Arch. Pol. Fish.	Archives of Polish Fisheries	Vol. 16	Fasc. 4	459-467	2008

Short communications

DYNAMICS OF CHANGES IN NITROGEN AND PHOSPHORUS COMPOUNDS DURING INTENSIVE REARING OF IDE, *LEUCISCUS IDUS* (L.), IN A RECIRCULATING SYSTEM

Daniel Żarski, Dariusz Kucharczyk, Katarzyna Targońska, Beata Chyła, Anna Dobrołowicz

Department of Lake and River Fisheries, University of Warmia and Mazury in Olsztyn, Poland

ABSTRACT. The aim of the study was to follow the dynamics of changes in nitrogen and phosphorus compounds during intensive rearing of larval and juvenile ide, *Leuciscus idus* (L.), in a recirculating system. The study was conducted during two experiments of fifteen days. A shelf biological filter was used with 4 mm polyethylene balls as the filler. The results obtained are evidence that nitrogen and phosphorus can be removed successfully from water with biological filtration. They also confirm the need for fully controlling physicochemical conditions in order to determine the production capabilities of recirculating systems. Additionally, the results also demonstrated that it is possible to limit the impact of intensive fisheries production on the natural environment through the application of appropriate water purification systems.

Key words: NUTRIENTS, BIOLOGICAL FILTRATION, FEEDING, LARVAE, JUVENILE, *LEUCISCUS IDUS*

One of the fundamental elements of restoration programs of endangered species is the production of stocking material under controlled conditions (Poncin and Philippart 2002). Increasingly, research is focusing on issues linked to intensifying production of stocking material through the application of high stocking density and intensive feeding, among other strategies (Kujawa 2004, Wolnicki 2005, Żarski et al. 2008). One of the most significant advantages of closed recirculation systems is lowered production costs (Blancheton 2000, Kupren et al. 2008). However, this rearing technique requires removing accumulated metabolic products, especially nitrogen compounds, from the water (Kolman 1999, Kujawa 2004). Ammonia is an end product of fish metabolism. Under

CORRESPONDING AUTHOR: Daniel Żarski, University of Warmia and Mazury in Olsztyn, Department of Lake and River Fisheries, Oczapowskiego 5, 10-957 Olsztyn, Poland. Tel./Fax: +48 895234436, +48 895233969; e-mail: danielzarski@poczta.interia.pl

DOI 10.2478/s10086-008-0033-1

conditions of both low and high pH, both forms of ammonia nitrogen are toxic, although the non-dissociated form (NH_3) is 300-400 times more toxic than is the dissociated form (NH_4^+) (Karpiński 1994). The significant role played by ammonia in the production of stocking material has been addressed by many authors (Frances et al. 2000, Foss et al. 2003, Biswas et al. 2006, Remen et al. 2008). The most commonly applied and the most effective method for removing ammonia is biological filtration, which relies on oxygenation during the nitrification process of first ammonia to nitrogen nitrite (N-NO_2), then to nitrogen nitrate (N-NO_3). This last form of nitrogen is not life threatening to fish at the concentrations confirmed during rearing (Karpiński 1994, Kolman 1999).

In recent years, there has been an upward trend in the production of stocking material of rheophilic cyprinid fish. Ide, *Leuciscus idus* (L.), is the most common species in Polish hatcheries (Wojda 2004), and the biotechnology of its breeding has been the subject of many studies (Kucharczyk 2002, Targońska-Dietrich et al. 2004), as has the rearing of larvae (Kujawa 2004, Kwiatkowski et al. 2008).

Fisheries production is a significant source of nutrient loading in open waters, which leads to the acceleration of eutrophication processes (Kajak 2001). This is especially true of intense production in open water systems when high-protein feeds are used. Appropriately equipped recirculation systems permit using water repeatedly (Krüger and Niewiadomska-Krüger 1990), which reduces the necessity of releasing polluted water into the natural environment. The aim of the current study was to follow the dynamics of change in the levels of nitrogen and phosphorous compounds during intensive rearing of ide larvae and juvenile in a closed recirculating system.

The studies were conducted during two rearing experiments in closed recirculating systems. The first focused on the rearing of ide larval stages, while the second focused on ide juveniles. Larvae were obtained from controlled breeding at the Department of Lake and River Fisheries, University of Warmia and Mazury in Olsztyn (Kucharczyk 2002). Juvenile forms were obtained from the same larvae that were reared in a closed recirculating system for about six months.

