SEASONAL DYNAMICS OF PRIMARY AND SECONDARY PRODUCTION IN CARP PONDS

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SEZONSKA DINAMIKA PRIMARNE I SEKUNDARNE PRODUKCIJE U ŠARANSKIM RIBNJACIMA

Abstrakt

Sezonska dinamika biomase i kvalitativnog sastava fitoplanktona, zooplanktona i makrozoobentosa je istraživana u odnosu na fizičke i hemijske faktore vodene sredine, međusobno kao i u odnosu na gajene ribe u tri zemljana bazena. Fitoplankton je imao veliki diverzitet vrsta, naročito jestivih, tokom prvog dela sezone. Kasnije, sa porastom temperature, ihtiomase, količine ekskreta riba, degradacijom nepojedene hrane kao i povremenim smanjenjem količine vode u jezerima, došlo je do promene u pravcu dominacije filamentoznih Cyanophyta. Zooplankton i makrozoobentos su tokom celog perioda istraživanja imali mali diverzitet vrsta. Sezonalna dinamika zooplanktona se karakterisala dominacijom dve Rotatoria*, Brachionus angularis* i *Keratella tropica* i malom *Cladocera Bosmina longirostris* u sva tri bazena. Makrozoobentos je imao malu gustinu i biomasu, a larvame Chironomidae su dominirale tokom cele sezone.

Ključne reči: *fitoplankton, biomasa zooplanktona, makrozoobentos, akvatične zajednice*

INTRODUCTION

Carp aquaculture ponds are complex ecosystems with a range of trophic cascading interactions including phytoplankton, zooplankton, marozoobenthos and fish. These types of ponds are specific given that they are earthen and may resemble a natural standing water ecosystem. Aquatic communities within depend on a complex of physical, chemical and biotic environmental factors (L e h m a n, 1991). Zooplankton grazing usually provokes a decrease in phytoplankton biomass S i n i s t r o et al. (2006). However, because of the effect of selective feeding by zooplankters, some uneatable algae may increase their abundance due to low competition for nutrients with other algae Q u e i m a l i n o s et al. (1998). Intensive grazing pressure by increased zooplankton abundance on small algae shifts the phytoplankton community to one dominated by larger, 'resistant' species, such as filamentous Cyanobacteria (P o r t e r, 1977; S a r n e l l e, 1993; C a r p e n t e r et al., 1996). In lakes dominated by small zooplankton such as *Bosmina*, small copepods or rotifers, algal biomass and primary production should be higher than in *Daphnia*-dominating lakes (K i t c h e l l and C a r p e n t e r, 1996). Except direct prey-predator interactions, high water temperature and nutrient loading are two major abiotic environmental factors that favor phytoplankton biomass increase. On the other hand, planktivory and food supply are often responsible for zooplankton community structure as well as seasonal succession (D e M o t t, 1989; G l i w i c z and P i j a n o w s k a, 1989). Small-bodied zooplankton will be more abundant the presence of planktivorous fish (B r o o k s and D o d s o n, 1965). Macrozoobenthos in carp ponds is mainly under the influence of fish predation and respective physical and chemical factors. In newly built fish ponds, they are usually low in density and biomass, since they need a few years to establish their communities at the pond substrata. Interaction with phytoplankton and zooplankton are indirect, through changes in the environmental conditions. By their activity in the ponds bottom they can cause resuspension of phosphates into the water.

The aim of this study was to evaluate the interdependency between seasonal successions of phytoplankton, zooplankton and macrozoobethos community structure in carp ponds. The main objectives were to examine shifts in dominant species (or groups), changes in size structure and biomass dynamics of these aquatic communities as key groups dominating in carp ponds.

MATERIAL AND METHODS

The study was conducted in three earthen fish ponds at the experimental fish farm of the Faculty of Agriculture, University of Belgrade. The ponds have a surface area of 0.09 ha. Several water sources were used for filling and maintaining the ponds: two open wells, accumulation pond and steam Sugavac. During the hottest months occasional water depletion occurred causing a rather variable water level in the ponds, ranging from 0.2 and 0.8 m. Ponds have been stocked with 400 carp yearling per pond, with average weight of 100 grams. Different supplementary feed was distributed in the three ponds using the standard feed percentage of 3% per kilogram of ichthyomass. In pond L2 and L3 extruded and pelleted feed was given, both with 25 % proteins and 7% fat and in D3 a mixture of wheat, corn and barley in equal relations (1:1:1) was applied. Fish were fed daily by hand, around noon. Field sampling was conducted from April till September.

