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THE INFLUENCE INTENZITY OF EUTROPHICATION ON FISHPOND YIELD

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Abstract

BRABEC, T., STRAKOVÁ, L., KOPP, R., VÍTEK, T., ŠŤASTNÝ, J., SPURNÝ, P., MAREŠ, J.: *The influence intenzity of eutrophication on fishpond yield.* Acta univ. agric. et silvic. Mendel. Brun., 2011, LIX, No. 6, pp. 53–62

Fish ponds have been always built for purpose of fish farming and some additional functions. We evaluated fish farming operation (in years 1990–2007) on the Sykovec and Medlov pond in altitude 700 meters above sea level and Jaroslavický dolní pond in altitude 200 m. The samples for hydrochemical and hydrobiological analyses were taken regularly at monthly intervals in 2008. We chose some parameters as a total nitrogen (N_T), total phosphor (P_T), chlorophyll-a and chemical oxygen demand (COD) and structure of phytoplankton which has an impact on fish production. We compared our result with former research work from 1996–1997. Higher levels of monitored parameters have got a negative effect on spectrum of fish kind in managed fishponds.

fish pond, fisherymanagenent, cyanobacteria, eutrophication

Today we have got more than 24 thousands of fish ponds and reservoirs in this country. All together it is 52,000 hectares of the man made water area and most of that we use for fish farming. Average production of Czech fish ponds was 467.7 kg fish per hectare in 2008 and total yield amount to 20,395 tons of market fish whereas carp has been 85.8% of total volume (MZe: 2009).

ŠUSTA (1898) has observed that production in some new or recently recovered ponds is higher and lowering due to depletion of nutrients from pond bottom. This aging process occurred in ponds established between 14–16th century. Average fish production in 1850 has been 30kg.ha^{-1}.

Basically these ponds performed more function as a fire reserve, flood protection or just a water source (PŘIKRYL, 2010). Since the beginning ponds were built for purpose of fish farming and their maintenance is integral part of it. Basically major part of Czech ponds has been oligotrophic or mesotrophic till the end of the 19th century. Fish farming were exclusively based upon nature produce potential and as a result of that ponds were aging and run out nutrients (PECHAR, POTUŽÁK, 2006). We observed that durable impact of abnormal nutrients inflow (N and P) cause expansion of the algae biomass as well as fish production. Obvious increase of the fish production came at thirties during the 20th century (that was 50kg.ha^{-1}) due to lime treatment and application of the mineral fertiliser, especially superphosphate. Another increase of the production is coming with applications of the organic fertiliser from farms, supplementary feeding by cereals and other mixtures in 1960s–1980s. Huge reserves of the phosphor set in sediment due to fish-cum-duck culture. Average fish production became stable (500–600 kg.ha^{-1}) in 1980s (PECHAR *et al.*, 2009; PŘIKRYL, 2010). All these new breeding models plus nutrients from drainage area had an important impact on structure and dynamic of the nature ecosystem. High fish stock along with high nutrients level especially organic fertiliser cause hypertrophy. Main symptoms of higher eutrophication are massive algae biomass development, fluctuation of the oxygen concentration and excess of organic material which is unbalancing fish ponds environment (PECHAR, 2002). Fish ponds are hypertrophic due to their function of the final sedimentation in the region. Nutrients from rivers cumulate and transform by primary production to littoral vegetation and by secondary production to increase in fish biomass, suggest that there is relation between water quality and fish growth (HARTMAN, 2010). Reduction or elimination of the fishery management doesn't mean better quality of the water (PŘIKRYL, 2010).

Management of the fish ponds follow categorization according to notice of Department of Agriculture (1988), which provide intensity of the fish farming. Relevant state agency grant a permission to a fish farm as directed the department. Basically is concerned about delivering of the biogenous elements and their ratio. With reference to intensive fish farming the most important element is phosphor.

Generally we can find four different groups of phosphor sources: reservoirs (especially sediment), point sources (sewage or waste water treatment), small villages or farms without stream flow-diffused spots or surface source as an erosion and atmospheric deposition. At this time are most important point sources, but eventually we can expect dominancy of surface sources (FIALA, ROSENDORF, 2009).

In addition, point sources emitting around 80–90% of dissolved phosphor, which is easily accessible for phytoplankton (REYNOLDS, DAVIES, 2001).

The biggest surface source in Europe is an agriculture (mould, grassland, meadows) which impact is even bigger than atmospheric deposition (KOPÁČEK *et al.*, 1997). We can not leave out of consideration that the scrap from animal husbandry within the range by presence (POKORNÝ, 2010).

HEJZLAR *et al.* (2008) mentioned as a main source of phosphor in drainage area of the Mostiště reservoir just a point sources from municipal sewage and as a source of nitrogen is believed to be soiltransport.

Fish farmers know that phosphor fixed in sediment is coming through primary production and causes organic revival and stress by water blooms, which can finally affect survival of the fish stock. They are not using phosphor on purpose for last 40 years at all (HARTMAN, 2010).