The water temperature during the rearing of both larvae and juveniles was 25±0.2°C, and the photoperiod was 14L:10D. The larvae were reared in six tanks with a volume of 50 dm^3, while the juveniles were in three tanks with a volume of 120 dm^3. The larval stocking density (mean initial weight 1.6 mg) was 50 indiv. dm^{-3}, while that of the juvenile forms was 25 g dm^{-3} (mean initial weight 3.5 g). The larvae were fed *ad libitum* (3 times daily) with live *Artemia* sp. nauplii stages, while the juveniles were fed (2 times daily) with carp feed (composition: 62% protein, 11% fat, 0.8% carbohydrates, 1.1% phosphorus, 10% ash) at a quantity of 1.5% of the initial biomass. The biological filter was comprised of six shelves with a volume of 12 dm^3 each filled with 4 mm polyethylene balls. The filter was sprayed with water directed from the rearing tanks.

Each of the rearing experiments was 15 days long. The fish were removed from the tanks, and the water quality was monitored for another three days. The water oxygen content was measured daily with a oxygen probe before the second feeding, and a Slandi LF 205 photometer was used to determine levels of ammonia nitrogen ($N\text{-}NH_4$), nitrite nitrogen ($N\text{-}NO_2$), nitrate nitrogen ($N\text{-}NO_3$), and phosphorous ($P\text{-}PO_4$). All of the analyses were performed in two replicates, and the results were compared to those of "0", which was clean tap water. Regression analysis was used to determine the dependencies of the dynamics of the changes in the studied compounds.

The content of dissolved oxygen in the water during both rearing experiments did not drop below 5 mg dm^{-3}. The concentrations of the analyzed compounds in the inflow water were as follows (mg dm^{-3}): $N\text{-}NH_4 < 0.1$; $N\text{-}NO_2 < 0.01$; $N\text{-}NO_3 = 2.0$; $P\text{-}PO_4 = 0.1$. The content of ammonia nitrogen during larval rearing did not exceed 0.2 mg $N\text{-}NH_4$ dm^{-3} (Fig. 1). After stocking the juveniles into the tanks, the concentration of ammonia nitrogen in the water ranged from 0.4 mg $N\text{-}NH_4$ dm^{-3} on the first day to 0.5 mg $N\text{-}NH_4$ dm^{-3} on the second day of the experiment. During further rearing the concentration of $N\text{-}NH_4$ did not exceed 0.3 mg dm^{-3}. A rapid increase in the concentration of ammonia (to 0.4 mg $N\text{-}NH_4$ dm^{-3}) was confirmed again on days 12 and 13 of rearing. After the fish were removed from the system, the concentration of ammonia nitrogen decreased to 0.1 mg dm^{-3} (Fig. 2).

The highest concentration of nitrogen nitrite was noted on day 4 of larval rearing (0.1 mg $N\text{-}NO_2$ dm^{-3}). From day 5 onward, the content of nitrites did not exceed 0.04 mg $N\text{-}NO_2$ dm^{-3} (Fig. 1). During the rearing of juvenile forms, the concentration of $N\text{-}NO_2$ did not exceed 0.02 mg dm^{-3}. A sudden increase of this element was noted on day 10 to 0.3 mg dm^{-3}. Until the end of rearing, the concentration of nitrites fluctuated from 0.2 to 0.3 mg dm^{-3} (Fig. 2). Following the removal of the fish from the rearing tanks in both experiments, the contents of nitrites decreased to 0.01 mg $N\text{-}NO_2$ dm^{-3}.

During the rearing of larvae, a slow increase in the concentration of nitrates was observed from days 1 to 12, following which a rapid increase was noted in the contents

