

THE TECHNOLOGICAL WATER NITROGEN COMPOUNDS DYNAMICS IN THE EXPERIMENTAL PONDS, INLET AND OUTLET CHANNELS

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Abstract. This study aims to identify proper solutions that can improve the sustainability of cyprinids pond aquaculture in terms of nitrogen releases to the environment. Therefore, two experimental variants, based on polyculture, respectively integrated multi-trophic aquaculture (IMTA) concept were tested, as follows: PCP – polyculture of common carp (CC) + grass carp (GC) + bighead carp (BC) + silver carp (SC); CP-PP – net divided pond with CC monoculture in CP part and CC+GC+BC+SC polyculture in PP part. In order to determine the nitrogen accumulation at the pond level, samples of water, sediments, fish meat and reed were analyzed. The results indicate that the highest nitrogen compounds concentrations in pond water were registered at CP part of CP-PP pond. However, the nitrogen concentration in pond effluents was significant higher in case of CP-PP pond, compared with PCP pond. The nitrogen compounds concentration of sediments registered the highest values in the ponds outlet area. Also, CP-PP pond recorded higher nitrogen concentration in sediments, compared with PCP pond. The CC registered the highest nitrogen compounds concentration in case of PP pond area, followed by CP pond area and PCP pond. Not significant correlation was found between reed and pond water/ fish meat/ sediments in terms of nitrogen compounds concentration. It can be concluded that the CP-PP pond feeding management, together with the tested technical solution (pond dividing) generated better water conditioning performances.

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Introduction

In the last decades, as Kibria and Haque (2018) mentioned, aquaculture production has intensified with a few selected species, causing several negative impacts such as deterioration of water and soil quality of ponds, stress, and poor growth of fish, a low profit margin, and overall environmental degradation. Sustainable aquaculture should be ecologically efficient, environmentally benign, product-diversified, profitable, and societally beneficial. Integrated multi-trophic aquaculture (IMTA) has the potential to achieve these objectives by cultivating fed species (e.g., finfish or shrimps fed sustainable commercial diets) with extractive species, which utilize the inorganic (e.g., seaweeds or other aquatic vegetation) and organic (e.g., suspension- and deposit-feeders) excess nutrients from fed aquaculture for their growth (Chopin, 2013).

In order to be considered sustainable production systems, aquaculture pond-based facilities must limit their impact on the environment. According to Shpiguel et. al. (2016), in Europe, national laws, directives and regulations penalize aquaculture farms that discharge organic nutrients into the environment with fines as high as €0.30 per kg feed used to grow the fish, fact that can often tip the sustainable balance between profit and failure of aquaculture production. Among nutrients, the concentrations of nitrogen in aquaculture ponds were always higher than those in the river, their primary water source, indicating that the aquaculture ponds are sources of nitrogen (Kawasaki et al., 2016; Kumar et al., 2018; Metaxa et. al., 2019).

One of the innovative solutions promoted for environmental sustainability (biomitigative services for improved ecosystem health), economic stability (improved output, lower costs, product diversification, risk reduction, and job creation in disadvantaged communities) and societal acceptability (better management practices, improved regulatory governance, and appreciation of differentiated and safe products) is IMTA (Chopin, 2013). The concept of IMTA is to create balanced systems for environmental sustainability, economic viability, and social acceptability (Barrington et al., 2009).

The integrated in IMTA refers to the more intensive cultivation of the different species in proximity to each other, connected by nutrient and energy transfer through water (Turcios and Papenbrock, 2014). The principle of IMTA is the co-cultivation of fed fish with organic and inorganic extractive species (Chopin, 2011; Chopin et al. 2012; Troell et al., 2009). Nevertheless, filter-feeders and seaweeds in open-water IMTA can withstand deteriorating water quality by removing suspended particles (Sreejariya et al., 2011; Nesar and Marion, 2016). In a perfect IMTA system the processing of biological and chemical wastes by other species would make the whole production cycle environmentally neutral (Bostok et al., 2008). Seaweeds in IMTA can clear the water as they have the capacities for

sediment trapping and binding (Björk et al., 2008; Nesar and Marion, 2016). Transparent water in IMTA can enhance ecological interactions among biotic and abiotic components (Troell et al., 2009; Nesar and Marion, 2016). The concept of IMTA is to create balanced systems for environmental sustainability, economic viability, and social acceptability (Barrington et al., 2009; Nesar and Marion, 2016). The IMTA as one of the promising methods for improving aquacultural performance while minimizing the environmental footprint and it offers an alternative approach for the long-term sustainability and profitability of the aquaculture industry (Le Gouvello et al., 2017; Lia et al., 2019).

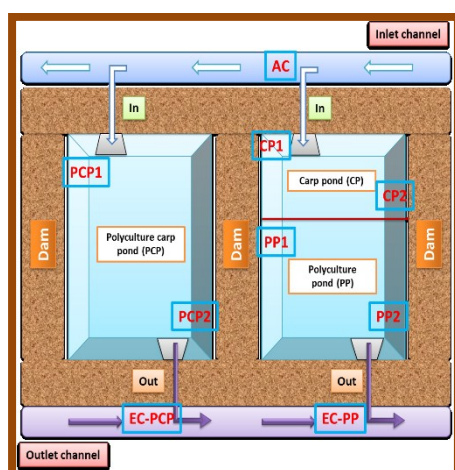
According to Lamprianidou et. al (2015), in order to evaluate the potential of IMTA as a nutrient bioremediation method, it is essential to know the ratio of fed to extractive organisms required for the removal of a given proportion of the waste nutrients. Therefore, a good IMTA design consists firstly in assuring high bioremediation performances throughout the entire production cycle.

The aim of this study is to identify proper IMTA technical design and technological solutions that can improve the sustainability of cyprinids pond aquaculture in terms of nitrogen releases to the environment.

1. Material and methods

Description of the study sites. This research was conducted at the "S.C. Piscicola Iași" fish farm, which is situated in the Larga Jijia village, 24 km north-west from Iași city, Romania. The location of the farm is described in the work published by Petrea et al (2017).