Definition "Fish production" means different weight of fish at the beginning and at the end of the year, usually in $kg.ha^{-1}$. Total fish production is divided into natural production alias natural growth increment, which depends on availability and use of natural food against supplementary feeding production occurs from feeding. The natural production is composite of primary and secondary production of the pond and in Czech conditions is about 230–250 $kg.ha^{-1}$ per year. Extremely nutrient poor fishponds contain just a few $kg.ha^{-1}$ and on the other side some ponds have almost 1 $t.ha^{-1}$ (SPURNÝ *et al.*, 2008). Fish production in ponds depends upon natural productivity that has been influenced by abiotic and biotic factors. Primary production is correlated with fish productivity because primary producers are used directly by fish, indirectly via zooplankton or as a substrate for heterotrophic bacterial production (BÍRÓ, 1995). The most important biotic factors are fish stock, amount of available feed and rate of C, N, P which directly affect quantity of the natural food in the pond. Limiting abiotic factors are levels of acid neutralizing liquid, pH, dissolved oxygen related to water temperature, duration of the growing season as well as changes in legislative (JANEČEK, 1976).

The main aim this study is to control fishery management and anthropogenic impact on the water quality i ponds of Českomoravská vrchovina and Southerm Moravia.

MATERIAL AND METHODS:

For monitoring of the present conditions we selected these fishponds: Sykovec and Medlov (Kinský Žďár, a. s.) elevation 700 meters above sea level and Jaroslavický dolní (Rybníkářství Pohořelice, a. s.) elevation 200 meters above sea level. Another aim was a comparison of the current state and results from 1996–1997 in ponds Sykovec and Medlov and we extend monitoring with another pond in similar climatic conditions.

Characteristic of the monitored area

Sykovec pond is situated in Českomoravská vrchovina, northeast of Žďár nad Sázavou, elevation 740 m above sea level (GPS position data N49 36.601 E16 02.495). This pond is watering by Medlovka stream which drain in coniferous forest circa 250 m from inflow. Medlovka is right-handed flow of the Fryšávka river in drainage area of the Svratka river. Sykovec is relatively deep pond and was sink on very poor bottom layer how shows sandy littoral zone. Banks of the pond are forested by conifers and farmland is mostly meadows or permanent grass stand. Near surrounding is built up with recreation properties and on right bank is operating summer camp. There are some streams which passing recreation areas and bringing nutrients to the water. This pond (area 17.22 ha) with semi-intensive breeding is under one-vegetation season system. Volume of water in Sykovec is 380,000 m^3. Fish keeping during the spring and winter time is impossible because of too low pH of inflow water.

Medlov pond is situated under Sykovec pond, 700 m above sea level (GPS position data N49 37.019 E16 03.165). Main water source is Medlovka stram with a few other streams. Small sewage work is sitting on main inflow and is similar to Sykovec pond. This pond (area 28.47 ha) with semi-intensive breeding is under one-vegetation season system and generally used for fish stock keeping during the winter. Volume of water in Medlov pond is 650,000m^3.

Jaroslavický dolní (Zámecký) pond is situated in Southern Moravia southeast of Znojmo, elevation 188,6 m above sea level (GPS position data N48 45.700 E016 14.260). This is area with intensive agriculture, but pond was build up on badlands. Jaroslavický dolní pond is watering by hammer pond from river Dyje and extra fertilize from farms.

In the middle of last century was this pond split by jetty into two parts (upper part 60 ha and lower part 188.7 ha). Till 1996 was lower pond used for intensive duck breeding. This pond belongs to the group of intensive production system, implied condition makes semi intensive farming possible. Fish are not maintained during the spring and winter time and pond is winterizing every two years. Volume of water in Jaroslavický dolní is 1,840,000 m^3.

Fish management was evaluated according to evidence of the fish production, chemical and hydrobiological methods which are characteristic for fish pond environment. We used data from 1990 to 2007. All data were electronically processed and rate with following criteria: progress of the production per monitored period ($kg.ha^{-1}$), progress of the production of main fish kinds, relative feed conversion ratio (FCR) and estimation of natural production ($kg.ha^{-1}$).

Chemical and hydrobiological methods

Samples of water and phytoplankton were collected once a month from March to September 2008. Samples were taken close to dam near water outlet by 30 cm long pipe. Water oxygen saturation (oxy), temperature (tem), pH, conductivity (cond) and water transparency were measured immediately on the locality. Basic physical and chemical parameters (oxygen saturation of water, pH, temperature and conductivity) were measured by CyberScan PCD 650 (Eutech Instruments, USA). The transparency of water assessed with a Secchi disc. Ammonium ions ($N\text{-}NH_4$) were determined by the indophenols method, nitrite nitrogen ($N\text{-}NO_2$) by a method using N-(1-naphthyl)-ethylenediamine, nitrate nitrogen ($N\text{-}NO_3$) by a method using sodium salicylate, total nitrogen (N_T) were measured with dimethylphenol after transformation of all nitrogen compounds into nitrate by Koroleff´s method, total phosphor (P_T) and orthophosphate ($P\text{-}PO_4$) by a method using ascorbic acid and ammonium molybdenate, acid neutralization capacity (ANC) by a method using hydrochloric acid, iron ions (Fe) were reduced by ascorbic acid and determined with triazine, sulphate ions ($S\text{-}SO_4$) were measured by turbidimetric method with barium, potassium (K) were measured by photometric turbidity method as potassium tetraphenylborate, calcium (Ca) were determined by EDTA titration, chlorine ions (Cl^-) by reaction with mercury thiocyanate, total organic carbon (TOC) by digestion with sulfuric acid and peroxodisulfate and transformation into carbon dioxide, chemical oxygen demand (COD_{Cr}) by a method using potassium dichromate, (COD_{Mn}) by a method using potash, and biological oxygen demand (BOD) by the standard diluting method (APHA, 1998). Cyanobacteria and algal biomass was evaluated by chlorophyll-*a* concentrations using heated ethanol extraction (ČSN ISO 10260 (75 7575). Native samples of phytoplankton were determined by microscope Olympus BX51 and finally we estimated percentage rate of phytoplankton biomass as well.

