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WATER QUALITY IN SEMI-INTENSIVE CARP PRODUCTION SYSTEM USING THREE DIFFERENT FEEDS

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Abstract

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In the era of growing demand for sustainable usage of water, all types of aquaculture systems are under reconsideration. Until recently semi-intensive production was concerned to be one of the least polluting. Nowadays, this fact has been reassessed especially in many countries culturing carp in this way. One of the most significant influences on a fish pond ecosystem in semi-intensive carp production is changing its characteristics by adding low quality supplemental feeding. Therefore, the type of fish feed, its physical and chemical characteristics can considerably change the water quality of a fish pond. Aiming to analyze the effect of commonly used feeds (cereals, pelleted and extruded feed) in semi-intensive production on the water quality, an experiment was carried out at three fish ponds during one production season. Even though the results of physical, chemical and biological parameters showed that there were no statistically significant differences in the water quality between fish ponds with different supplemental feed, looking at the overall picture it could be concluded that the pond that had the lowest quality of feed (row cereals), having high organic mater and chlorophyll *a* during most of the trial period as well as the specific phytoplankton successions including potentially harmful blue-green alga, had consequently the lowest water quality.

Key words: carp, semi-intensive system, feed, water quality
Abbreviations: dH - Water hardness; ISO - International Organization for Standardization; S - Saprobity idex; h - Absolute abundance of individual taxa; s - Individual taxa saprobic value

Introduction

In the view of the worldwide increasing demands on sustainable usage of primary resources, such as land and water, and the necessity of applying sustainable aquaculture practices, there is an urgent need to improve semi-intensive farming systems, especially in the area concerning nutrition of omnivorous fish within such systems. In semi-intensive pond-based farming systems the dietary nutrient requirements of the cultured species is largely met through the consumption of natural food organisms produced endogenously

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within the pond and through the direct consumption of exogenously supplied “supplementary” feed inputs (Tacon and De Silva, 1997).

Semi-intensive system is the main type of fish culturing in Serbia. Until recently, the typical form of semi-intensive system was practiced in Serbia. It is based on natural food (zooplankton and macrozoobenthos) as the main source of protein component while energy requirements are fulfilled by carbohydrates from row cereals (wheat, barley, corn etc.) as supplementary feed (Markovic and Mitrovic-Tutundzic, 2003). Supplementary feed usually consists of cheap and locally available raw ingredients (Ghosh et al., 1984).

Improvement of semi-intensive system is provided by better quality supplemental feed. In nowadays there is a big array of ingredients that can be used as feedstuffs as, sunflower seed cake, maize bran, cottonseed cake, soy been, and other plants as well as different quality fish meal depending on the part of fish used. Fish feeds prepared with plant protein typically are low in methionine; therefore, extra methionine is always added to plant based diets in order to promote optimal growth and health. Total protein content in cereals grains is different depending on the plant species ranging between 7 and 15% (Przybyl, and Mazurkiewicz, 2004). These proteins are poor in essential amino acids for fish and have antinutritional agents – chemical compounds naturally occurring in grains which can disturb the regular metabolism in fish. Use of good quality pelleted and especially extruded feed, has proven to be less expensive, can minimize water pollution and spread of diseases owing it to high digestibility, low conversion rate - better fish growth, less organic waste per kg of fish produced (Cho et al., 2006).

In order to analyze the water quality in carp ponds beside physical and chemical analysis of water phyto- and zooplankton organisms can be used as bioindicators (Dulic et al, 2006, 2009a). Using biological methods of water assessment are a very useful tool since they can reflect overall ecological quality, integrate variations in the environment and indicate biologically available nutrients which chemical analysis cannot measure (Lyngby, 1990; Gol’d et al., 2003). Zooplankton are small and rapidly reproducing organisms that respond quickly to environmental changes and may be effective indicators of subtle alterations in water quality (Attayde and Bozelli, 1998; Hakkari, 1972; Pontin and Langley, 1993; Zakaria et al., 2007). Phytoplankton organisms are also very valuable indicators of water quality (Wu, 1984; Webber and Webber, 1998) that are integrated extensively into water quality monitoring programs worldwide. They are highly responsive to nutrient loadings due to rapid reproduction and short life cycles. Since they are at the bottom of the food chain, algal responses are mostly attributed to physical and chemical changes (US EPA, 1990). By integrating the effects of anthropogenic and natural influences, the additional information provided by bioindicators gives a more refined measure of water quality that does chemical sampling alone (Keeler and McLemore, 1996).