Experimental design. In this study were used two ponds with an area of 0.45 ha each. The experimental design is presented in Fig. 1.



Sampling areas:

- AC –inlet channel,
- EC-PCP – outlet channel from polyculture carp pond,
- EC-PP – outlet channel from polyculture pond,
- PCP1 – polyculture carp pond 1,
- PCP2 – polyculture carp pond 2,
- CP1 – carp pond 1,
- CP2 – carp pond 2,
- PP1 – polyculture pond1,
- PP2 – polyculture pond2.

Fig. 1 - Experimental design

Two experimental variants, based on polyculture, respectively integrated multi-trophic aquaculture (IMTA) concept were tested.

The first pond (polyculture carp pond - PCP) was used for rearing polyculture common carp (*Cyprinus carpio*) with bighead carp (*Aristichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*). Initial stocking consisted in: 2500 common carp specimens (63.0 ± 7.80 g/fish), 40 silver carp specimens (2006.3 ± 213.80 g/fish), 40 bighead carp specimens (1937.0 ± 191.48 g/fish) and 100 grass carp specimens (200.4 ± 20.01 g/fish).

The second pond (IMTA pond) was divided by using a net, as follows: first part with an area of 0.15 ha CP (carp pond) and the second part with an area of 0.30 ha PP (polyculture pond). The CP pond was stocked with 2000 common carp specimens (61.2 ± 11.60 g/fish) and the PP pond was stocked with 500 common carp specimens (60.0 ± 10.45 g/fish), 40 silver carp specimens (2044.0 ± 289.80 g/fish), 40 bighead specimens (1824.1 ± 182.59 g/fish), and 100 grass carp specimens (199.4 ± 20.00 g/fish).

Feed (28% crude protein) was administered twice/day, only in PCP and CP, for five days/week. The nitrogen input from administered feed is presented in Fig. 2. The nitrogen cycle applied concept is presented in Fig.3.

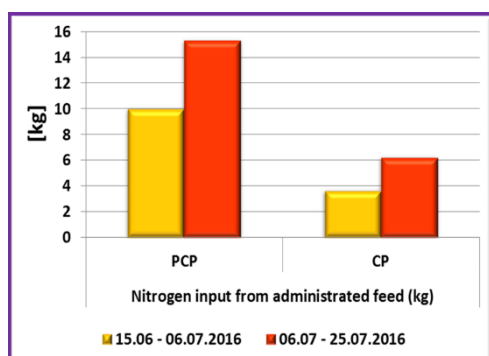


Fig. 2 - Nitrogen input from feed

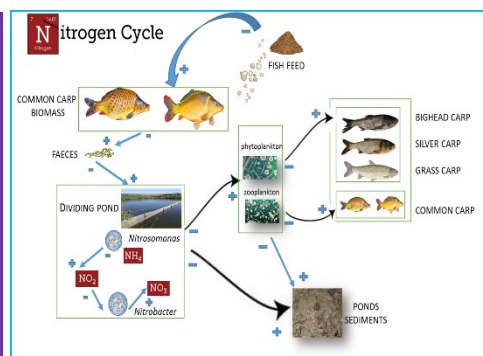


Fig. 3 - Nitrogen cycle in the fish pond

The experimental research has lasted for 41 days from 15 June to 26 July 2016. During this experimental period, samples were performed both at the beginning and at the end, but also at the intermediary stage (6 July 2016).

Sampling method and analysis.

Regarding the water quality assessment, from each pond, the water temperature, dissolved oxygen and pH were analysed daily, using the HQ40d portable pH and dissolved oxygen multi-parameter (HACH) devices

Other parameters as: the concentration of N-NO_3 , N-NO_2 , N-NH_4 , COD and total suspended solids (TSS) were analysed monthly. The nitrogen compounds and COD were determined with Merck kits, by using the Spectroquant Nova 400. The TSS was determined by water filtration at pre-weighed glass fiber filter, followed by constant heating the filter at $104 \pm 1^\circ \text{C}$.

During 25 – 26 July 2016, a 24h kinetic was made by taking water samples every 6 hours.

Biochemical analysis, were performed on all fish, sediments and reed samples, as described below, on the sampling paragraph.

The nitrates concentration was determined by spectrophotometrically method based on the diazotization-coupling reaction of sulfanilamide with N-(1-naphthyl)ethylenediamine dihydrochloride, using the Specord Analytik Jena 210 spectrophotometer.

The nitrites were determined by reduction of nitrate to nitrite with cadmium, a spectrophotometric method using the Specord Analytik Jena 210 spectrophotometer.

The total Kjeldahl nitrogen was determined using Kjeldahl method for nitrogen/protein with Gerhardt equipment.

Statistical analysis. The results obtained in this research were statistically analysed using IBM SPSS Statistics 20.0. To determine significant differences among groups was used the one-way analysis of variance (ANOVA); $p < 0.05$ was considered as significant.

2. Results and discussion

Dissolved oxygen concentration in pond technological water (DO)

The concentration in DO of pond technological water had an upwards tendency in all sampling points, except the inlet sampling point PCP1 (Fig. 4), where the difference between the values registered at 06 July and 25 July are not statistically significant ($p > 0.05$). Also, at the end of the experimental period, the highest values of DO in pond water are recorded in case of PP part of CP-PP pond ($\text{PP1} = 15.41 \text{ mg L}^{-1}$; $\text{PP2} = 16.29 \text{ mg L}^{-1}$), while the lowest values are encountered at PCP pond ($\text{PCP1} = 6.53 \text{ mg L}^{-1}$). The water DO concentration in the outlet channel has a relatively downward tendency, fact manifested especially in case of EC-PCP (from 3.89 mg L^{-1} , to 1.10 mg L^{-1}). This can be explained by the accumulation of sediments and organic matter, generated during the production cycle. Also, the evolution of pond water DO concentration can be significantly influence by the upward tendency of this parameter, registered at the level of inlet channel.