Overall 13 environmental variables have been assessed, six (NO_3, $KMnO_4$, dH, PO_4-P, TP, Ca) were sampled bi-weekly and analyzed at the Institute for public health "Batut" (according to APHA, 1998) and seven (temperature, oxygen and oxygen saturation, electroconductivity, NH_3, pH and transparency) were measured daily, around noon, using a water field kit, MULTI 340i/SET (WTW, Germany).

Phytoplankton zooplankton, macrozoobenthos and fish were sampled, bi-weekly from April till September from three points in the ponds. Qualitative samples for phytoplankton were taken by puling a plankton net (22 µm mesh size) through the surface layer, fixed with 2% formalin solution and analyzed by using standard keys for identification (H u b e r –P e s t a l o z z i et al 1983; K o m a r e k and A n a g n o s t i d i s, 1998; K o m a r e k and A n a g n o s t i d i s, 2005; K r a m m e r and L a n g e – B e r t a l o t, 1986, 1988, 1991a, b). Quantitative sample were collected with a 1-liter bottle, preserved with 4% formalin solution and analyzed by Utermöhl method (1958) using a invert microscope Leica DMIL. Chlorophyll a was analyzed spectrophotometrically after water sample filtration and ethanol extraction according to ISO 10260:1992 (E). In this study chlorophyll was used as a measure of phytoplankton production. Sampling of phytoplankton started later in later in the season, from the second half of May (III sampling).

A qualitative and quantitative sampling of zooplankton was performed by using a plastic tube, 1 liter in volume (T o n o l l i, 1971; A P H A, 1998). After filtering through the plankton net, (mesh size of 76 μm), the sample was fixed with 4% formalin solution. Samples were analyzed using a binocular microscope Carl Zeiss (Jena) with maximal magnification of 160x. Zooplankton was identified to the level of species, variety, and form. Identification of zooplankton was conducted using appropriate keys (Š r a m e k-H r u š e k et al., 1962; D u s s a r t, 1969; K o s t e, 1978). The quantitative composition of zooplankton was determined by direct counting in the Sedgewick-Rafter cell. Every sample was examined using a subsampling technique, after which the number of identified species was recalculated for the whole sample of 1 liter. Estimation of biomass was done by using tables of average values for different zooplanktonic species (M o r d u h a i-B o l t i s k o i, 1954; U l o m s k i, 1958) multiplied by the number of individuals of each species.

Macrozoobenthos was sampled with the Eckman dredge modified for use on carp farms. The dredge has 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 placed in placed in plastic bottles and fixed with 96% alcohol in the field. The raw biomass of macroinvertebrates was measured with a Mettler analytical balance (AE 163) accuracy of 10^{-4}g.

Fish were sampled bi-weekly by pulling a net, with 50 fish captured and measured per pond. Body weight was measured using a digital balance CASBEE balance, Model MW 120**;** Casbee**,** Samsung, Korea, (accuracy 0.01g).

Statistical analysis of the results obtained in the experiment was carried out using statistical package STATISTICA v.6. All the results were statistically evaluated using ANOVA and LSD or by Kruskal-Wallis and Mann-Whitney U test depending on the coefficient of variation and the results of Levene's test for homogeneity of variances. Correlations between pairs of biotic and abiotic variable were quantified using Spearman correlation coefficient.

RESULTS AND DISCUSSION

Physical and chemical environmental factors

Between fish ponds no significant difference was recorded in relation to investigated physical and chemical environmental variables, except for transparency and electroconductivity. LSD test showed statistical difference between ponds L3 and D3, very significant for transparency (p=0.001) and significant for electroconductivity (p=0.042), and additionally for transparency between L2 and L3 (p=0.026). Water temperature was rather high throughout the investigation period being in the range from 15^{0}C up to 28.9 ^{0}C. Presence of organic loads was detected through raising values of $KMnO_4$, being over 30 mg/L from the beginning till the end of the season, with a short decrease during the first half of May (III and IV sampling). The rest of the measured environmental variables were in the acceptable range for carp production (B o y d, 1982).