RESULTS

Results of hydrochemical analyses presented in tab. I. Data are showing an arithmetic average with maximum and minimum value during the vegetation season.

I: *Average, maximum and minimum value of physical – chemical parameters in all monitored ponds during the year 2008 (monitored monthly)*

	Sykovec	Medlov	Jaroslavický dolní
Temperature (°C)	14.8 2.8–23.5	14.7 2.5–23.5	19.1 7.6–26.0
Oxygen (%)	94.1 60.6–116.5	91.7 69.6–117.5	108.3 51.3–140.2
Conductivity ($mS.m^{-1}$)	8.05 7.1–9.4	10.23 9.00–11.75	32.69 18.40–40.11
Transparency (cm)	125 65–200	96.4 70–150	25.0 15.0–35.0
pH	6.99 5.92–8.1	6.85 5.81–8.63	8.47 7.13–9.47
$N\text{-}NH_4^-$ ($mg.l^{-1}$)	0.17 < 0.01–0.460	0.184 < 0.01–0.494	0.125 0.01–0.38
$N\text{-}NO_2^-$ ($mg.l^{-1}$)	0.005 0.0–0.02	0.008 0.0–0.023	0.022 0.000–0.061
$P\text{-}PO_4^{3-}$ ($mg.l^{-1}$)	0.025 0.012–0.048	0.048 0.024–0.082	0.022 0.007–0.033
$N\text{-}NO_3^-$ ($mg.l^{-1}$)	0.56 0.0–1.4	0.6 0.0–1.4	0.4 0.1–0.8
COD_{Mn} ($mg.l^{-1}$)	13.46 9.53–20.64	14.92 11.20–21.28	21.34 13.90–37.48
COD_{Cr} ($mg.l^{-1}$)	41.63 26.0–52.7	45.9 33.6–52.4	71.81 45.8–109.3
ANC ($mmol.l^{-1}$)	0.32 0.16–0.43	0.52 0.22–0.69	2.00 1.85–2.41
Chlorophyll a ($\mu g.l^{-1}$)	22.46 1.48–47.36	75.80 40.40–149.48	201.67 53.28–346.32
N_T ($mg.l^{-1}$)	1.27 0.7–1.8	1.7 1.0–3.1	2.7 2.0–3.1
P_T ($mg.l^{-1}$)	0.067 0.038–0.102	0.1 0.050–0.162	0.273 0.170–0.370
Ca^{2+} ($mg.l^{-1}$)	10.4 8.02–14.03	11.08 8.18–18.04	35.1 10.22–44.09
TOC ($mg.l^{-1}$)	29.6 16.3–96.5	23.7 18.7–38.7	25.3 18.9–41.1
Water hardness ($mmol.l^{-1}$)	0.3 0.26–0.46	0.52 0.40–0.71	1.67 1.43–2.00
Cl^- ($mg.l^{-1}$)	5.31 4.23–7.15	6.42 5.67–7.09	28.88 26.34–32.26
Fe ($mg.l^{-1}$)	0.08 0.04–0.18	0.14 0.07–0.27	0.13 < 0.04–0.25
K ($mg.l^{-1}$)	< 2 < 2	< 2 < 2	6.6 3.0–8.0
BOD ($mg.l^{-1}$)	3.19 2.01–4.37	5.5 2.87–15.41	12.94 2.88–26.00

Due to low ANC and location of Sykovec and Medlov ponds near the peat bogs were measured very low values of pH (5.92 to 5.97) during march. Increase of pH (8.10 resp. 8.63) occurred due to abnormal phytoplankton biomass development, during the vegetation season when cyanobacteria became dominant which corresponded to chlorophyll-*a* content (graphs 1 and 2). Measured values in Jaroslavický dolní pond were completely different. Value of water pH during March–April was alkaline and reached values 9.24 resp. 9.47. High pH was caused by spring chlorococcal bloom, while during the summer pH decreased again. The increase in pH occurred again at the end of vegetation season because of phytoplankton development expressed by chlorophyll-*a* (graph 3).