Regarding the kinetics, the higher DO values are recorded during the day, while the lowest values are registered at night (Fig. 5). This may be due to the presence of algae biomass, which produce oxygen during the daylight hours, as a

by-product of photosynthesis. Therefore, the highest values of water DO concentration during the day are registered in case of PP pond (24.96 mg L⁻¹, respectively 21.73 mg L⁻¹), fact that reveals a high abundance of algae, as a direct consequence of the applied technical solution.

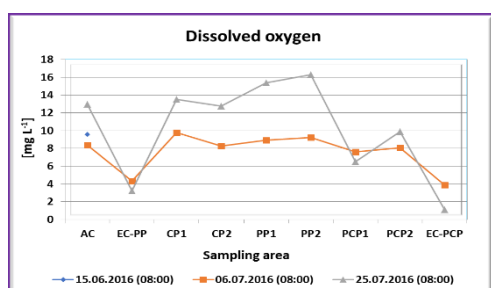


Fig. 4 - The dynamics of water DO concentration

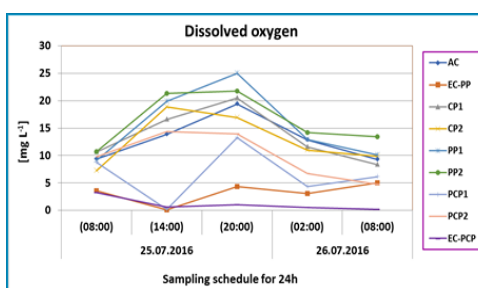


Fig. 5 - The 24h kinetics of water DO concentration

Temperature values in pond technological water (T°C)

The pond technological water temperature had an upwards tendency in all sampling points (Fig. 6). Also, at the end of the experimental period, the highest values of temperature in pond water are recorded in case of PCP pond (23.3 °C), while the lowest values are encountered at PP pond (19.4 °C).

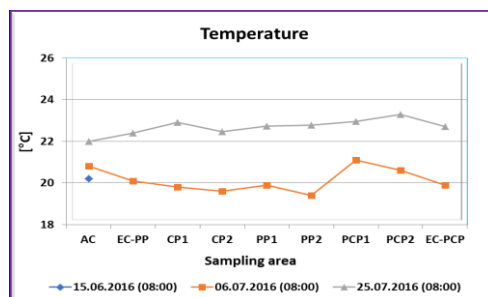


Fig. 6 - The dynamics of water temperature

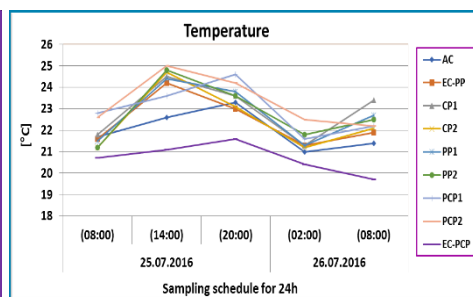


Fig. 7- The kinetics of water temperature

Regarding the kinetics, the higher water temperature values are recorded during the day (PP2=24.8°C, respectively PCP2=25.0°C), while the lowest values are registered at night (EC-PCP=20.40°C, respectively AC=21.0°C) and in the morning (EC-PCP19.7°C). The differences between the ponds sampling points were not statistically significant (Fig. 7).

pH values in pond technological water (upH)

The pond technological water pH has a clear upward tendency in case of all sampling points, with lower values in case of PCP pond (PCP1=8.01 upH, PCP2=8.02upH in 6 July, respectively PCP1=8.72 upH and PCP2=8.88 upH in 25 July), compare with CP-PP pond (8.31 in PP1 and PP2 in 6 July, respectively 9.16 upH – PP1 and 9.22 upH –PP2 in 25 July) (Fig. 8). This fact can be due to the accumulation of organic matter at the sediments level, in case of PCP pond.

Regarding the kinetics, the higher water pH values are recorded during the day (9.43 upH – PP1, respectively 9.42upH – PP2), while the lowest values are registered in the morning (7.88 upH – EC-PCP, respectively 8.60 upH - PCP2) (Fig. 9).

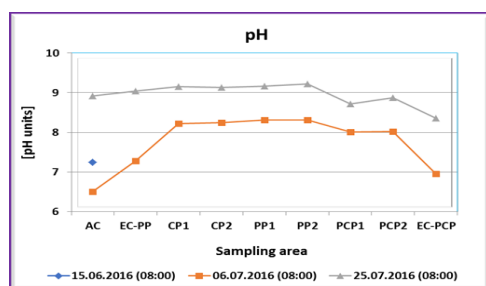


Fig. 8 - The dynamics of water pH

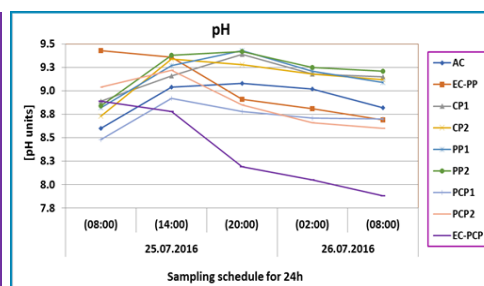


Fig. 9- The 24h kinetics of water pH

Nitrate-nitrogen concentration in pond technological water ($N-NO_3$)

The pond technological water $N-NO_3$ concentration has an accumulation tendency, manifested at PCP level (Fig. 10), from a value of 4.10 mg L^{-1} , till 6.19 mg L^{-1} at PCP1, respectively from a value of 6.30 mg L^{-1} , till 6.89 mg L^{-1} at PCP2.