Phytoplankton

High group and species diversity of phytoplankton was recorded in all three ponds. Around 90 species of phytoplankton belonging to groups Chlorophyta, Euglenophyta, Chrysophyta, Pyrrophyta, Xanthophyta, Bacillatiophyta and Cyanophyta, have been identified. Although composition varied in the ponds, qualitative analysis showed a similar general pattern of group domination in the investigated ponds. However, at the beginning of the season, Chlorophyta mostly dominated with Scenedesmus spp, Chlorella spp., *Closterium limneticum*, *Actinastrum hantzschii*, in all three ponds. Later during the season, the domination turned towards Cyanophyta with species *Planktolyngbya limnetica* and Bacillatiophyta with *Nitzschia acicularise.* This trend was especially evident in pond D3 with filamentous Cyanophyta *Planktolyngbya limnetica* increasing in number of cells per trichomes, from 20 at the beginning of their domination up to 50 and 70 late in the season. Additionally, in this pond an algal bloom consisting of *Anabena spiroides* was recorded during the second half of August, occurring only on the surface of the water, not being present in the water column. Such expansion of filamentous Cyanophyta in all three ponds were probably due to high grazing pressure on other groups of algae, rather high water temperature, mostly above 25^{0}C, and high levels of $KMnO_4$, indicating organic loads, throughout the investigation period. Being the most primitive of algae (having protective shields) they can easily adapt to environmental conditions unfavorable for most of the other phytoplankton groups and as weak competitors for nutrients can typically thrive under such conditions (S o m m e r, 1987). Chlorophyll a varied among ponds as well as within ponds during the investigation period (Fig.1). The highest phytoplankton production on average was in pond D3 (823.43 μm^3/L), then in L2 (731.81 μm^3/L) and the lowest was in L3 (621.24 μm^3/L). Correlation between the number of cells per liter (cell/L) and chlorophyll content (Ch) showed no significant difference, justified by Kruskal-Wallis ANOVA and Mann-Whitney U Test. A significant difference was recorded in the number of individuals per liter (ind/L) between pond L2 and L3 ($Z = 2.117$; $p= 0.034$). Concerning environmental variables a negative significant correlations occurred in ponds L3 and D3 between ind/L with phosphates ($r=-0.695$, $p=0.026$; $r=-0.757$, $p=0.011$) and very significant correlation between cel/L with phosphates ($r=-0.787$, $p=0.007$; $r=-0.925$, $p<0.000$) meaning that a high rate of phytoplankton production used up most of the available phosphate resources. Additionally, in ponds D3, between chlorophyll and $KMnO_4$ a very significant positive correlation ($r=0.770$, $p=0.009$) occurred justifying the above statement that of organic load can increase Cyanophyta expansion.

Zooplankton

Species diversity of zooplankton was very low throughout the season, ranging from 8 to 16, mostly Rotifers. The seasonal dynamics of zooplankton species was characterized by three distinctive aspects present in all investigated ponds: (1) domination of Rotifera *Brachionus angularis* in the fist half and *Keratella tropica* in the second half of study period, mostly in density, since they are small species; (2) Domination of Cladocera *Bosmina longirostis* and Copepoda Cyclops sp. (adult, and two larval instars) in density and biomass especially during first half of the investigation period; (3) three subsequent spring to summer peaks of zooplankton biomass in three fish ponds; end of May in ponds L2 (and L3), middle of June in pond D3 and end of June in pond L3 with absolute dominance of *B. longirostris* (Fig.1). Dynamics of *B. longispina* and Cyclops sp. mainly comprising the biomass of zooplankton show a similar trend at all three ponds. The maxima of *Bosmina* biomass occured during the third (L2) and fifth (L3) sampling having similar values, 320 and 350 mg/L, and much lower in D3, 60 mg/L (Fig.2). Domination of the small bodied Cladocera during the first part of the investigation period probably resulted in high grazing pressure on small edible algae (<30 µm), as were most of the Chlorophyta species (e.g. Chlorella sp., Scenedesmus sp.) recorded at that time. Consequently, this probably altered the phytoplankton community towards Cyanophyta proliferation. A total absence of *B. longirostris* as well as any other Cladocera occurred after the end of July, possibly as a result of nutrition depletion as well as invertebrate predation by cyclopoid copepods present in the ponds (C h a n g and H a n a z a t o, 2003). Biomass of Cyclops sp. was rather consistent but quite low throughout the investigation period, having a few small maxima in different periods. Overall, for the whole investigation period, the highest biomass of zooplankton on average was in pond L3 and the lowest in D3. Analysis of variance revealed no statistical differences in zooplankton biomass or density between ponds. A single (negative) correlation was significant, between zooplankton biomass and chlorophyll a in pond D3, using Spearman correlation coefficient ($r=-0.669$, $p=0.049$) suggesting that there was a considerable control of phytoplankton production on zooplankton in this pond (C r i s m a n and B e a v e r, 1990, H a v e n s et al., 2000). That can, as mentioned before, be connected with the fact that D3, more the other ponds, had a very distinctive domination of filamentous Cyanophyta, non-eatable for small zooplankton species, thereby limiting their food source. Nevertheless, occurrence of an algal bloom formed by *Anabena spiroides*, affected the overall environmental conditions (e.g. lowering the light penetration) in the pond, thus affecting zooplankton production.