The aim of this paper is determination of differences between experimental carp ponds regarding physical, chemical and biological parameters of water quality.

Material and Methods

The experiment was conducted in three earthen fish ponds, each with surface area of 900 m^2 and average depth of 1 m, located at Experimental estate „Radmilovac“, Center for Fishery and Applied Hydrobiology, Faculty of Agriculture, University of Belgrade, in period from mid May till the beginning of September. In order to have identical conditions, all weeds from ponds bottom and the internal sides of the embankments were removed before the start of the experiment. Water supply for the ponds was from various sources: reservoir pond, a small nearby stream Sugavac, two small accumulations (open wells) and deep tube-well. During the hottest months occasional water depletion occurred causing a rather variable water level in the ponds, ranging from 0.4 and 1.2 m. Ponds have been stocked with 400 carp yearling per pond, with average weight of 100 grams.

Commercial extruded and pelleted fish feed, both with 25 % proteins and 7% fat, were given to fish in pond No. 1 and 2. In the third pond (3) combination of wheat, corn, and barley grains in equal ratio (1:1:1) was applied. Fish were fed daily by hand, around noon using the standard feed percentage of 3% per kilogram of ichthyomass.

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 "Dr Milan Jovanovic Batut" (according to APHA, 1998) and seven (temperature, oxygen and oxygen saturation, electrical conductivity, ammonia nitrogen, pH and transparency) were measured daily, around noon, using a water field kit, MULTI 340i/SET (WTW, Germany). Chlorophyll *a* was analyzed spectrophotometrically after water sample filtration and ethanol extraction according to ISO 10260:1992 (E).

Samples for phyto- and zooplankton qualitative and quantitative analysis were collected at 15 days interval. For qualitative analysis phytoplankton net of 22 μm was used and samples were fixed in 2 % formaldehyde. Phytoplankton was identified up to the species level by using standard keys for identification (Huber –Pestalozzi et al., 1983; Krammer and Lange – Bertalot, 1986, 1988, 1991a, b; Komarek and Anagnostidis, 1998; Komarek and Anagnostidis, 2005). Samples for quantitative analysis were collected using 1 L hydrological bottle and preserved in plastic bottles by 4 % formaldehyde. Phytoplankton counting was analyzed by method of Utermöhl (1958) using an invert microscope Leica DMIL. Zooplankton was sampled with a plastic tube, 1 liter in volume that is a usually procedure for shallow lakes (Tonolli, 1971, APHA, 1998). After filtering through the plankton net, (76 μm mesh), the sample was fixed with 4% formalin solution. Zooplankton was identified in most cases up to the species level using appropriate keys (Sramek-Hrusek et al., 1962, Dussart, 1969; Koste, 1978). Samples were analyzed using a binocular microscope Carl Zeiss (Jena) with maximal magnification of 160x. The quantitative composition of zooplankton was determined by direct counting in the Sedgewick-Rafter cell.

Saprobiological analysis was applied by using Pantle-Buck method (Pantle and Buck 1955) based on qualitative composition and absolute abundance of phytoplankton and zooplankton (Rotifera, Cladocera and Copepoda) summarized. Saprobity values were used from the list of indicator species given by Wegl (Wegl, 1983). There saprobity index values for saprobity levels are: for oligosaprobity 0.51 - 1.50, β mesosaprobity, 0.51 - 2.50, α mesosaprobity 2.51 - 3.50 and for polysaprobity 3.51 - 4.50 (Pantle Buck, 1955).

h – absolute abundance of individual taxa;

$$S = \frac{\sum h \cdot s}{\sum h}$$

s – individual taxa saprobic value.