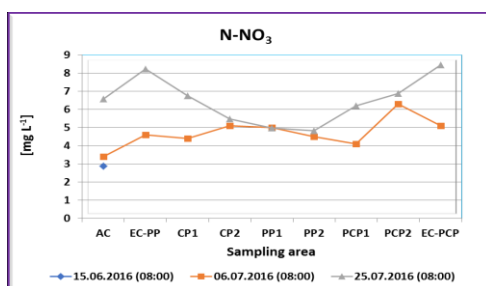


Fig. 10 - The dynamics of water $N-NO_3$ concentration

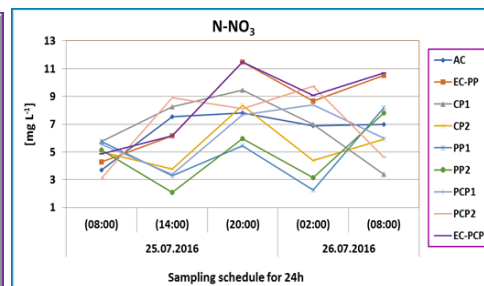


Fig. 11 - The kinetics of water $N-NO_3$ concentration

The lower values of N-NO_3 concentration in pond technological water, recorded at the end of the experimental period, in case of CP2, PP1 and PP2, compared with the rest of pond sampling points, reveals a better valorisation of this nitrogen compound when using the CP-PP pond dividing technique. Also, higher values of nitrate-nitrogen concentration, recorded at EC-PP (8.22 mg L^{-1}), respectively EC-PCP (8.45 mg L^{-1}) sampling points, reveals the accumulation tendency of this compound, at the level of outlet channel.

Regarding the kinetics, the higher values of water nitrate-nitrogen concentration are recorded especially in the afternoon (11.48 mg L^{-1} - CP1, respectively 9.44 mg L^{-1} - CP2), while the lowest values are registered in the first part of the day (2.10 mg L^{-1} - PP2, respectively 3.10 mg L^{-1} - PCP2) (Fig.11).

Nitrite-nitrogen concentration in pond technological water (N-NO_2)

The concentration of N-NO_2 pond technological water has a downward tendency, manifested at PCP level (Fig. 12), from a value of 0.13 mg L^{-1} , till 0.12 mg L^{-1} at PCP1, respectively from an value of 0.14 mg L^{-1} , till 0.11 mg L^{-1} at PCP2. The higher values of pond technological water N-NO_2 concentration, recorded at the end of the experimental period, in case of CP1, compared with the rest of pond sampling points, reveals an accumulation of this nitrogen compound, as a direct consequence of fish feeding regime applied. Also, higher values of nitrite-nitrogen concentration, recorded at EC-PP (0.16 mg L^{-1}), respectively EC-PCP (0.17 mg L^{-1}) sampling points, reveals the accumulation tendency of this compound, at the level of outlet channel.

Regarding the kinetics, the higher values of water nitrite-nitrogen concentration in ponds are recorded especially at the middle of the day (0.14 mg L^{-1} in PCP1, PCP2 and CP1, respectively 0.12 mg L^{-1} in PP1), while the lowest values are registered in the morning and at night, especially in CP-PP pond (0.08 mg L^{-1} , respectively 0.09 mg L^{-1}) (Fig. 13).

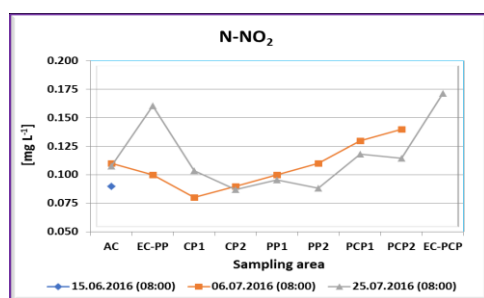


Fig. 12- The dynamics of water N-NO_2 concentration

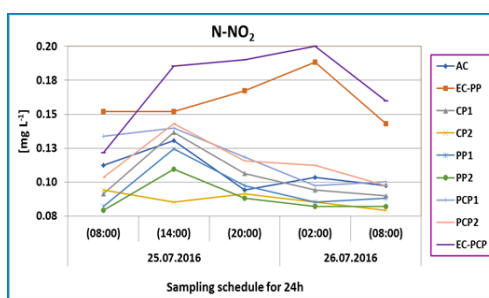


Fig. 13 - The kinetics of water N-NO_2 concentration

Ammonium-nitrogen concentration in pond technological water ($N-NH_4$)

The concentration of pond technological water $N-NH_4$ has an accumulation tendency, manifested at PCP level (Fig. 14), from a value of 0.18 mg L^{-1} , till 0.25 mg L^{-1} at PCP1, respectively from a value of 0.20 mg L^{-1} , till 0.26 mg L^{-1} at PCP2. The lowest values of $N-NH_4$ concentration in pond technological water, recorded at the end of the experimental period, in case of CP2, PP1 and PP2, compared with CP1 sampling point, reveals an accumulation of this nitrogen compound in first part of CP-PP pond, as a direct consequence of fish feeding regime applied. Also, higher values of ammonium-nitrogen concentration, recorded at EC-PP (0.40 mg L^{-1}), respectively EC-PCP (0.45 mg L^{-1}) sampling points, reveals the accumulation tendency of this compound, at the level of outlet channel.

Regarding the kinetics, higher values of water $N-NH_4$ concentration, in case of pond sampling points, are recorded especially at the middle of the day (0.48 mg L^{-1} – CP1, respectively 0.40 mg L^{-1} – PCP1), while the lowest values are registered at night (0.12 mg L^{-1} – PP2, respectively 0.14 mg L^{-1} – CP1) (Fig. 15). In case of outlet channel, the situation is exactly the opposite, the highest values of water $N-NH_4$ concentration being recorded during the night period.

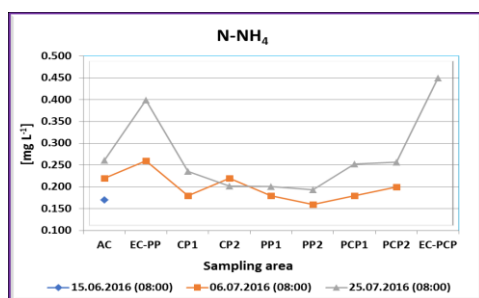


Fig. 14 - The dynamics of water $N-NH_4$ concentration

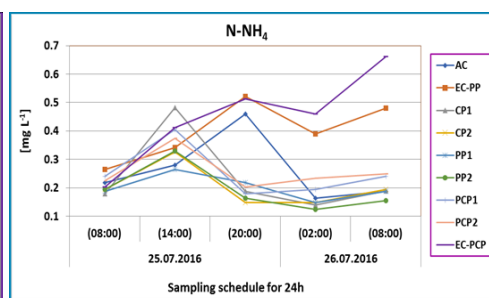


Fig. 15 - The kinetics of water $N-NH_4$ concentration

Therefore, it can be concluded that the highest nitrogen compounds concentrations in pond water were registered at CP part of CP-PP pond. However, the nitrogen concentration in pond effluents was significant higher in case of CP-PP pond, compared with PCP pond.