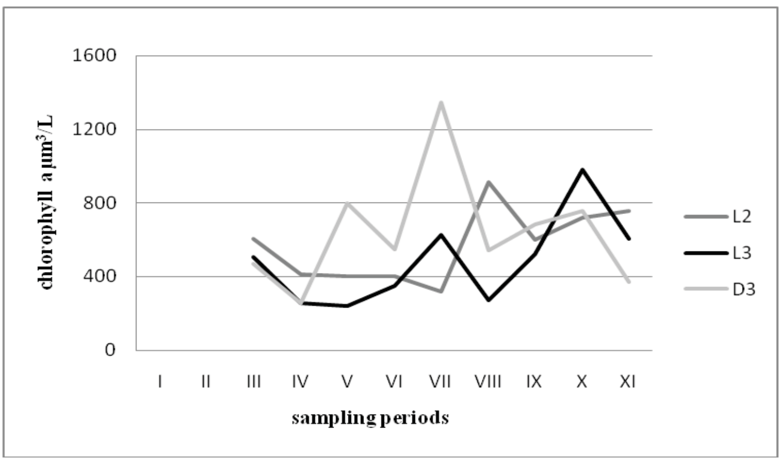

Figure 1. Dynamic of chlorophyll a during the investigation period in ponds.

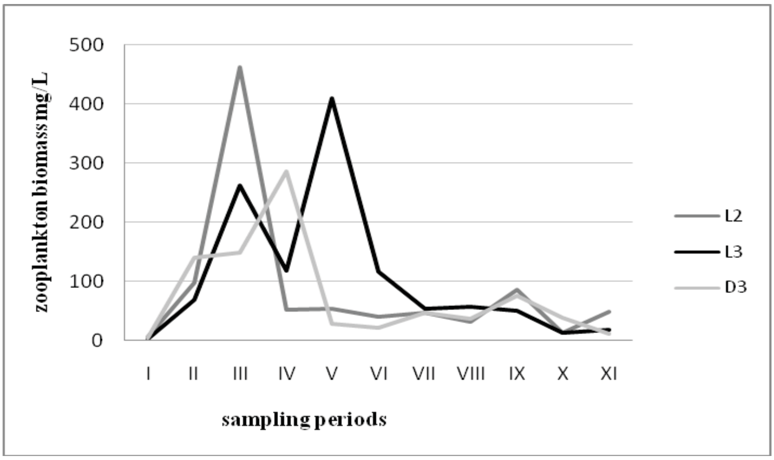

Figure 2. Dynamic of total biomass of zooplankton during the investigation period in ponds.

Macrozoobenthos

Macrozoobenthos was dominated in biomass and density by larvae Chironomidae in all three ponds. Except Chironomidae other groups (and species) were recorded during the investigation period as Mollusca, *Planorbarius corneus*, *Lymnaea peregra*, *Bithynia tentaculata* and Diptera species *Pericoma calilega*, Bezzia sp., *Chaoborus crystallinus*. The density of species was very low since it was the first year of fish culturing and the pond bottom was poorly inhabited by macrozoobenthos. The biomass was on average the highest in pond L2 and lower and relatively similar in-between in L3 and D3, but there was no statistically significant differences (F=2.206; p=0.128). Same as biomass, the highest abundance was recorded in pond L2 but there was no significant difference between ponds (Fig.3.). Between biomass of macrozoobenthos and environmental parameters, no significant correlations were recorded except for ponds L3 and dissolved oxygen justified by Spearman coefficient of correlation (r=-0.742, p=0.014).