Water quality parameters were analyzed by descriptive and analytical statistics. Statistical differences in mean values of water parameters between ponds were analyzed, according to the results of Levene's test, with parametric or nonparametric tests: ANOVA and LSD test or Kruskal-Wallis test and Mann-Whitney U test. Two-factor analysis of variance with one repeating and correlation analysis have been applied.

All statistical analyzes were conducted with the aid of statistical package Statistica 6.0.

Results and Discussion

Average values and variability of physical and chemical parameters and chlorophyll *a* in all experimental ponds over the 18 weeks growing of carp yearlings are presented in Tables 1 and 2. Some of the water quality parameters significant for carp culture in semi-intensive ponds were within their optimal ranges for carp rearing (Boyd, 1982.). However, high values of water temperature (>32°C) and very low values of dissolved oxygen (< 2 mg/l) were occasionally recorded in all ponds (Tables 1 and 2). pH values in three ponds were higher than recommended for fish culturing (>8.5) probably due to intensive photosynthetic activity of phytoplankton, that can raise water pH (Svobodova et al., 1993) since measurements

Table 1
Results of descriptive statistics for physical and chemical parameters and chlorophyll a in ponds 1 and 2 during the 18 weeks of experiment

Parameters	Pond 1			Pond 2		
	Average	i_v	c_v	Average	i_v	c_v
Temperature, °C	26.410	17.30-33.20	11.542	26.720	17.30-33.30	11.591
Transparency, m	0.142	0.017-0.215	21.439	0.165	0.097-0.270	20.816
Electrical conductivity, µS/cm	981.435	728-1113	7.795	1056.650	911-1180	7.068
Dissolved oxygen, mg/l	8.250	1.74-23.70	48.990	9.774	1.90-20.30	46.927
pH	9.569	7.86-10.96	6.748	9.547	7.75-10.9	6.348
Nitrate, mg/l	3.40	0.003-6.20	83.870	3.90	0.001-5.60	74.773
$KMnO_4$ oxidation, mg/l	84.00	7.00-118.00	58.763	74.00	4.20-102.00	64.722
Total hardness, dH	20.733	17.80-27.00	13.040	22.956	15.60-29.00	16.134
Phosphates, mg/l	0.028	0.003-0.170	139.025	0.044	0.002-0.309	137.597
Total phosphorus, mg/l	0.370	0.220-0.770	44.207	0.320	0.019-0.590	58.210
Calcium, mg/l	58.444	38.00-72.00	19.208	63.00	43.00-78.00	16.090
Ammonia nitrogen, mg/l N	0.119	0.02-0.22	63.351	0.194	0.02-0.540	87.304
Total nitrogen, mg/l	3.375	1.500-5.01	40.891	3.230	1.100-4.840	44.148
Chlorophyll a, µg/l	504.650	317.9-957.3	35.935	427.805	239.7-979.8	45.711

have been performed at noon, during intensive sunlight. Transparency was slightly bellow minimal values (<0.2m) for carp rearing (Markovic and Mitrovic-Tutundzic, 2000). Phosphates concentrations were very low (>0.1 mg/l) throughout the investigation period in all three ponds, even though high productivity of phytoplankton indicated by chlorophyll *a* was recorded. A high rate of phytoplankton production caused the used up of most of the available phosphate resources that was justified by a negative correlation between the number of individuals per liter of phytoplankton and phosphates published in an earlier paper of Dulic et al. (2009a). Amount of organic matter detected by $KMnO_4$ oxidation was very high (>80 mg/l), from the end of June till the end of the investigation period, especially in pond 3 that had the lowest quality of fish feed – row cereals, probably caused by the accumulation of the feed in the water deteriorating it's quality (Ghosh et al., 1984).