ANC is an important factor for evaluation of pond fertility. Carbonate complex provides buffering capacity of water and consequently the stability of pH. In the Sykovec and Medlov pond were measured very low values of ANC (0.32 resp. 0.52 $mmol^{-1}$) during the vegetation season. Low values of ANC matches to low content of Ca^{2+}, in monitored ponds 10.4 resp. 11.08 $mg.l^{-1}$ (tab. I.). The result is average to low fertility of ponds and fluctuating pH. In Jaroslavický dolní pond was ANC approximately 2 $mmol^{-1}$ and content of Ca^{2+} was around 35.1 $mg.l^{-1}$ (tab. I.). This pond has got good fertility (graph No. 7)

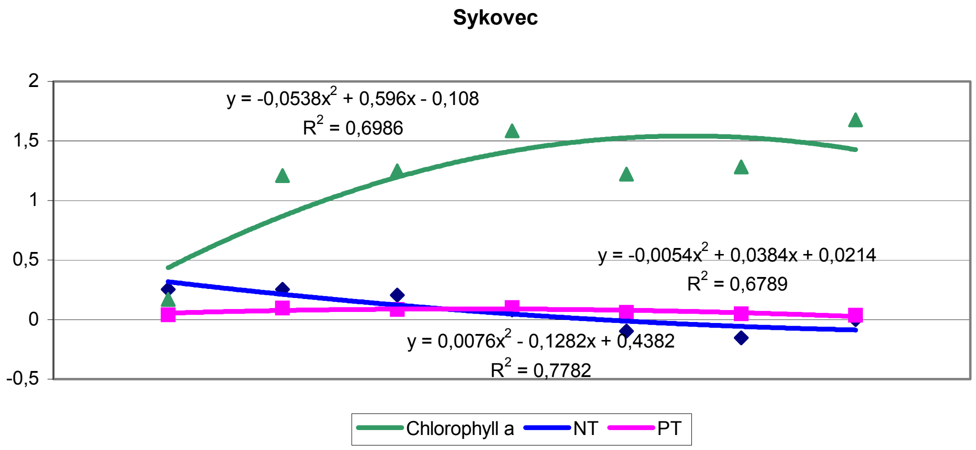
During the spring season is coming more nitrogen from drainage area, because of lower ability of farmland to fix nutrients and snow melt. Spring snow water is mainly use for filling of monitored ponds. In that time the anorganic nitrogen were mainly nitrates.

In second part of vegetation season was concentration of free nitrogen ($N\text{-}NO_3^-$ and $N\text{-}NH_4^-$) reduced by photosynthetic activity of phytoplankton, water plants and denitrification. Levels of free reactive phosphor ($P\text{-}PO_4^{3-}$) and total phosphorus (P_T) didn't change at all. This implies that nitrogen compound becomes a limiting factor for phytoplankton (especially green algae) and fish production in second part of vegetation season. Graph 1. shows two typical seasonal trends in Sykovec pond. Graph 4. shows decrease in the concentration of N_T during the growing season, growth of phytoplankton biomass (especially cyanobacteria) and chlorophyll-a. Concentration of P_T during the season was relatively unchanged. Same situation occurred in Medlov pond, N_T concentration decreases on the beginning of the season and decrease on the end due to death and decomposition of cyanobacteria population. Increased nitrogen availability and reduced competitiveness of cyanobacteria are using green algae for their development (graph 5.) and for this reason has got chlorophyll-a concentration a growing tendency. As shows graph 3. the concentration of N_T in Jaroslavický dolní pond has been stable for all season. Concentration of chlorophyll-a decreased during the growing season due to lower biomass of green algae and cyanobacteria. Chlorophyll-a is increasing repeatedly on the end of the season. The spring maximum is characterized by strong development of green algae called spring chlorococcal bloom but during the summer time are important part of plankton diatoms and cyanobacteria us well, domination of green algae is coming on the end of the season (graph 6.). The content P_T declined but did not become a limiting biogen for production.

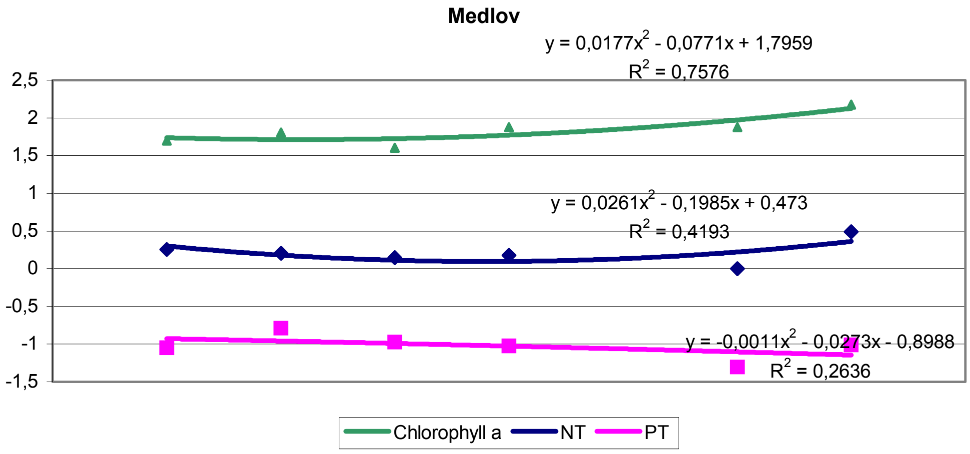
In fish ponds with salmonids can organic damage increase a risk of branchial disease. Higher levels of BOD in Sykovec (4.37 $mg.l^{-1}$) and Medlov (15.41 $mg.l^{-1}$) were measured in September and matched to high trophy of the water. Level of COD_{Mn} get over the limit for trout during the May–June (Sykovec 20.64 resp. 19.31$mg.l^{-1}$, Medlov 21.28, resp. 20.16$mg.l^{-1}$).

