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RESEARCH PAPER

Polyculture of juvenile pikeperch (*Sander lucioperca* (L.)) and sterlet (*Acipenser ruthenus* L.) in a recirculating system

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Abstract. The experiment examined the possibility of rearing juvenile pikeperch, *Sander lucioperca* (L.) in polyculture with sterlet *Acipenser ruthenus* L. in a recirculating system. Three variants of pikeperch rearing were tested: monoculture (group S), with the addition of sterlet at 10% (group S10) and 20% (group S20) of the initial pikeperch biomass. After 56 days of rearing, no differences in the growth rates or survival of the pikeperch were noted. The value of the feed conversion ratio in the monoculture group was 1.19 and was significantly statistically higher than in the polyculture groups, the values of which were 0.84 (S10) and 0.74 (S20). The mean oxygen consumption and ammonia excretion values did not differ significantly statistically among the studied groups. Including the sterlet stock with the pikeperch permitted obtaining the additional value of the sterlet biomass using the same quantity of feed. Additionally, the inclusion of sterlet decreased the labor intensity of pikeperch rearing since the tanks did not need cleaning as frequently.

Keywords: oxygen consumption, ammonia excretion, polyculture, recirculating system, feed conversion ratio

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Introduction

One of the fastest developing aspects of aquaculture is production in recirculating aquaculture systems (RAS) (Martins et al. 2010). Pikeperch, *Sander lucioperca* (L.), is one of the most promising species for intensive rearing (Zakęś 2009, Kozłowski et al. 2013). This fish is prized for its delicious meat and the high market price it commands. Among a variety of factors that determine the effectiveness of intense culture, the cost of feeding fish is one of the most important, and it can account for as much as 30% of total culture costs (STECF 2013). One aspect of pikeperch behavior is that it only feeds on food that is suspended in the water column, which means that feed falls to the bottom (Kozłowski et al. 2008). The result is the loss of protein, which is the most expensive feed component, and worse water quality from increased concentrations of harmful compounds (Thomas and Piedrahita 1998, Zakęś 1999). Another side effect of leaving unconsumed feed in tanks is the possible development on it of pathogens that increases the risk of disease. This is why unconsumed feed must be removed from tanks, which increases the labor intensity of rearing and contributes to stress among the fish being cultured. A solution for this problem could be introducing additional fish to the tanks that would feed on the food on the bottom and not cause any harm to the primary stock. The sturgeon is a candidate for this since it is not predatory and is almost exclusively a bottom feeder. The aim of the study was to determine what impact the addition of sterlet, *Acipenser ruthenus* L., would have on the growth and feed conversion ratio of pikeperch and on the aquatic environment during rearing in a recirculating system.

Materials and methods

The experiment was conducted at the Department of Sturgeon Breeding in Pieczarki (IFI Olsztyn) in a recirculating system with a total volume of 25.9 m^3 that was fitted with an SDK CN 3.2 biofilter with a volume of 3.2 m^3 (SDK Poland) that was filled with synthetic Light Bioelementer with a combined volume of 1.5 m^3 (RK Plast A/S, Denmark). The thickness of the filter was 0.93 g cm^{-3}, and its surface area proper was 750 m^2 m^{-3}. The fish were held in green, rectangular tanks made of a synthetic material that were filled to a depth of 0.5 m and had a working volume of 0.54 m^3.

The study material comprised juvenile pikeperch and sterlet obtained through artificial reproduction and reared initially at the Department of Sturgeon Breeding according to published methods (Zakęś and Szczepkowski 2004, Zakęś 2009). The age of the fish at the beginning of the experiment was 189 days post hatch (DPH; pikeperch) and 86 DPH (sterlet). The mean pikeperch body weight at the beginning of the experiment was 4.4 g and body length was 7.0 cm, the sterlet measurements were 6.5 g and 9.7 cm, respectively. The initial stocking density in each tank was 230 pikeperch specimens (biomass approximately 1 kg). Three variants of additional sterlet stock were used in the experiment:

- rearing pikeperch in a monoculture (group S);
- rearing with sterlet at a biomass of 10% of the initial pikeperch biomass (group S10);
- rearing with sterlet at a biomass of 20% of the initial pikeperch biomass (group S20).

Each of the variants was conducted in four replicates. The running time of the experiment was 56 days. Water temperature, oxygen concentration, water pH, and the concentration of nitrogen compounds at the tank outflows was monitored throughout the experiment. Measurements of temperature, oxygen concentration, and pH were done with a Cyber Scan 5500 device (Eutech Instruments, USA). Levels of total ammonia nitrogen (TAN = NH_4^+-N + NH_3-N) were determined with the direct nesslerization method, and nitrite was determined with the sulfanil method (Hermanowicz et al. 1999) with a spectrophotocolorimeter (Carl Zeiss 11, Germany).

The mean water temperature during the experiment was 20°C ± 1.2. The oxygen concentration at the outflows did not fall below 8.3 mg O_2 dm^{-3}, and water pH ranged from 7.3-7.6. The maximum content of ammonia nitrogen did not exceed 0.33 mg TAN dm^{-3}, while nitrites did not exceed 0.14 mg NO_2-N dm^{-3}. The water flow through the tanks was constant at 12 dm^3 min^{-1} during rearing.