No statistical differences between ponds were found comparing average values of, phosphates (H=0.787, p=0.675), total phosphates (H=0.604, p=0.740), nitrate (F=1.068, p=0.586), total hardness (H=2.956, p=0.228), total nitrogen (H=0.012, p=0.994), ammonia nitrogen (F=1.005, p>0.05), $KMnO_4$ oxidation (H=0.597, p=0.742), calcium (H=2.482, p=0.994) and chlorophyll *a* (F=1.426, p<0.05) during the whole investigation period. Statistical differences between ponds have been found for dissolved oxygen and oxygen saturation (H=5.425, p=0.066; H=5.336, p=0.069), transparency (Z=23.366, p=0.000) and electrical conductivity (F=47.623, p=0.000). The results of Mann-Whitney U Test showed that there was a significant difference in the average values of oxygen concentration and oxygen saturation between pond 1 and 3 (Z=-2.309, p=0.021; Z=-2.297, p=0.022). LSD test showed that average values for transparency and electrical conductivity for pond with cereals was very significantly different (P<0.01) compared to ponds 2 and signifi-

Table 2
Results of descriptive statistics for physical and chemical parameters and chlorophyll a in pond 3 during the 18 weeks of experiment

Parameters	Pond 3		
	Average	i_v	c_v
Temperature, °C	26.862	16.90- 34.60	12.558
Transparency, m	0.134	0-0.225	25.456
Electrical conductivity, µS/cm	959.930	775-1157	8.717
Dissolved oxygen, mg/l	10.080	1.74-23.50	49.712
pH	9.566	7.32-12.45	7.073
Nitrate, mg/l	3.80	0.001-7.70	58.949
$KMnO_4$ oxidation, mg/l	82.00	5.10-169.00	70.618
Total hardness, dH	21.222	15.10-26.00	19.955
Phosphate, mg/l	0.032	0.002-0.140	123.071
Total phosphorus, mg/l	0.390	0.019-0.97	61.919
Calcium, mg/l	51.00	36.00-107.00	39.448
Ammonia nitrogen, mg/l N	0.080	0.001-0.350	85.833
Total nitrogen, mg/l	3.165	2.120-5.760	36.435
Chlorophyll *a*, µg/l	504.650	254.0-1346.5	52.104

cantly different (P<0.05) from pond 3 concerning transparency. Moreover, there was a statistically very significant difference between pond 2 and 3 concerning transparency and electrical conductivity. Even though there was no difference in ammonia nitrogen concentration between ponds (F=1.005, p>0.05), factor time had a statistically significant effect on the concentration of ammonia nitrogen (F=11.986, p<0.01). In the II sampling period concentration of ammonia nitrogen was very significantly higher (p<0.01) than during the rest of the sampling periods. During the V period, the ammonia concentration was the lowest and very statistically different from the rest of the periods (p<0.01), except from period VIII, and significantly different from period VII (p<0.05). Concentration of ammonia nitrogen in the VII period was significantly lower than in the VI period. During the VIII sampling period, ammonia nitrogen concentration was significantly lower the in the III period a very statistically significantly lower than in the IV and VI period. However, the concentration of ammonia nitrogen was under the critical values for carp rearing during the whole investigation period.

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. A total of 39 indicator taxa were identified represented mainly by green algae, euglenoids and diatoms, and in some cases by blue-green algae. The lowest number of identified indicator taxa was in pond 2, 28, while ponds 1 and 3 had the same number, 33, mostly dominated by Chlorophyta.

Zooplankton was represented by a lower number of taxa identified during the investigation period in all three ponds, compared to phytoplankton. The lowest number of identified taxa was in pond 3, 25 taxa, possibly indicating a lower water quality (Goel, 2006). Pond 1 and 2 had 28 identified taxa, with the domination of Rotatoria as the most frequent group of zooplankton in all three ponds.