The highest observed value of BOD (26.0 $mg.l^{-1}$) in Jaroslavický dolní pond was measured during the April–May probably due to dissolved organic substances in water.

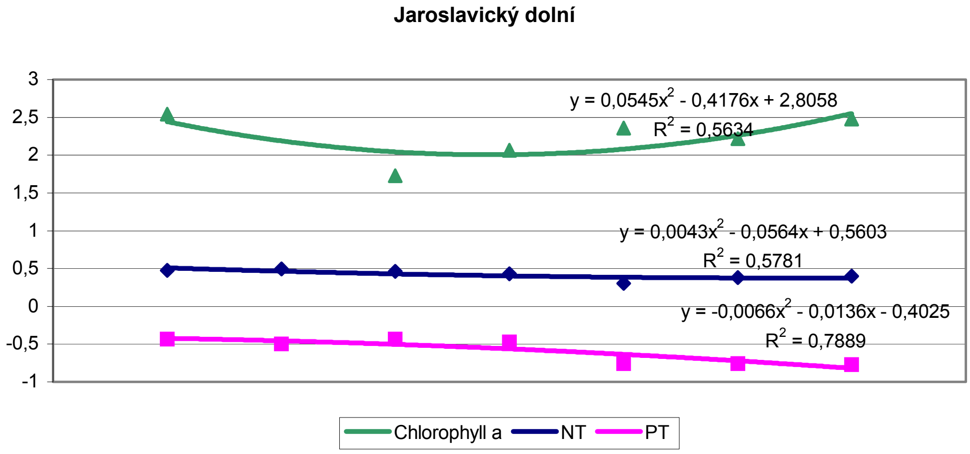
Higher values of TOC in Sykovec and Medlov ponds were caused by humic substances in flowing



1: *Change of the total nitrogen (N_T) concentration and total phosphorous (P_T) and chlorophyll-*a *in Sykovec pond during the vegetation season ($mg.l^{-1}$)*



2: *Change of the total nitrogen (N_T) concentration and total phosphorous (P_T) and chlorophyll –* **a** *in Medlov pond during the vegetation season (mg.l*$^{-1}$*)*



3: *Change of the total nitrogen (N_T) concentration and total phosphorous (P_T) and chlorophyll –* **a** *in Jaroslavický dolní pond during the vegetation season (mg.l*$^{-1}$*)*

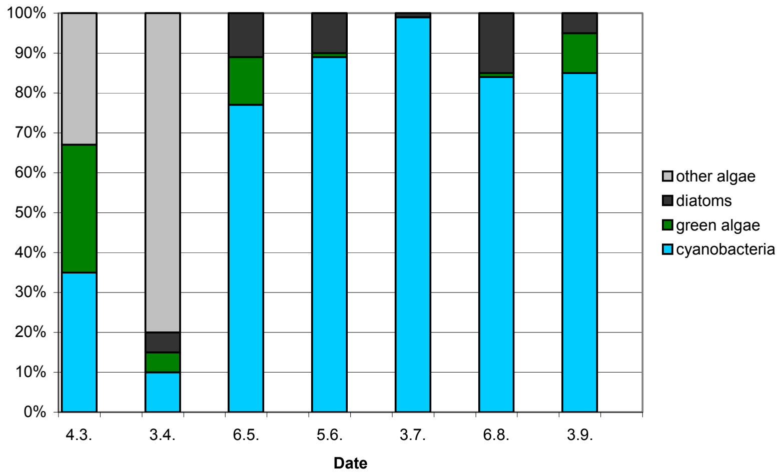
water during the spring. In Jaroslavický dolní fish pond was high TOC in July due to abnormal biomass development.

Concentration of chlorophyll-a in Sykovec pond was the highest (47.36 µg.l^{-1}) in September which is in accordance with classification of water trophy OECD (1982). At that time cyanobacteria took 85% of all algal community, 10% were green algae and just 5% of diatoms. Concentration of chlorophyll-a in Medlov pond was the highest (149.48 µg.l^{-1}) in September which is in accordance with classification of water trophy OECD (1982). At that time cyanobacteria took 75% of all plankton community and the rest completed just a green algae. We measured the highest concentration of chlorophyll-a in Jaroslavický dolní pond in March 2008 (346.32 µg.l^{-1}) in September which is in accordance with classification of water trophy OECD (1982) as a hypertrophy. At that time green algae formed 65% of all algal community, 15% diatoms and 20% some other algae. Concentration of chlorophyll - a decreased after that and reached a second peak in September (300.44 µg.l^{-1}) when abundance of the algal community was: 57% green algae, 40% diatoms and 3% other algae.