Total suspended solids in pond technological water (TSS)

The TSS in pond technological water has accumulated significantly in case of all sampling points. The lowest values of TSS concentration in pond technological water, recorded at the end of the experimental period, in case of PCP pond, compared with CP-PP pond, can be a direct consequence of fish feeding regime

applied. Also, higher values of TSS concentration, recorded at EC-PP (1650 mg L⁻¹), respectively EC-PCP (1437 mg L⁻¹) sampling points, reveals that the accumulation tendency of this compound, at the level outlet channel, is more accelerated, comparing with the pond sampling points (Fig.16).

Regarding the kinetics, the lowest values of water TSS concentration in case of pond sampling points are recorded especially in the afternoon (312 mg L⁻¹ – PCP1, respectively 576 mg L⁻¹ – CP2), while the highest values are registered during the day, especially in the morning (1768 mg L⁻¹ – PP2, respectively 1476 mg L⁻¹ – CP1) (Fig. 17).

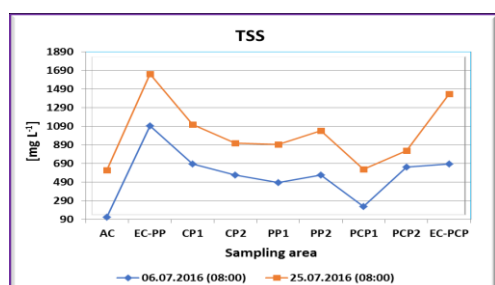


Fig. 16 - The TSS dynamics in pond technological water

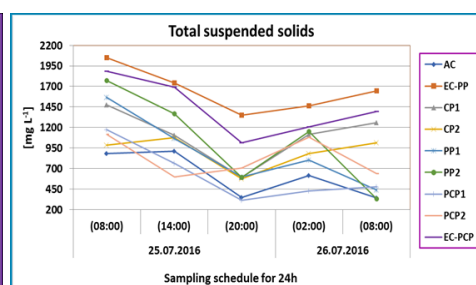


Fig. 17 - The kinetics of TSS in pond technological water

Chemical oxygen demand concentration in pond technological water (COD)

The pond technological water COD has accumulated significantly in case of all sampling points. The lowest values of COD concentration in pond technological water, recorded at the end of the experimental period, are registered in case of PP2 sampling point (120 mg L⁻¹), fact that indicates a better valorization of phytoplankton in case of CP-PP pond, compared with PCP pond (152 mg L⁻¹ – PCP1 and 149 mg L⁻¹ – PCP2) (Fig.18).

Regarding the kinetics, the lowest values of water COD concentration in case of pond sampling points are recorded in the morning (111 mg L⁻¹ – PP2, respectively 130 mg L⁻¹ PP1), fact probably due to the planktonic activity (Fig.19).

The dynamics of fish meat nitrogen compounds concertation

The nitrogen compounds presence in aquatic organisms is strongly related with the water matrix, the type of aquatic organism and also the environmental factors as temperature or atmospheric pressure (Simionov et al., 2017). Nitrites and nitrates are considered natural components which result as intermediate products from bacterial processes of the nitrogen cycle in ecosystems, such as nitrification and de-nitrification.

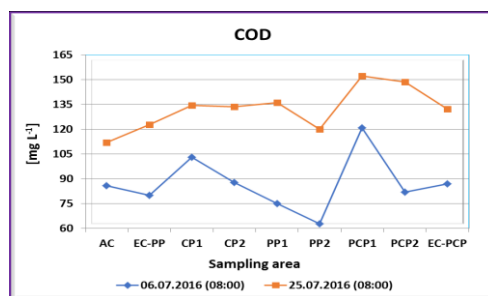


Fig. 18- The COD dynamics in pond technological water

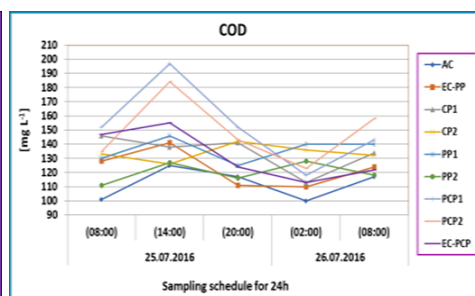


Fig. 19- The kinetics of COD in pond technological water

The dynamics of fish meat nitrates concentration

No statistically significant differences ($p > 0.05$) were found at the beginning of the experimental period between the exemplars belonging to the same species from both CP and PP parts of IMTA pond, as well as from PCP polyculture pond. Bighead carp registered the highest concentration of nitrates in meat, at the beginning of the experimental period ($22.37 \pm 0.60 \text{ mg kg}^{-1} \text{ FW}$) (Fig. 20), while after 41 days, common carp from PP part of CP-PP pond recorded the most significant accumulation of nitrates in meat ($40.98 \pm 1.64 \text{ mg kg}^{-1} \text{ FW}$) (Fig. 22).