Note: for homogenous values (c_v <30%) mean is used as the average and for inhomogeneous values (c_v >30%) median is used

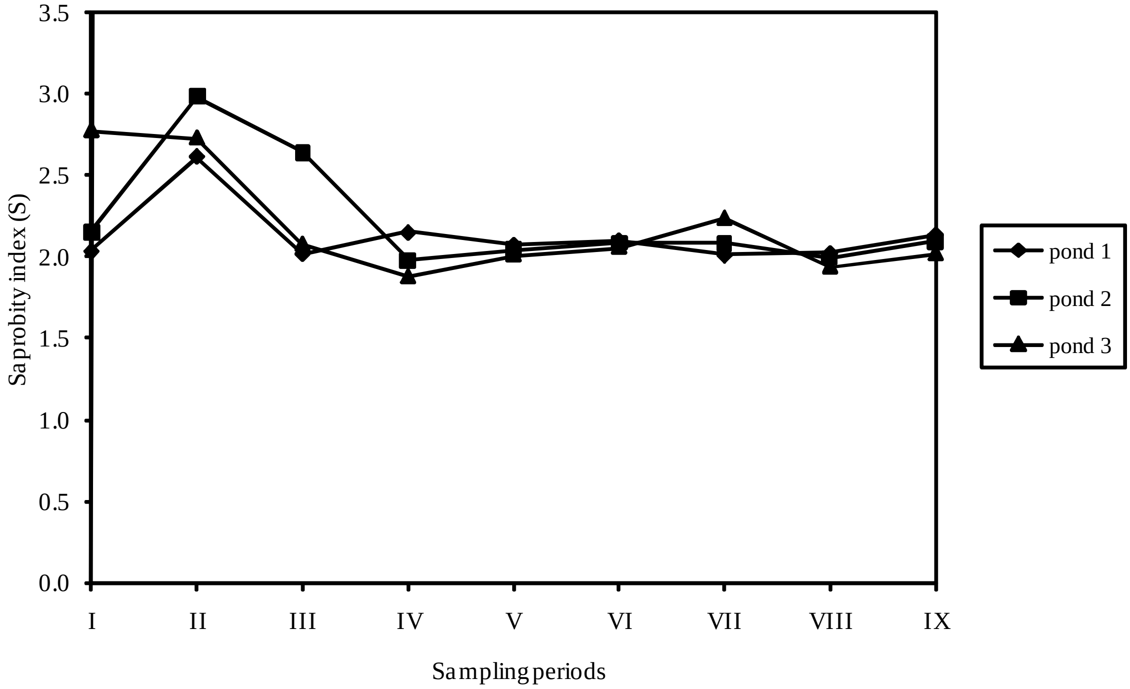

Fig. 1. Variations in saprobity index S in three ponds during the research period

The values of saprobe index *S*, calculated from the individual absolute abundances of identified algal and zooplankton taxa and their saprobe values, from the list given by Wegl (1983), ranged from 2.01 to 2.61 in pond 1, 1.98 to 2.98 and 1.88 to 2.77 in pond 2 and 3, respectively. However, there was no statistically significant differences between ponds concerning this parameter (F= 0.376, p=0.691). Saprobe indices for the whole investigated period showed that water quality of ponds has been â mesosaprobic and occasionally á mesosaprobic especially in the beginning (sampling periods II and III) of the experiment (Figure 1). One of the reasons for rather high saprobe index in all experimental ponds was a massive development of á mesosaprobic green algae *Chlorella vulgaris*, having up to 48 million individuals per litre. The high production of this alga was probably due to high water temperatures that was prominent in all three pond (Tables 1 and 2), since their optimal growth is on temperatures over 30^{o}C (Mayo, 1997) and they are common in organically enriched waters (Tripanthi and Pandey, 2009). However, no oxygen depletion was recorded during these periods of higher saprobe in ponds, indicating that this green alga has probably been efficiently used by zooplankton grazers (Nandini et al., 2003).