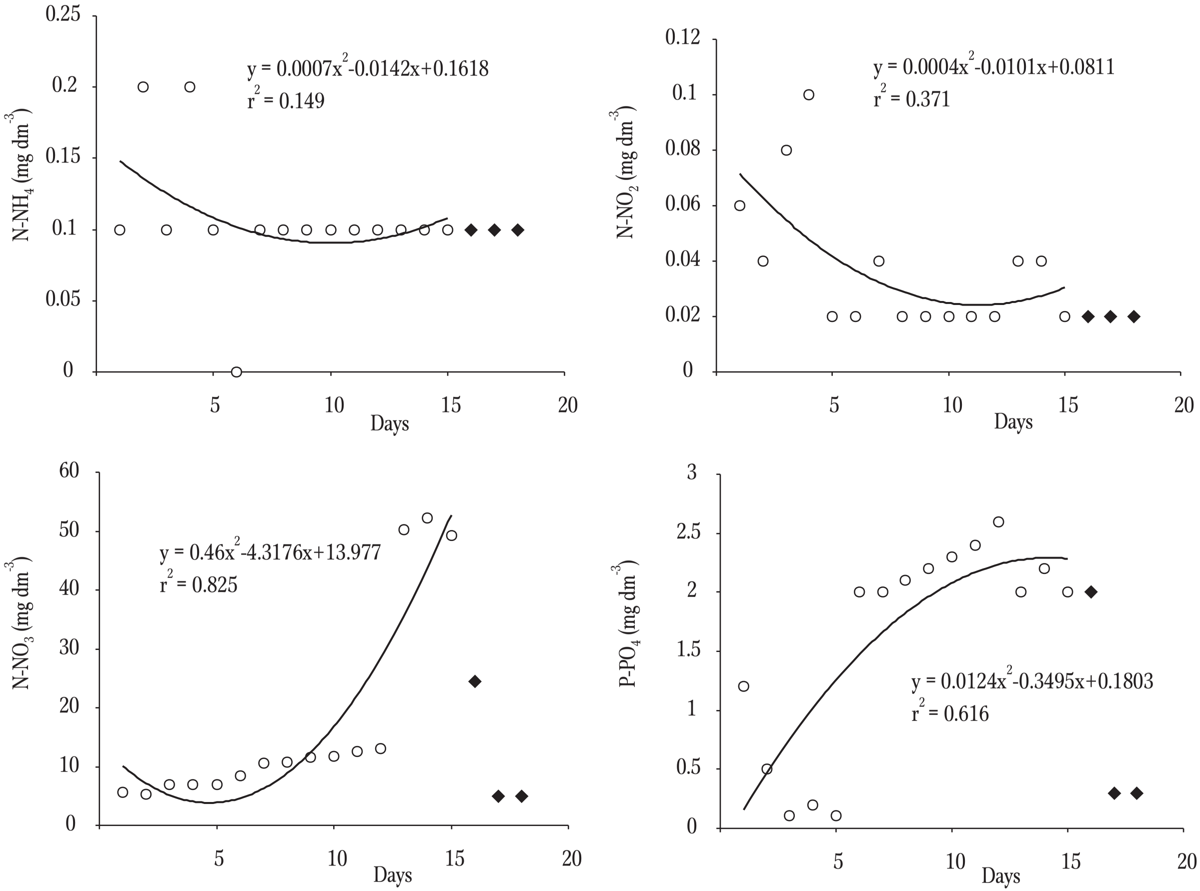

Fig. 1. Concentrations of the studied compounds in the water during the rearing of ide, *Leuciscus idus* larvae (○) in a closed water system and following the removal of the fish from the experimental system (♦). Regression equations were calculated for the values obtained until the moment the fish were removed from the system.