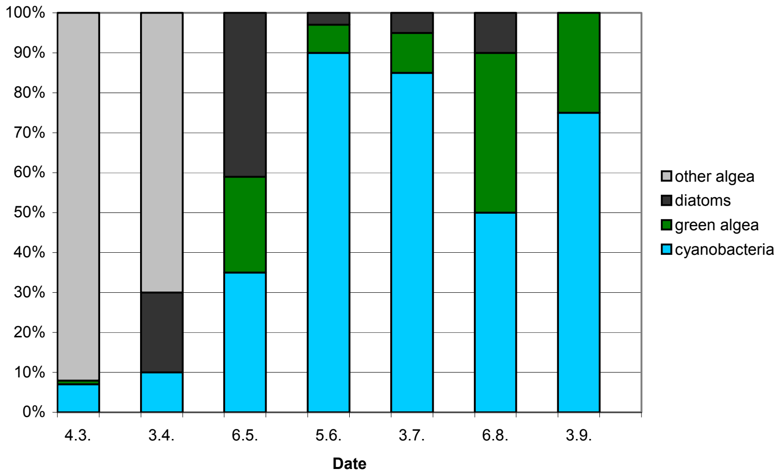
Scale OECD is designated for lakes therefore ponds seems to be hypertrophy. Concentration of chlorophyll-a change during the year so it is not an important indicator of water trophy and it is just additional information.

We monitored three basic groups of algae – green algae and diatoms which are a diet of zooplankton and cyanobacteria which are inconsumable due to colony-producing.

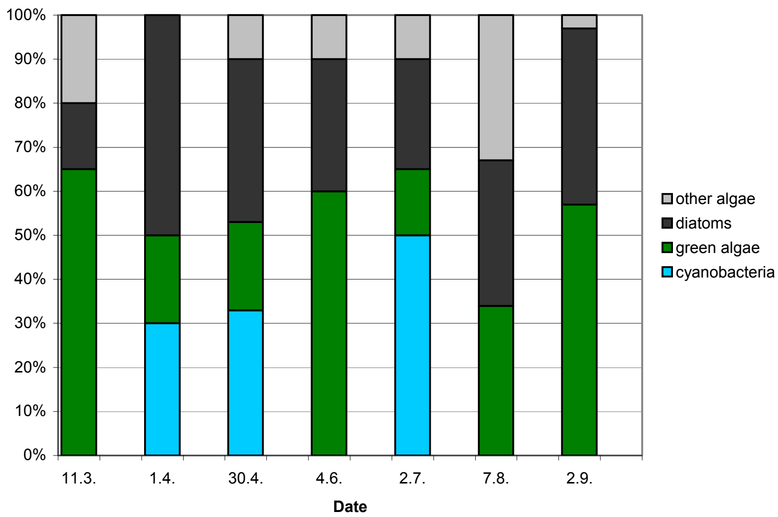
Abnormal cyanobacteria development started in second part of vegetation season. Abundance of cyanobacteria in Sykovec pond (Graph 4) was over 84% and development of other algae (1–16%) was limited. Medlov pond (Graph 5) has got 50% of cyanobacteria in this time, but situation in Jaroslavický dolní pond (Graph 6) was completely different. This hypertrophic pond had stable algal community and abundance of cynobacteria was under 50% only in July. Green algae and diatoms dominate for all vegetation season.



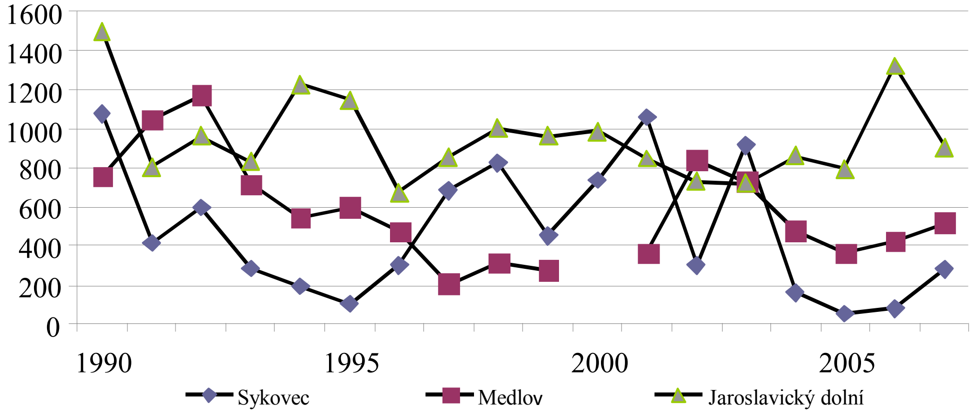
4: *Structure of the phytoplankton community (%)in the Sykovec pond during the vegetative season 2008*



5: *Structure of the phytoplankton community (%) in the Medlov pond during the vegetative season 2008*



6: *Structure of the phytoplankton community (%) in the Jaroslavický dolní pond during the vegetative season 2008*



7: *Total fish production during the period 1990–2007(kg.ha^{-1})*

We have to see hydrochemical analysis as a complex. Classification of water quality is pretty affected by weather during the season. We focused on characteristics parameters important for fish production.

During the last 17 years has been kept 6 species of fish in Sykovec and Medlov ponds: mainly common carp (*Cyprinus carpio*) and rainbow trout (*Oncorhynchus mykiss*) and additional species as tench (*Tinca tinca*), pikeperch (*Sander lucioperca*), northern whitefish (*Coregonus peled*) and Maraena whitefish (*Coregonus maraena*) in different age category.