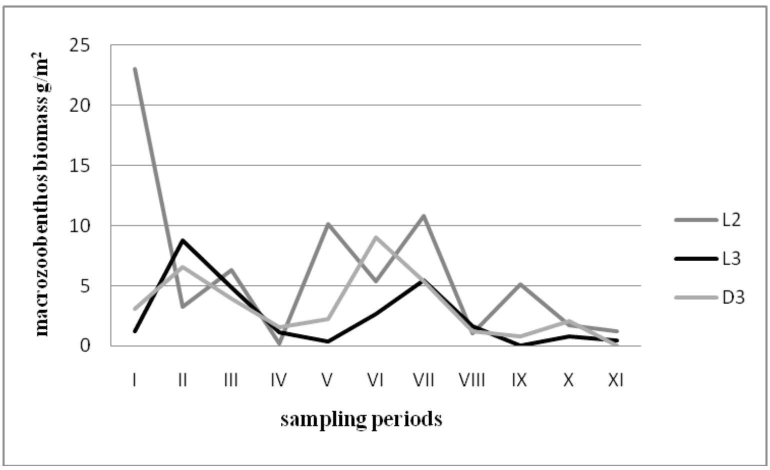

Figure 3 Dynamic of total biomass of macrozoobentos during the investigation period in ponds.

Fish

The highest average fish mass was obtained in pond L3, 726.40 g, the lowest in D3, 669.80g, and L2 in-between, 705.40g (Fig.4), but no statistical differences were recorded between ponds (Kruskal-Walis test: H=0.257; p=0.879). Apparently no significant correlations were obtained either between fish and zooplankton, fish and macrozoobenthos or between fish and supplementary feed, in any of the ponds, whatsoever.

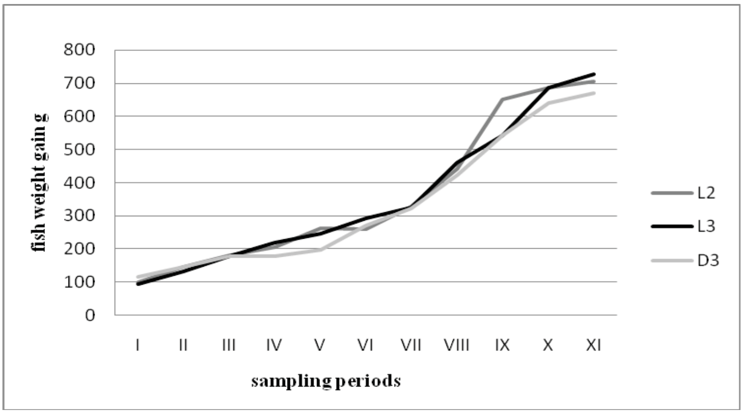

Figure 4. Dynamic of fish weight gain during the investigation period in ponds.

CONCLUSIONS

Values of physical and chemical environmental parameters were similar between ponds, with exclusion of electroconductivity and transparency.

Zooplankton was dominated only by one small bodied Cladocera *Bosmina longirostris*, dominating usually in ponds with planktivorous (and bottom feeding) fish. In the case of investigated ponds stocked with common carp yearling having low density (and biomass) of macrozoobenthos, probably the supplemental feed was the main source of nutrients for the fish. Nevertheless, the size structure of zooplankton in this study was also shaping the algal biomass primarily by grazing pressure. As a result, a high production of inedible algae occurred in ponds, probably not only as a result of low competition for nutrients with other algae, but also by favorable environmental conditions, as very high water temperatures and a vast amount of nutrients present in ponds.

Macrozoobenthos organisms were in the early phase of inhabiting the ponds substrata, thereby having low densities and biomass.

Knowing that three type of supplementary feed, were applied to ponds, the obtained results concerning fish are logical. However, in pond D3 fish were fed with row cereals (wheat, maize and barley) the lowest fish mass was obtained, the highest Cyanophyta domination and algal bloom occurred, as well as the lowest zooplankton biomass production. Pond L2 had extruded pellets as supplemental feed, presuming to be the best utilized by fish. During the first two months of the study period, a mistake concerning feed calculation for L2, resulted in a amount of uneaten feed in the pond, probably causing a lower weigh gain in fish. Consequently, pond L3 had the highest weight gain in fish and highest zooplankton production.

Finally, it can be concluded that aquatic communities are influenced by a complex of physical, chemical environmental factors as well as by strong interdependencies. In the present study a significant negative correlation between crustacean biomass and chlorophyll a in pond D3 suggests that there was a high control of phytoplankton production, mainly Cyanophyta, on zooplankton biomass, indicating a more prevailing bottom-up than top-down process.

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