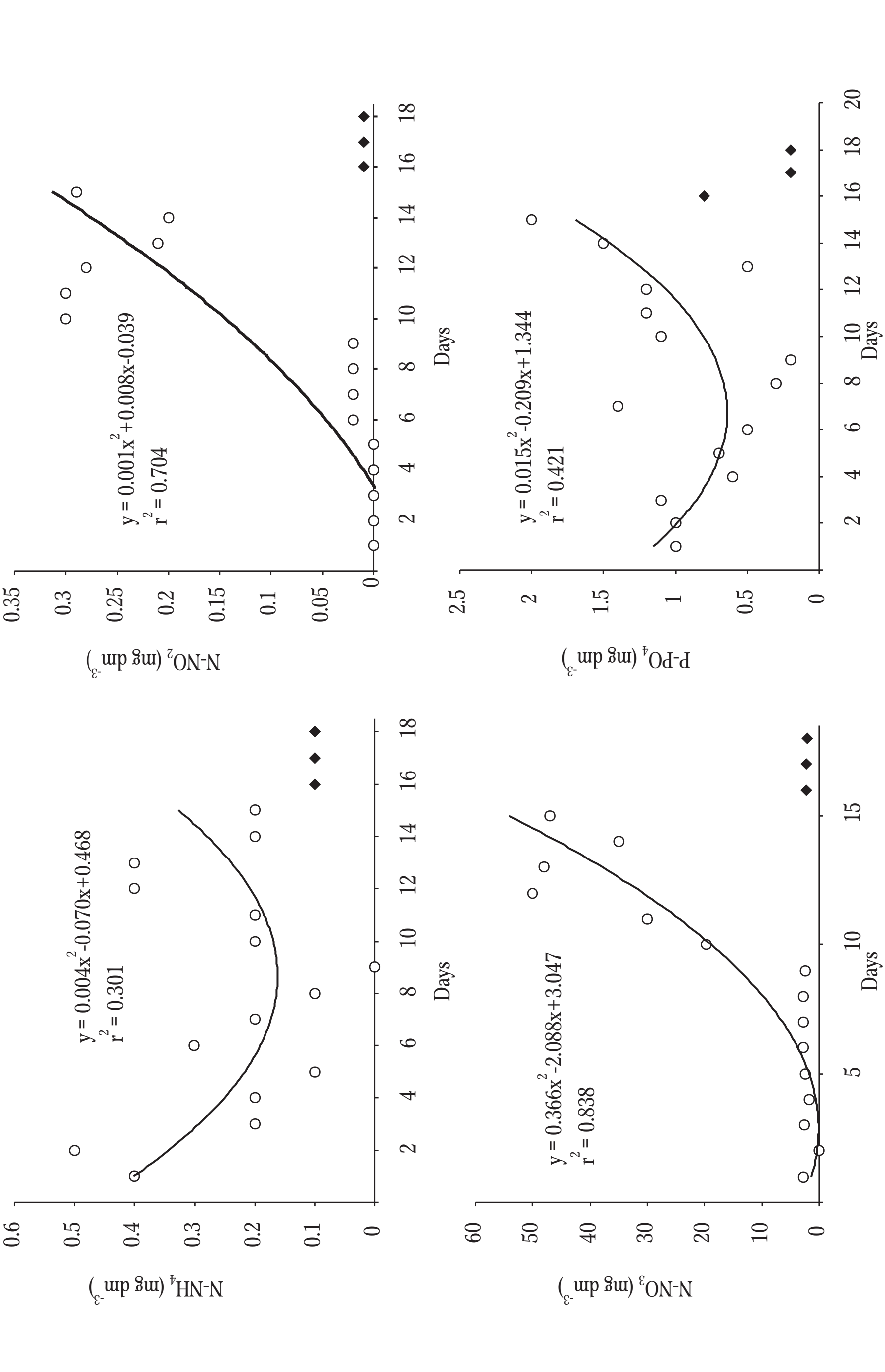

Fig. 2. Concentrations of the studied compounds in the water during the rearing of ide, *Leuciscus idus* juvenile (○) in a closed water system and following the removal of the fish from the experimental system (◆). Regression equations were calculated for the values obtained to the moment the fish were removed from the system.

of nitrogen nitrate to a level exceeding 50 mg N-NO_3 dm^{-3} (Fig. 1). The content of nitrates in the tanks in which the juveniles were reared did not exceed 3 mg N-NO_3 dm^{-3} up to day 9 of the experiment. Not until day 10 was a rapid increase noted in the concentration of this compound which reached its maximum value of 50 mg N-NO_3 dm^{-3} on day 12 of the experiment (Fig. 2). Removing the fish from the system resulted in a drastic decrease in the content of nitrates in both the first and second experiments.

The highest concentration of phosphorous compounds was noted on day 12 of larval rearing (2.6 mg P-PO_4 dm^{-3}), following which it remained about 2.0 mg P-PO_4 dm^{-3} (Fig. 1). During the rearing of juveniles, the concentration of phosphorans oscillated between 0.2 and 1.5 mg P-PO_4 dm^{-3} (Fig. 2). Removing the fish from the rearing tanks resulted in a rapid decrease in the quantity of phosphorans in the water.

The nutrient accumulation rate during the rearing of fish in closed systems is very high, and the high level of nitrogen compounds has a negative impact on rearing results (Foss et al. 2007). This is why it is important to remove them effectively with, for example, biological filters (Kolman 1992, van Rijn et al. 2006). The results obtained in the current study confirm that it is possible to effectively remove ammonia nitrogen from the system through nitrification that occurs on the biological substrate. During both rearing experiments, the concentration of this compound did not exceed 0.5 mg dm^{-3}, and this is clearly not a threat to cyprinid fish (Kolman 1999).

