limits desirable in carp farming (1-4 mg/L for nitrates, 0.1-0.5 mg/L for phosphates) (Marković and Mitrović-Tutundžić, 2003). These nutrients incorporate into biomass (algae and zooplankton) and, through a complex web of nutrient assimilation and recycling, finally incorporate into fish (Mischke and Zimba 2004). Therefore, lower concentrations of phosphorus and nitrates than optimal for carp production can cause low primary (Ravera, 1980; Boyd and Musig, 1981) and secondary production (Hessen, 1992; De Mott et al., 1998).

As for the relationship between components of natural food (zooplankton and bottom fauna) and the total amount of natural food (Fig. 2), bottom fauna biomass showed no statistically significant correlation ($p = 0.137$, $r = 0.491$) whereas zooplankton biomass was very significantly correlated ($p<0.001$, $r = 0.830$) with the total amount of natural food. This indicates that zooplankton was the dominant component of natural food in the investigated fish pond, while bottom fauna was poorly developed and did not affect the total amount of natural food.

The daily weight gain of cultured carp was the highest (2.3%) during the initial phase of carp farming, in April. Throughout the season GBW varied, but generally, after negative growth at the end of May (-0.2%) a gradual increase of weight gain was recorded until the beginning of September (Fig. 3). As availability of natural food is one of the major factors that contribute to fish weight gain (Lam and Shephard, 1988; Islam, 2002) specially in semi-intensive fish production (Kormendi and Hancs, 2000) a significant decrease in production during the second half of May (Fig. 3), could have provoked a negative weight gain of fish at the end of May.

Comparing changes in weight gain of cultured carp and total biomass of natural food per kilogram of ichthyomass throughout the investigation, a 15 day interval between the increase of zooplankton and fish weight gain was indicated (Fig. 3). The time lag that developed between the increase of zooplankton and fish biomass was predictable owing to the fact that fish gain weight after a consuming a vast amount of proteins. This relationship, between available proteins (natural food) and fish weight gain was justified by a positive very significant statistical correlation ($p=0.006$, $R=0.960$). Since the major component of natural food biomass was zooplankton biomass indicated by positive correlation ($p= 0.034$, $r = 0.907$), therefore the main effect on the increase of fish weight had the amount of zooplankton.

The present study has confirmed that producing higher yields at of fish at minimal cost in semi-intensive systems depends on a good combination of natural and applied food and is primarily based on the very delicate balance between abiotic and biotic parameters prevailing in the fish pond environment. The availability of natural food as well as its composition in a fish pond, as the major protein source, is of big importance specially since supplementary food in semi-intensive system is usually of low quality and with carbohydrates constituting the highest percentage.

Acknowledgments — The study was supported by Serbian Ministry of Sciences and Technological Development (project No. TR20047) and Sojaprotein (Novi Bečej).

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УТИЦАЈ АБИОТИЧКИХ И БИОТИЧКИХ ЧИНИЛАЦА СРЕДИНЕ НА ПРИРАСТ ГАЈЕНОГ ШАРАНА У ШАРАНСКОМ РИБЊАКУ

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У току производне сезоне 2000. године, у периоду од априла до септембра, два пута месечно, вршена је анализа седам хемијских чиниоца водене средине у корелацији са динамиком природне хране (зоопланктона и фауне дна), као и корелација између природне хране и динамике раста шарана у рибњачком објекту бр. 4, шаранског рибњака "Дубица" из Банатске Дубице, Србија.

Истраживања су показала негативну корелацију измeдју: pH (p<0,001, k=-0,875), електропроводљивости (p=0,0294, k=-0,673), HPK (p=0,0052, k=-0,782), укупне тврдоће воде (p=0,0186, k=-0,709), карбонатне тврдоћу воде (p=0,0087, k=-0,758) и количине природне хране (зоопланктона и фауне дна) исказане по килограму ихтиомасе.

Статистички значајна позитивна корелација констатована је између концентрације нитрата (p<0,001, k=0,841) и ортофосфата у води (p=0,0427, k=0,640) и количине природне хране по килограму ихтиомасе.

Посматрајући однос компоненти природне хране: зоопланктона и фауне дна према укупној количини природне хране, биомаса фауне дна не показује статистичку значајну корелацију (p=0,137, k=0,491) са укупном биомасом природне хране по килограму ихтиомасе, док биомаса зоопланктона показује значајну корелацију (p<0,001, k=0,830) са укупном количином природне хране (изражене по килограму ихтиомасе), а што указује на чињеницу да је у испитиваном рибњаку доминантна компонента природне хране зоопланктон.

Дневни процентуални прираст гајене рибе био је највећи почетком сезоне гајења шарана тј. у априлу -2.3%. После негативног прираста крајем маја (-0.2%), забележен је постепено повећање прираста све до почетка септембра.

Компарацијом биомасе природне хране (изражене по килограму ихтиомасе) и процентуалног дневног прираста шарана, констатовано је да прираст шарана најчешће прати количину природне хране, тако што се бележи повећање прираста 15 дана након повећања биомасе такве хране.