A small number of silver carp exemplars from PP part of CP-PP pond was harvested, therefore, statistically representative results could not be recorded. Also, common carp from CP-PP experimental variant had a superior nitrate accumulation rate ($35.14 \pm 2.27 \text{ mg kg}^{-1} \text{ FW}$, respectively $31.47 \pm 3.32 \text{ mg kg}^{-1} \text{ FW}$ in CP pond) ($p < 0.05$), comparing with the exemplars from PCP pond ($25.19 \pm 1.91 \text{ mg kg}^{-1} \text{ FW}$, respectively $18.49 \pm 0.77 \text{ mg kg}^{-1} \text{ FW}$ in PCP pond), fact valid both at the intermediary stage (06 July) (Fig. 21) and at the end (25 July) of the experimental period. The bighead carp had a better nitrate accumulation in PP pond ($31.94 \pm 0.57 \text{ mg kg}^{-1} \text{ FW}$, respectively $32.22 \pm 1.50 \text{ mg kg}^{-1} \text{ FW}$), as a direct consequence of applying the pond dividing technical solution. However, grass carp reared in PCP pond ($30.46 \pm 1.20 \text{ mg kg}^{-1} \text{ FW}$) recorded a higher nitrate accumulation rate ($p < 0.05$), comparing with the exemplars from PP ($21.22 \pm 0.70 \text{ mg kg}^{-1} \text{ FW}$), fact probably due to feed competition between this fish species and common carp (Fig. 21, 22).

The dynamics of fish meat nitrites concentration

No statistically significant differences ($p > 0.05$) were found at the beginning of the experimental period, between the exemplars belonging to the same species from both CP and PP parts of IMTA pond, as well as from PCP polyculture pond (Fig. 23). Grass carp registered the highest concentration of nitrites in meat, at the

beginning of the experimental period ($3.22 \pm 0.26 \text{ mg kg}^{-1} \text{ FW}$), while after 41 days, bighead carp from PCP pond ($6.12 \pm 0.22 \text{ mg kg}^{-1} \text{ FW}$) recorded the most significant accumulation of nitrites in meat.

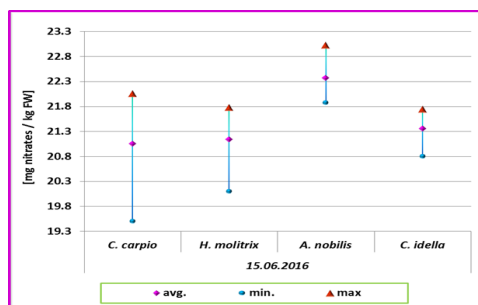


Fig. 20 - The fish meat nitrates concentration at the beginning of the experiment

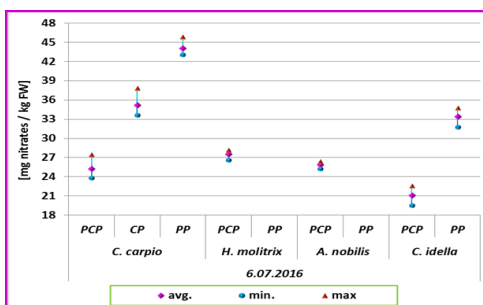


Fig. 21 - The fish meat nitrates concentration at the intermediary stage

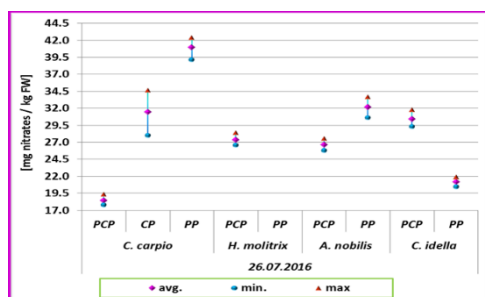


Fig. 22 - The fish meat nitrates concentration at the end of the experiment

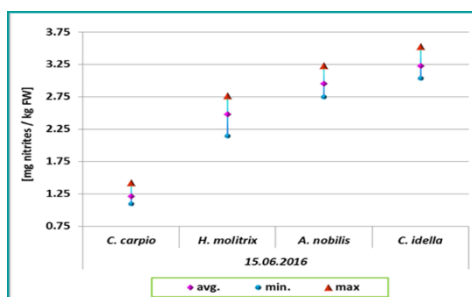


Fig. 23 - The fish meat nitrites concentration at the beginning of the experiment

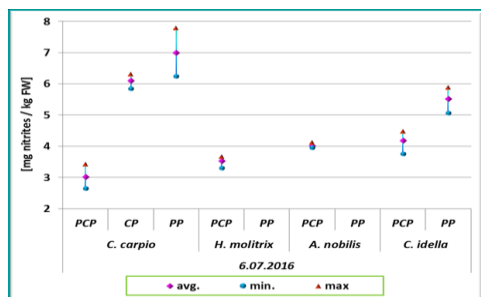


Fig. 24 - The fish meat nitrites concentration at the intermediary stage

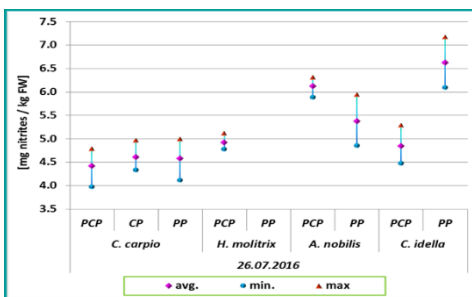


Fig. 25 - The fish meat nitrites concentration at the end of the experiment

At the intermediary stage, common carp from CP-PP pond registered the highest nitrite concentration in meat (6.99 ± 0.77 mg kg⁻¹ FW in PP, respectively 6.11 ± 0.23 mg kg⁻¹ FW in CP) (Fig. 24). However, in the second half of the experimental period, the meat nitrite concentration of this biological material registered a downward tendency, while the phytoplanktonophag fish species had an upward tendency (Fig. 25).

The dynamics of fish meat TKN concentration

No statistically significant differences ($p > 0.05$) were found at the beginning of the experimental period between the exemplars belonging to the same species from both CP and PP parts of IMTA pond, as well as from PCP polyculture pond (Fig. 26). The phytoplanktonophag fish species registered the highest concentration of TKN in meat (2.85 ± 0.07 g%FW – grass carp, 2.80 ± 0.08 g%FW – silver carp, 2.76 ± 0.08 g%FW – bighead carp), at the beginning of the experimental period, while after the first half of the experimental period, common carp from PP part of CP-PP pond recorded the most significant accumulation of TKN in meat (3.02 ± 0.09 g%FW) (Fig.27).