In Jaroslavický dolní pond has been kept 9 kinds of fish, mainly common carp (*Cyprinus carpio*) and additional as a tench (*Tinca tinca*), pikeperch (*Sander lucioperca*), northern whitefish (*Coregonus peled*), northern pike (*Esox lucius*), grass carp (*Ctenopharyngodon idella*), big head carp (*Aristichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), European catfish (*Silurus glanis*) in different age category.

Relative high fish production in nineties of the last century in Medlov and Sykovec ponds has been done by semi - intensive fish keeping of rainbow trout. The production of this species has formed 47.7% in Medlov and 49% of total fish production in Sykovec. Rainbow trout was feed by complete feeding mixture from native or foreign production. Feed was applied by pneumatic feeder. Whole rearing is characterized by tendency to keep optimal water quality in all system by controlled actions.

Common carp was adds to the ponds as an additional species and fish for biomelioration. Production of carp has been 34.1% of total fish production in Medlov and 39% in Sykovec. In same time the production of northern whitefish in Medlov has been 15.4% and 17.6% of total fish production in Sykovec. In 2002 the trout rearing was replaced by common carp due to long term environmental adversity and unconfirmed exception. Some psychrophile species were still reared, for example the production of northern whitefish increase to 30% of total fish production.

In Jaroslavický dolní pond wasn't progress too dramatic. During the period under consideration has been main kind of fish just a common carp which took 88.4% of total fish production. This ratio matches to state average for fish farming. Other important fish species were silver carp and big head carp with production around 9.3% and some other additional species were under 1% of total fish production. Progress of the total production shows graph 7.

Estimated natural production of Sykovec pond was 105–135 kg.ha^{-1}. Total fish production of Medlov pond in same drainage area and with similar bottom layer reached 255–285 kg.ha^{-1} which is a double value of Sykovec.

Estimated natural production of Jaroslavický dolní pond was 355–385 kg.ha^{-1}. Production level has been supported by application of organic fertiliser. They started with regular additional fertilisation in 2000, using mulch in dose 1,060–3,180 kg.ha^{-1} per year.

Defined by methodology is maximum value of FCR for carp fingerling 2.5. Feed conversion ratio of feeding mixture for salmonids should not be above 1.5. Rainbow trout has been fed by mixture from Czech producer PD2 (company from Stříbrné Hory) and foreign producer BioMar and Dibag. Carp is usually additionally feed with cereals, especially wheat. FCR for common carp in Sykovec pond was 2.38, in Medlov pond 1.88 and 2.1 in Jaroslavický dolní. Feed conversion ratio for rainbow trout has been 2.48 in Sykovec and 1.96 in Medlov.

DISCUSSION

Long term average temperature in Českomoravská vrchovina in 1961–1990 was 7.2 °C. The average annual temperature in Českomoravská vrchovina in 2008 was 8.5 °C which is about 1.3°C higher. Precipitation in comparison with normal 1961–1990 was in 2008 89%, 574 mm. Long term average temperature in South Moravia in 1961–1990 was 8.3 °C. The average annual temperature in South Moravia in 2008 was 10.0 °C. Precipitation in comparison with normal 1961–1990 was in 2008 89%, 485 mm. (Vodohospodářský věstvík 2008, 2009).

SPURNÝ *et al.* (1998) studied in 1996 and 1997 in Medlov and Sykovec pond impact offishery management on quality of aquatic environment. Complex results are in tab. II.

II: *Average, maximum and minimum value of physical – chemical parameters in monitored ponds during the years 1996 (August, October) and 1997 (June, July) (SPURNÝ et al., 1998)*

	Sykovec	Medlov
Temperature (°C)	16.03 10.3–19.2	15.75 10.6–19.1
PH	7.98 7.21–8.8	8.02 6.87–8.85
Conductivity ($mS.m^{-1}$)	23.98 11.5–57.7	31.5 12.4–84.4
ANC ($mmol.l^{-1}$)	0.65	0.8
COD ($mg.l^{-1}$)	8.90 8.0–10.2	12.35 9.8–16.3
BOD ($mg.l^{-1}$)	4.73 1.8–9.7	7.00 5.08–9.2
$N\text{-}NH_4^-$ ($mg.l^{-1}$)	0.37 0.23–0.46	0.41 0.3–0.62
$N\text{-}NO_2^-$ ($mg.l^{-1}$)	0.02 0.01–0.04	0.015 0.01–0.03
$N\text{-}NO_3^-$ ($mg.l^{-1}$)	1.38 0.5–3.9	0.53 0.5–0.6
$P\text{-}PO_4^{3-}$ ($mg.l^{-1}$)	0.11 0.06–0.17	0.22 0.19–0.24
$P\text{-}PO_4^{3-}{}_{celk.}$ ($mg.l^{-1}$)	0.37 0.19–0.53	0.69 0.59–0.74
Chlorophyll - a ($\mu g.l^{-1}$)	38.8	30.0

When comparing the results from 1996–1997 and 2008 is shows a slight reduction in nutrient concentrations and ANC, but increase of maximum values of organic load. DVOŘÁK *et al.*, (1985) shows the maximum values of organic load for rainbow trout BOD 5 $mg.l^{-1}$, COD 15 $mg.l^{-1}$ and minimum value ANC 1.2 $mmol.l^{-1}$. In fish ponds with salmonids can organic damage increase a risk of branchional disease. We can understand that high nutrient income and higher organic load, together with law, probably affected change of fish stock structure and during the years 2002–2004 rainbow trout has been replaced with modest northern whitefish. This problem previously pointed out in their work HETEŠA *et al.* 1999 and SUKOP 2007. SPURNÝ *et al.* (1998) classified trophy of water in Sykovec a Medlov ponds by chorophyll-a content dle FELFOLDY (1976) as a meso - eutrophic water.