The high abundance of *Chlorella vulgaris* was also the reason for higher saprobe index value in pond 3 at mid of August (sampling period VII) (Figure 1). Moreover, in this pond, at the same time, in August an algal bloom occurred, produced by a potentially harmful Cyanophyta, *Anabena spiroides*. This alga belongs to one of the main toxin producing Cyanophyta genera in freshwaters (Chorus and Bartram, 1999) that often forms extensive and persistent blooms in freshwater aquaculture ponds (Paerl and Tucker, 1995). Another blue-green algae *Planktolyngbya limnetica*, was also abundant, progressively increasing the number of cells per trichomes, from 20 up to 50 and 70 late in the season mostly affecting the abundance of zooplankton, since they are inedible for them (Geller and Muller, 1981). Consequently, this pond also had the highest amount of chlorophyll *a* on average and as referred by Webber et al. (2005) ponds with higher chlorophyll *a* also tended to have higher frequency of occurrence of potentially harmful phytoplankton species. A â mesosaprobic species *Bosmina longirostis* was the dominant zooplankter in all three ponds, during the II, III and IV sampling periods. High abundance (and biomass) of this Cladoceran was following the high phytoplankton production, with a time lag of 2 weeks according to an earlier paper by Dulic et al. (2009a). However, a total shift in the domination of species happened during the second half of the investigation period, when Rotifer *Keratella tropica* also a â mesosaprobic species was very abundant.

Conclusions

Results of water quality monitoring in three different semi-intensive carp ponds showed that the some of the water quality parameters important for carp rearing (nitrates, total hardness, calcium concentration, ammonia nitrogen and electrical conductivity) were within their recommended optimal ranges. Occasionally temperature, dissolved oxygen, pH and transparency had undesirable values that affected the overall environmental conditions in ponds. During most of the experimental period organic mater ($KMnO_4$ oxidation) and chlorophyll *a* were out of the optimal range, especially in pond 3, deteriorating the water quality. Phosphates concentration was very low throughout the investigation period, in all three ponds, but it seams that it was readily absorbed by phytoplankton that had a high production throughout the experimental period. No statistical differences between ponds were found comparing average values of measured parameters during whole investigation period except for transparency, dissolved oxygen, electrical conductivity and chlorophyll a. However, there were some differences in suboptimal values of temperature, dissolved oxygen, pH and transparency and time of their duration between experimental ponds that probably affected fish culturing in a different subtle ways.

Saprobe indices showed that water quality in all ponds was mostly â-mesosaprobic (moderately polluted with organic compounds) which is optimal saprobe level for semi-intensive carp production. á mesosaprobity that was recorded at the beginning of the experiment, was mostly due to the domination of a Chlorophyta, *Chlorella vulgaris*, with a high saprobe value of 3.1. Favourable environmental conditions, as very high water temperatures and medium to high organic load had the biggest role in inducing the domination of this alga. Apparently high algal biomass, indicates through chlorophyll *a*, in most investigation periods, didn't affect the oxygen regime of the ponds. In pond 3, except a domination of *Chlorella vulgaris*, at the beginning and the end of the investigation, an algal bloom of a potentially harmful blue-green alga *Anabena spiroides* occurred. Bloom-forming Cyanophyta are undesirable in aquaculture ponds because they are in most cases inedible for smaller Cladocera as *Bosmina longirostris*, that is significant for the present case, they are poor oxygenators of the water and have undesirable growth habits, some strains produce metabolites that are odorous that can affect the flavour of cultured animal and some species may produce compounds that are toxic to aquatic animals. Basically it could be concluded that pond 3 that had the lowest quality of feed, row cereals, had consequently the lowest water quality, looking at the overall picture of phytoplankton successions even though there was no statistically significant differences among ponds, concerning the saprobe index and chlorophyll *a*.

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References

Attayde, J. L. and R. L. Bozelli, 1998. Assessing the indicator properties of zooplankton assemblage to disturbance gradients by canonical correspondence analysis. *Can. J. Fish. Aquat. Sci.*, **55**: 1789–97.

Blazencic, J., 2000. Sistematika algi. *Naucna knjiga*, Beograd, 297 pp. (Sr).

Bogut, I., L. Horváth, Z. Adamek and I. Katavic, 2006. *Ribogojstvo*. Poljoprivredni fakultet u Osijeku, Osijek, 523 pp.