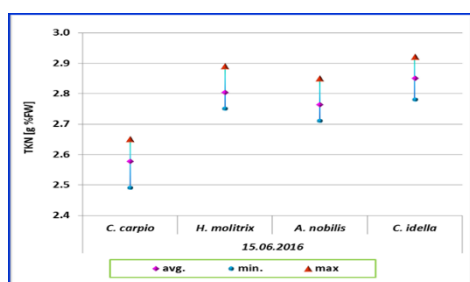


Fig. 26- The fish meat TKN concentration at the beginning of the experiment

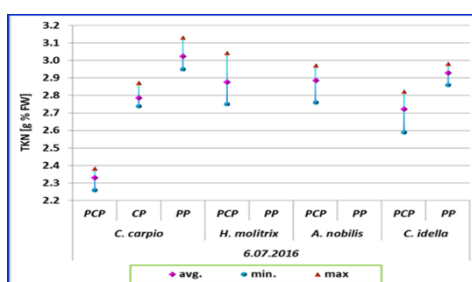


Fig. 27 - The fish meat TKN concentration at the intermediary stage

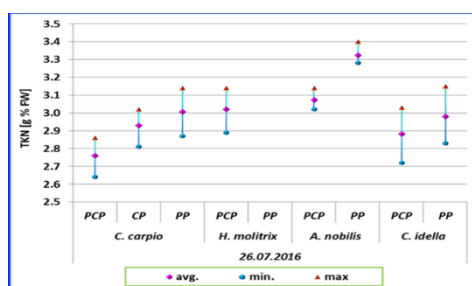


Fig. 28 - The fish meat TKN concentration at the end of the experiment

Also, the biological material from PP part of CP-PP pond registered a superior TKN concentration in meat, comparing with PCP exemplars, fact valid at the end of the experimental period (Fig. 28).

Therefore, it can be concluded that CC registered the highest nitrogen compounds concentration in case of PP pond area, followed by CP pond area and PCP pond. Also, it can be stated that because of the net capacity, in conjunction with the hydraulic gravitationally regime of the pond to induce a uniform distribution of nutrients in PP pond area, the availability of phytoplankton and zooplankton in this pond sector was higher, fact sustained by the high nitrogen compounds concentration recorded in the meat of the phytoplanktonophagous and macrophytophagous fish, compared with their counterparts from PCP pond.

The dynamics of sediments nitrogen compounds concentration

The dynamics of sediments nitrates concentration

The nitrates concentration in sediments registered a statistically significant ($p < 0.05$) upward tendency in case of CP-PP outlet channel sampling point, while in case of PCP outlet channel sampling point, the differences between the sediments nitrates concentration registered at the middle and at the end of experimental period, are not significant ($p > 0.05$).

In case of CP-PP experimental pond, significant ($p < 0.05$) downward tendency is recorded for CP2 and PP1 sampling points, same as in case of PCP2 sampling point, from PCP pond. However, in case of CP-PP pond sampling points, the dynamics of sediments nitrates concentration is more pronounced, comparing with PCP sampling points. This can be explained by the pond dividing technical solution, combining with the hydraulic regime, which was applied during the experimental period.

Not significant differences ($p > 0.05$) were recorded on the dynamics of sediments nitrates concentration from inlet channel. The highest concentration of nitrates in sediments is recorded in case of PP1 ($15.14 \pm 0.23 \text{ mg kg}^{-1} \text{ FW}$) and PP2 ($18.3 \pm 0.27 \text{ mg kg}^{-1} \text{ FW}$), at the intermediary stage of the experimental period, while the lowest are registered at PCP1 sampling point, both at the intermediary ($5.46 \pm 0.34 \text{ mg kg}^{-1} \text{ FW}$) and at the end ($6.31 \pm 0.08 \text{ mg kg}^{-1} \text{ FW}$) of the experimental period (Fig. 29).

The dynamics of sediments nitrites concentration

The nitrites concentration in sediments registered a statistically significant ($p < 0.05$) upward tendency in case of both CP-PP and PCP outlet channel sampling points, while in case of inlet channel sampling point, the differences between the sediments nitrites concentration registered at the middle and at the end of experimental period, are not significant ($p > 0.05$).

In case of CP-PP experimental pond, significant ($p<0.05$) upward tendency of sediments nitrites concentration is recorded at CP2 and PP2 sampling points, same as in case of PCP2 sampling point, from PCP pond.

Not significant differences ($p>0.05$) were recorded on the dynamics of sediments nitrites concentration from CP1 and PCP1 sampling points. The highest concentration of nitrites in sediments is recorded in case of CP2 (3.12 ± 0.07 mg kg⁻¹ FW) and PP1 (2.91 ± 0.08 mg kg⁻¹ FW), both in the intermediary stage and at the end of the experimental period, while the lowest are registered at PCP1 (1.87 ± 0.09 mg kg⁻¹ FW) sampling point (Fig. 30).

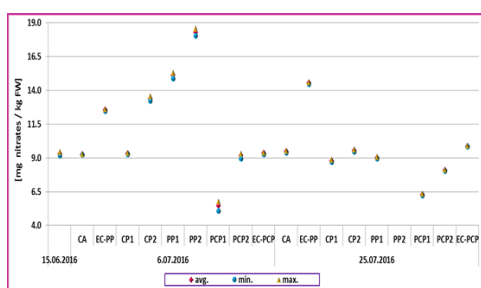


Fig. 29 - The dynamics of sediments nitrates concentration

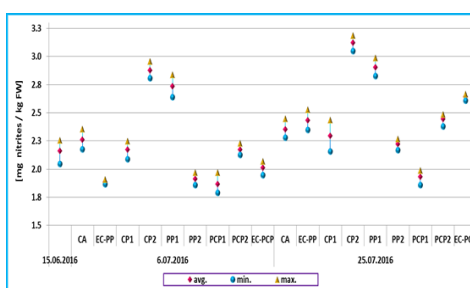


Fig. 30 - The dynamics of sediments nitrites concentration

The dynamics of sediments TKN concentration

The TKN concentration in sediments registered a statistically significant ($p<0.05$) upward tendency in case of both CP-PP and PCP outlet channel sampling points, while in case of inlet channel sampling point, significant ($p<0.05$) downward tendency is recorded.