While the concentration of nitrogen nitrite was not confirmed to have increased substantially during larval rearing, it did increase substantially during juvenile rearing. This could have resulted from either a disruption in phase II nitrification possibly caused by factors that destroyed microflora (Karpiński 1994), or from the input into the system of a large amount of organic matter resulting from overfeeding (Madison and Wang 2006). This is why the dynamics of nitrite concentrations should be considered in parallel with changes in the quantity of nitrates, which exhibited a significant upward trend in the current experiment ($r^2 > 0.8$). Significantly elevated concentrations of N-NO_3 were noted during juvenile rearing when there were rapid increases in nitrite concentrations; this is an indication that phase II nitrification was not disrupted. Thus, it can be concluded that high concentrations of nitrites and nitrates occurred as a result of the accumulation of a large quantity of organic matter in the system. Karpiński (1994) reported that high concentrations of nitrogen nitrate are typical in closed rearing systems, and that lethal concentrations are above 1000 mg dm^{-3}. It should, however, be mentioned that the levels of nitrates confirmed did not pose a threat to the fish, and attest to the fact that the biological substrate was functioning effectively. The biological filtration system applied also permitted removing phosphorus compounds from the water, as was also confirmed by Barak and van Rijn (2000).

The results obtained in the current study are confirmation that it is necessary to continually monitor nitrogen and phosphorus concentrations in closed recirculating systems during intense fish rearing. It is also significant that evaluating each compound separately does not provide a full picture of the changes occurring in the system, and only a complete analysis permits determining the actual effectiveness of the system. Knowledge of the dynamics of these compounds and the capability of counteracting their negative impacts could significantly improve the effectiveness of stocking material production. In consideration of the load of the analyzed compounds placed on the system, it is clearly evident that the maximum production capacity (intensity) of rearing juvenile ide was achieved. With larvae, however, the capacity was significantly higher. Additionally, it is noteworthy that running the system following the conclusion of rearing is justified to reduce the concentrations of nutrients in the water. This permits limiting the negative impact of fisheries production on the natural environment.

ACKNOWLEDGEMENTS

This study was financed as part of the project "Optimizing the production of stocking material of rheophilic cyprinids under controlled conditions", Sectoral Operational Programme "Fisheries and Fish Processing 2004-2006" (00040-61535-OR1400009/07).

REFERENCES

Barak Y., van Rijn J. 2000 – Biological phosphate removal in a prototype recirculating aquaculture treatment system – Aquacult. Eng. 22: 121-136.

Biswas J.K., Sarkar D., Chakraborty P., Bhakta J.N., Jana B.B. 2006 – Density dependent ambient ammonium as the key factor for optimization of stocking density of common carp in small holding tanks – Aquaculture 261: 952-959.

Blancheton J.P. 2000 – Developments in recirculation systems for Mediterranean fish species – Aquacult. Eng. 22: 17-31.

Foss A., Vollen T., Øiestad V. 2003 – Growth and oxygen consumption in normal and O_2 supersaturated water, and interactive effects of O_2 saturation and ammonia on growth in spotted wolffish (*Anarhichas minor* Olafsen) – Aquaculture 224: 105-116.

Foss A., Imsland A.K., Roth B., Schram E., Stefansson S.O. 2007 – Interactive effects of oxygen saturation and ammonia on growth and blood physiology in juvenile turbot – Aquaculture 271: 244-251.

Frances J., Nowak B.F., Allan G.L. 2000 – Effects of ammonia on juvenile silver perch (*Bidayanus bidyanus*) – Aquaculture 183: 95-103.

Kajak Z. 2001 – Hydrobiology-Limnology. Inland Aquatic Ecosystems – PWN, Warszawa. (in Polish).

Karpiński A. 1994 – Water quality in intensive fisheries production – Broszura IRS, Olsztyn, 164 (in Polish).

Kolman R. 1992 – Effectiveness of biological shelf filtration for water purification in recirculation systems – Arch. Pol. Fish. 1: 1-37 (in Polish).

Kolman R. 1999 – Closed water recirculation in the production of hatch and fry – Broszura IRS, Olsztyn, 180 p. (in Polish).

Krüger A., Niewiadomska-Krüger D. 1990 – Permissible concentrations of nitrogen mineral substances in waters for nursing and rearing cyprinid fish – Broszura IRS, Olsztyn, 149 p. (in Polish).

Kucharczyk D. 2002 – Controlled reproduction and androgenesis of selected cyprinid fish species – Rozprawy i monografie 63, Wyd. UWM, Olsztyn, 81 p. (in Polish).