Bogut, I., D. Novoselic, and J. Pavlicevic, 2006a. *Biologija riba*. Poljoprivredni fakultet u Osijeku, Osijek, 620 pp.

Boyd, C. E., 1982. Water Quality Management of Pond Fish Culture. *Developments in Aquaculture and Fishery Science*, 9. *Elsevier,* Amsterdam, 318 pp.

Cho, S. H., S-M. Lee, B. H. Park and S-M. Lee, 2006. Effect of feeding ratio on growth and body composition of juvenile olive flounder *Paralichthys olivaceus* fed extruded pellets during the summer season. *Aquaculture,* **251**: 78– 84.

Chorus I. and J. Bartram, 1999. Toxic Cyanobacteria in Water. *E and FN Spon*, London. 416 pp.

De Silva, S. S. and B. F. Davy, 1992. Fish Nutrition Research for Semi-Intensive Culture Systems in Asia. *Asian Fisheries Science*, **5**: 129-144.

Dulic, Z., V. Mitrovic-Tutundzic, Z. Markovic and I. Zivic, 2006. Monitoring water quality using zooplankton organisms as bioindicators at the Dubica fish farm, Serbia. *Arch. Biol. Sci.,* **58**: 245-248.

Dulic, Z., V. Poleksic, B. Raskovic, N. Lakic, Z. Markovic, I. Zivic and M. Stankovic, 2009a. Assessment of the water quality of aquatic resources using biological methods. *Desalination and Water Treatment*, **11**: 264 – 274.

Dulic, Z., I. Zivic, G. Subakov –Simic, N. Lakic and M. Ciric, 2009b. Seasonal dynamics of primary and secondary production in carp ponds In: Z. Markovic (Editor), *IV International Conference "Fishery", 2009*. Faculty of Agriculture, University of Belgrade, pp. 161 – 169.

Geller, W. and H. Müller, 1981. The filtration apparatus of Cladocera: filter mesh-sizes and their implications on food selectivity. *Oecologia*, **49**: 316–321.

Goel, P. K., 2006. Water Pollution: causes, effects and control. *New Age International Publishers Ltd*, New Delhi, 432 pp.

Gol'd, Z. G., L. A. Glushchenko, I. I. Morozova, S. P. Shulepina and I. A. Shadrin, 2003. Water Quality Assessment Based on Chemical and Biological Characteristics: An Example of Classification of Characteristics for the Cheremushnyi Creek-Yenisey River Water System. *Water Resources*, **30**: 304-314.

Ghosh, S. K., B. K. Mandal and D. N. Borthakur, 1984. Effects of feeding rats on production of common carp and water quality in paddy-cum-fish culture. *Aquaculture,* **40**: 97– 101.

Hakkari, L., 1972. Zooplankton species as indicators of environment. *Aqua. Fennica*, **P**: 46–54.

ISO 10262 Water Quality, 1992. Measurement of biochemical parameters- Spectrometric determination of the chlorophyll a concentration.

Keeler, A. G. and D. McLemore, 1996. The value of incorporating bioindicators in economic approaches to water quality control. *Ecological Economics,* **19:** 237 - 245.

Krammer, K. and H. Lange–Bertalot, 1986. Bacillariophyceae. 1. Teil: Naviculaceae. In: Süâwasserflora von Mitteleuropa (Ettl, H., Gerloff, J., Heynig, H. & Mollenhauer, D., Eds.). Band 2/1. VEB Gustav Fischer Verlag. Jena. 876 pp.

Krammer, K. and H. Lange–Bertalot, 1988. Bacillariophyceae. 2. Teil: Bacillariaceae, Epithemiaceae, Surirellaceae. U: Süâwasserflora von Mitteleuropa (Ettl, H., Gerloff, J., Heynig, H. & Mollenhauer, D., Eds.). Band 2/2. VEB Gustav Fischer Verlag. Stuttgard-New York. 596 pp.