In case of CP-PP experimental pond, significant ($p<0.05$) downward tendency of sediments TKN concentration is recorded for CP1, CP2 and PP1 sampling points. In case of PCP experimental pond, a not significant ($p>0.05$) upward tendency is observed.

The highest concentration of TKN in sediments is recorded in case of both outlet channels (EC-PP – 1.35 ± 0.02 g%FW and EC-PCP – 1.02 ± 0.05 g%FW), at the end of the experimental period, while the lowest are registered at inlet channel (0.68 ± 0.02 g%FW), CP2 (0.66 ± 0.01 g%FW) and PP1 (0.67 ± 0.01 g%FW) sampling point (Fig. 31).

Therefore, it can be concluded that nitrogen compounds concentration in sediments registered the highest values in the ponds outlet area. Also, CP-PP pond recorded higher nitrogen concentration in sediments, compared with PCP pond. Shpigel et. al (2016) concluded that an integrated rearing system with seabream

and mullet had a higher nitrogen quantity percentage recover in particulate sludge, compared to normal seabream and mullet monoculture systems, from 10.03%, respectively 14.08%, to 1.47%, while the overall biomass production will increase by 5.6–8.3%.

The dynamics of reed nitrogen compounds concentration

The dynamics of reed nitrates concentration

The dynamics of reed nitrates concentration reveals a clear accumulation tendency of this nitrogen compound, fact valid for all sampling points, significant differences ($p < 0.05$) being recorded between the sampling periods (Fig.32). The highest concentrations of nitrates in reed biomass are recorded at CP part of CP-PP pond (CP1 – 2282 mg kg⁻¹ FW and CP2 – 2592 mg kg⁻¹ FW), as well as in PCP2 (2323 mg kg⁻¹ FW).

The dynamics of reed nitrites concentration in both cyprinids pond systems

The dynamics of reed nitrites concentration reveals a clear accumulation tendency of this nitrogen compound, fact valid for all sampling points, significant differences ($p < 0.05$) being recorded in case of all pond sampling points. The highest concentrations of nitrites in reed biomass are recorded at CP1 (42.40 mg kg⁻¹ FW) and PCP2 (42.81 mg kg⁻¹ FW) pond sampling points (Fig. 33). This can reveal that the availability of nitrite decreases throughout the outlet part of the pond, when applying the dividing technique. Also, lower reed nitrites concentrations are recorded in the outlet channel (EC-PP – 36.58 mg kg⁻¹ FW and EC-PCP – 40.57 mg kg⁻¹ FW), comparing with the inlet channel (42.44 mg kg⁻¹ FW).

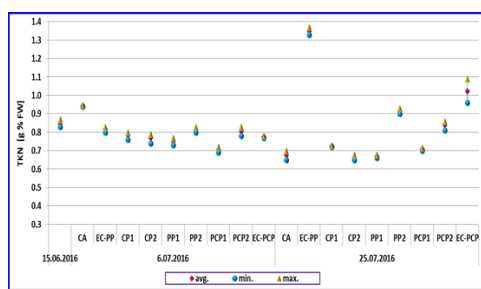


Fig. 31 - The dynamics of sediments TKN concentration in both cyprinids pond

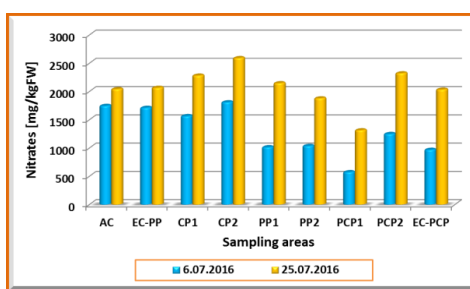


Fig. 32 - The dynamics of reed nitrates concentration in sampling areas

The dynamics of reed TKN concentration in both cyprinids pond systems

The dynamics of reed TKN concentration registered an upward tendency in all sampling points, except CP2 and especially PCP1, where significant downward

tendency (from an average value of 2.98 g%FW to 2.72 g%FW) can be observed (Fig. 34). This may be due to both the position of PCP1 sampling point, at the inlet part of undivided cyprinids pond system.

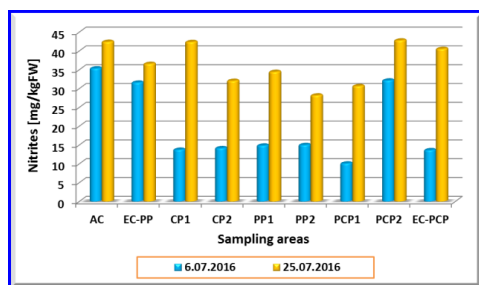


Fig. 33 - The dynamics of reed nitrites concentration

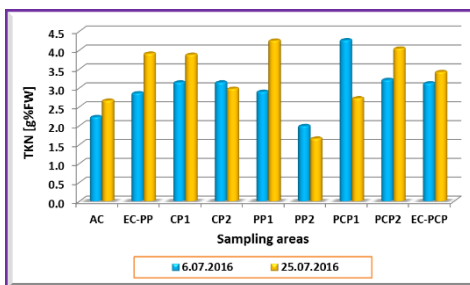


Fig. 34 - The dynamics of reed TKN concentration

However, higher reed TKN concentrations are recorded at the outlet part of PCP pond (PCP2 – 4.04 g%FW), comparing with the same pond area, corresponding to CP-PP pond (PP2 – 1.66 g%FW). The reed TKN concentrations at the outlet channel sampling points (EC-PP – 3.91 g%FW and EC-PCP – 3.42 g%FW) are significant higher, comparing with those from inlet channel sampling point (2.66 g%FW).

It must be stated that no significant correlations were found between reed and pond water/ fish meat/ sediments in terms of nitrogen compounds concentration.

Conclusion

It can be concluded that the CP-PP pond feeding management, together with the tested technical solution (pond dividing) generated better water conditioning performances. Thus, implementing the IMTA concept, as was applied in CP-PP pond, generates a reducing of nitrogen discharges from cyprinids pond aquaculture economic activity, on the water environment.

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