Kujawa R.J. 2004 – Biological foundations for nursing the larvae of rheophilic cyprinid fish under controlled conditions – Rozprawy i monografie 88, Wyd. UWM, Olsztyn, 88 p. (in Polish).

Kupren K., Turkowski K., Kucharczyk D., Krejszeff S., Żarski D., Hakuć-Błażowska A., Targońska K., Kwiatkowski M., Jamróz M., Czarkowski T. 2008 – Economic aspects of rearing larval asp, *Aspius aspius* (L.), and ide, *Leuciscus idus* (L.) in closed recirculating systems – Arch. Pol. Fish. 16: 413-420.

Kwiatkowski M., Żarski D., Kucharczyk D., Krejszeff S., Jamróz M., Kupren K., Targońska K., Hakuć-Błażowska A., Kujawa R., Mamcarz A. 2008 – Influence of feeding natural and formulated diets on chosen rheophilic cyprinid larvae – Arch. Pol. Fish. 16: 383-396.

Madison B.N., Wang Y.S. 2006 – Haematological responses of acute nitrite exposure in walleye (*Sander vitreus*) – Aquat. Toxicol. 79: 16-23.

Philippart J.C. 1995 – Is captive breeding an effective solution for the preservation of endemic species? – Biol. Conserv. 72: 281-295.

Poncin P., Philippart J.C. 2002 – The role of aquaculture in fish conservation: a case study of Barbus barbus in Belgium – In: Conservation of Freshwater Fishes (Eds) M. Collares-Pereira, I.G. Cowx and M.M. Coelho, Fishing News Books, Blackwell Science: 402-413.

Remen M., Imsland A.K., Steffanson S.O., Jonassen T.M., Foss A. 2008 – Interactive effects of ammonia and oxygen on growth and physiological status of juvenile Atlantic cod (*Gadus morhua*) – Aquaculture 274: 292-299.

Targońska-Dietrich K., Zielazny T., Kucharczyk D., Mamcarz A., Kujawa R. 2004 – Out-of-season spawning of cultured ide (*Leuciscus idus* L.) under controlled conditions – EJPAU 7(2): http://www.ejpau.media.pl/volume7/issue2/fisheries/art-02.html.

van Rijn J., Tal Y., Schreier H. J. 2006 – Denitrification in recirculating systems: Theory and applications – Aquacult. Eng. 34: 364-376.

Wojda R. 2004 – Production of stocking material of rheophilous fishes in Poland in 1995-2002: possibilities and necessities of further increases – Arch. Pol. Fish. 12 (suppl. 2): 359-369.

Wolnicki J. 2005 – Intensive rearing of early stages of cyprinid fish under controlled conditions – Arch. Pol. Fish. 13 (suppl. 1): 5-87.

Żarski D., Kucharczyk D., Kwiatkowski M., Targońska K., Kupren K., Krejszeff S., Jamróz M., Hakuć-Błażowska A., Kujawa R., Mamcarz A. 2008 – The effect of stocking density on the growth and survival of larval asp *Aspius aspius* (L.) and European chub *Leuciscus cephalus* (L.) during rearing under controlled conditions – Arch. Pol. Fish 16: 371-381.

Received – 06 August 2008

Accepted – 13 October 2008

STRESZCZENIE

DYNAMIKA ZMIAN ZWIĄZKÓW AZOTU I FOSFORU W TRAKCIE INTENSYWNEGO PODCHOWU JAZIA *LEUCISCUS IDUS* (L.) W OBIEGU ZAMKNIĘTYM

Celem niniejszej pracy było prześledzenie dynamiki zmian związków azotowych i fosforu w trakcie intensywnego podchowu larw i form juwenalnych jazia w obiegu zamkniętym. Badania prowadzono podczas dwóch piętnastodniowych doświadczalnych podchowów. Zastosowano półkowy filtr biologiczny, którego wypełnienie stanowiły polietylenowe kulki o średnicy $\phi \sim 4$ mm. Uzyskane wyniki świadczą o skutecznym usuwaniu związków azotu i fosforu z wody za pomocą filtracji biologicznej oraz dowodzą o potrzebie kompleksowej kontroli warunków fizykochemicznych wody w celu określenia zdolności produkcyjnej obiegu recyrkulacyjnego. Ponadto wskazują na możliwość ograniczenia wpływu intensywnej produkcji rybackiej na środowisko naturalne poprzez stosowanie odpowiedniego systemu uzdatniania wody.