Krammer, K. and H. Lange-Bertalot, 1991. Bacillariophyceae. 3. Teil: Centrale, Fragialiraceae, Eunotiaceae, Achnanthaceae. U: Süß wasser von Mitteleuropa (Ettl, H. et al., Eds.) Band 2/1. VEB Gustav Fischer Verlag. Jena. 576 pp.

Komarek, J., and K. Anagnostidis, 1998.

Cyanoprokariota. 1. Teil: Chroococcales. Spektrum. *Akademischer Verlag. Heidelberg*. Berlin. 548 pp.

Komarek, J., and K. Anagnostidis, 2005. Cyanoprokaryota 2. Teil: Oscillatoriales. U: Süâwasserflora von Mitteleuropa (Budel, B., Gartner, G., Krienitz, L., Schagerl, M., Eds.) Spektrum Akademischer Verlag, 759pp.

Lyngby, J. E., 1990. Monitoring of nutrients availablility and limitation using the marine macroalge Ceramium rubrum (Huds). *C. Ag. Aquat. Bot.*, **38:** 153 – 161.

Markovic, Z. and V. Mitrovic-Tutundzic, 2003. Gajenje riba. Zaduzbina Andrejevic. Beograd, p. 138.

Mayo, A. W., 1997. Effects of temperature and pH on the kinetic growth of unialga *Chlorella vulgaris* cultures containing bacteria. *Water Environment Research,* **69**: 64-72.

Nandini, S. and S. S. S. Sarma, 2003. Population growth of some genera of cladocerans (Cladocera) in relation to algal food (*Chlorella vulgaris*) levels. *Hydrobiologia*, **491**: 211–219.

Pantle, R. and H. Buck, 1955. Die biologishe Uberwachung der Gewasser und die Darstellung der Ergebnisse, Gas und Waserfach 96, 604pp.

Paerl, H. W. and C. S. Tucker, 1995. Ecology of Blue-Green Algae in Aquaculture Ponds. *Journal of the World Aquaculture Society,* **26***:* 109 – 131.

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

Pontin R. M. and J. M. Langley, 1993. The use of rotifer communities to provide a preliminary national classification of small water bodies in England. *Hydrobiology*, **255/256**: 411–9.

Svobodova, Z., R. Lloyd, J. Machova and B. Vykusova, 1993. Water quality and fish health. EIFAC Technical Paper. No. 54. Rome, FAO. 59 pp.

Tacon, A. G. J. and S. S., De Silva, 1997. Feed preparation and feed management strategies within semi-intensive fish farming systems in the tropics. *Aquaculture,* **151** (1-4): 379-404.

U. S. Environmental Protection Agency, Office of Water, 1990. Biological Criteria, National Program Guidance for Surface Waters, EPA – 440/5-90-004, Washington, DC.

Webber, D. F. and M. K. Webber, 1998. The water quality of Kingston Harbour: evaluating the use of the planktonic community and traditional water quality indices. *Chemistry and Ecology***, 14**: 357–374.

Webber, M., E. Edwards-Myers, C. Campbell and D. Webber, 2005. Phytoplankton and zooplankton as indicators of water quality in Discovery Bay, Jamaica. *Hydrobiologia,* **545**: 177–193.

Wegl, R., 1983. Index furs die Limnosaprobitat. Wasser und Abwasser. Aus Beitrage zur Gewasserforschung XIII, Bd. 26, Wien-KaisermA° hlen, 175 pp.

Wu, J - T., 1984. Phytoplankton as bioindicator for water quality in Taipei. *Bot. Bull. Acad. Sin.*, **25**: 205-214.

Utermohl, H., 1958. Zur vervolkmmung der quantitativen phytoplankton methodik. *Mitt. int. Ver. Limnol.*, **9:** 1-38.

Zakaria, H. Y., M. H. Ahemed and R. Flower, 2007. Environmental assessment of spatial distribution of zooplankton community in Lake Manzalah Egypt. *Acta Adriat.*, **48**: 161–72.