Almost no phytoplankton (less than 2 $\mu g.l^{-1}$ chlorophyll – a) was present in the spring in Sykovec pond. The increase of phytoplankton density has started in early May and peaked during the September, when was 47.36 $\mu g.l^{-1}$ chlorophyll-a. The same phenomenon described (FOTT 1972) and consider that this can be caused by later start with carp stocking. This hypothesis seems to be right, because Sykovec pond is usually set out on the end of April. In accordance with FOTT *et al.* (1974) development of phytoplankton during the growing season its happen in several stages (spring maximum, depresion, development of water bloom, chlorococcal maximum). This trend is described on ponds with a small fish stock. In Jaroslavický dolní pond were observed these stages (graph 3 and 6) 850 $kg.ha^{-1}$ a 635 $ind.ha^{-1}$. In ponds with higher fish stock is higher percentage of single celled algae (KOMÁRKOVÁ *et al.*, 1986). Consequently the stocking level affects not only development, but species composition of algae communities. KOMÁRKOVÁ *et al.* (1986) and PECHAR (1995) describe on high stock fishponds just a spring maximum. Subequent period "the clear water period" is not related to a higher pressure of fish stock on zooplankton. This was not confirmed on Jaroslavický dolní pond. Two years management cycle in ponds affects the composition of the phytoplankton communities in different years (FOTT *et al.*, 1980).

Cyanobacteria became usually dominant part of phytoplankton for all summer. Because of their size, content of biological substances and changes of basic hydrochemical parameters cyanobacteria are limiting for zooplankton and natural fish production (SEVRIN-REYSSAC and PLETIKOSIC 1990, POTUŽÁK, HŮDA and PECHAR 2007).

Lower ANC and low nitrogen concentration in 2008 have got a negative impact on natural fish production of Sykovec pond. Compare to 1996–1997 (tab. III.) natural production decreased by more than 100 $kg.ha^{-1}$ and FCR get lower as well. In Medlov pond increased natural fish production along with a slight decrease of FCR. HEJZLAR *et al.* (2008) mentioned results of FCR for common carp in ponds with similar environment and type of fish farming as a Sykovec and Medlov: Matějovský 2.3, Rendlíček 3.1, Veselský 2.3. The gradual increase in production of Sykovec and Medlov pond during the last three years (graph 7.) we can explain by higher nutrients income (especially phosphor)

III: *Estimated natural production and FCR in Sykovec and Medlov ponds (SPURNÝ et al., 1998)*

	Estimated natural production ($kg.ha^{-1}$)	FCR Common carp Rainbouw trout
Sykovec	190–220	2.85 2.53
Medlov	220–250	2.35 2.00

from recreation. Higher phosphor above 0.3 $mg.l^{-1}$ concentration does not bring higher fish production (MADHAV *et al.*, 1996). Therefore we can expect a gradual increase of production when is optimal fish stock and sufficiency of biogens N and C.

CONCLUSION

Our hydrochemical and hydrological analysis is resulting that water quality get worse in both monitored ponds compared to 1996 and 1997. The most significant deterioration of water quality was in Medlov pond. It is really interesting that concentration of chlorophyll-a was higher in the end of the vegetation season (August–September) instead of peak of the season (July–August) how the quantity of nutrients in aquatic environment indicated. The concentration of free nitrogen declines but the concentration of the free phosphorus and carbon remained the same level. This unbalance of the nutrients causes abnormal cyanobacteria development which became a major part of the phytoplankton. As a result of abnormal cyanobacteria development there is a change of physical and chemical parameters and more frequented oxygen deficit. Worse water quality has been main reason for end of the rainbow trout breeding in both monitored fish ponds in years 2002–2004. Another reason was no licence for feed application for salmonids.

Main polluter of the pond is usually the drainage area. Hotels and other recreation centre without tertiary wastewater treatment are major point source of the pollution. Large quantity of this clarified sewage water is flush into the pond where should be finally cleaned by self cleaning effect. However a small capacity of ponds is not sufficient to the progress of the tourist industry. In this paradoxical position the tourists gets worse the water quality themselves. SPURNÝ *et al.* (1998) mentioned similar results for Medlov and Sykovec ponds but describing much better water quality in Velké Dářko pond. Velké Dářko pond has got better self cleaning effect due to the greater capacity. Ponds Sykovec and Medlov were quite unstable. We suppose that unbalance is caused by absence of nitrogen which became limiting factor. These environmental conditions are convenient especially for blue green algae which make use of atmospheric nitrogen. The evidence of our theory could be conditions in Jaroslavický dolní pond with great fish production and no abnormal cyanobacteria development. Green algae and diatoms became dominant due to sufficiency of dissolved nitrogen in the water and inhibit overgrowth of cyanobacteria.

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