The fish were fed with an automated band feeder (FIAP, Fischtechnik, Germany). The feed used was from the Nutra commercial feed line (Nutreco, France) with a protein content of 52%, lipid content of 20%, and a digestible energy of 19.9 MJ kg^{-1}. For the first three weeks of the experiment, the fish were fed feed T-1.5 (with a granule size of 1.5 mm), then, for a week, this feed was mixed with feed T-1.9 (with a granule size of 1.9 mm) at a proportion of 50:50. From the fourth week, only feed T-1.9 was used. The daily feed ration was calculated based on pikeperch biomass, and for the first four weeks of the experiment it was 4% of the stock biomass, and then it was reduced to 3%.

Experimental procedures and statistical analysis

In order to determine fish growth rates and condition, the feed conversion ratio, and the daily feed ration, the fish were measured every 14 days. Twenty-five pikeperch and 10 sterlet were retrieved from each tank to determine their body weight (± 0.1 g) and body length (± 1 mm). These measurements were performed after the fish had been anesthetized in a Propiscin anesthetic aqueous solution (Kazuń and Siwicki 2001) at a dose of 0.8 ml dm^{-3}. At the conclusion of the experiment, the total stock biomass of each tank was determined, and all the fish from each rearing tank were counted to determine stock survival and losses to cannibalism.

The following indexes were calculated:

- daily growth rate, DGR (g d^{-1}) = (final body weight (g) – initial body weight (g)) × rearing $time^{-1}$ (days);
- specific growth rate, SGR (% d^{-1}) = 100 × (ln final body weight (g) – ln initial body weight (g)) × rearing $time^{-1}$ (days);
- body weight variation coefficient, CV (%) = 100 × (body weight standard deviation (g) × mean body $weight^{-1}$ (g));
- Fulton condition coefficient, K = 100 × (body weight (g) × body length Lc^{-3} (cm)),
- stock survival, S (%) = 100 × (final number (specimens) × initial $number^{-1}$ (specimens));
- feed conversion ratio, FCR = weight of feed delivered (g) × (final stock biomass (g) – initial stock biomass $(g))^{-1}$.

On the penultimate day of rearing oxygen consumption (OC, mg O_2 kg^{-1} h^{-1}) and ammonia excretion (AE, mg TAN kg^{-1} h^{-1}) were measured. The calculations were done with the following formulas:

$$OC = (O_{in} - O_{out})\, Q\, B^{-1}$$

$$AE = (A_{out} - A_{in})\, Q\, B^{-1}$$

where: O_{in} and O_{out} (mg dm^{-3}) – oxygen content of inflowing and outflowing tank water, A_{out} and A_{in} (mg dm^{-3}) – ammonia content of inflowing and outflowing tank water , Q (dm^3 min^{-1}) – water flow through the tanks, B (kg) – biomass of the fish in the tanks.

Oxygen and ammonia contents were measured throughout the daily cycle every two hours.

The results obtained were analyzed statistically with Statistica for Windows 7.1 (StatSoft, Inc. 2004). Significant differences among the mean values of the rearing indicators, oxygen consumption, and ammonia excretion in the groups analyzed were determined with single factor analysis of variance (ANOVA) and Tukey's test (HSD) ($P \leq 0.05$).

Results

Pikeperch weight and length growth was similar in the different groups (Table 1), and the differences were not statistically significant, nor were the mean specific (SGR) or daily (DGR) values of body weight growth. The feeding coefficient values calculated based on pikeperch biomass growth ranged from 1.13 (group S20) to 1.19 (group S). Final pikeperch survival rates ranged from 95.6% in group S to 97.7% in group S20 ($P > 0.05$).

The sterlet growth rates in the polyculture groups differed, and after eight weeks of rearing the sterlet from group S10 had achieved a body weight 86.4 g, which was 18.5% higher than that of the sterlet in group S20 ($P < 0.05$, Table 1). Daily (DGR) and relative (SGR) sterlet body weight growth in these two groups also differed statistically ($P < 0.05$). Sterlet survival in both groups were 100%. At the conclusion of the experiment the share of sterlet in comparison to pikeperch biomass increased and was 30.7% in group S10 and 46.3% in group S20.

Different feed conversion ratio values were noted when total fish biomass increases (pikeperch and sterlet together) were considered. The highest value was in the pikeperch monoculture (1.19) and it decreased as the additional sterlet biomass increased. In group S10, the FCR was 0.84, and in group S20 it was 0.74. The FCR values in these groups were statistically significantly lower than in group S (Fig. 1).

The mean oxygen consumption values ranged from 242.7 (group S10) to 271.0 mg O_2 kg^{-1} h^{-1} (group S) ($P > 0.05$). The mean ammonia excretion values were from 7.1 to 7.8 mg TAN kg^{-1} h^{-1} ($P > 0.05$). No statistically significant differences were noted in the maximum or minimum OC or AE values (Table 2).

Discussion

The additional sterlet stock did not have a negative impact on the results of rearing juvenile pikeperch. The growth and survival rates in the mono- and polyculture

Table 1

Final rearing results for pikeperch (*S. lucioperca*) reared with sterlet (*A. ruthenus*) (mean values ± SD, n = 4) (group S – pikeperch without additional sterlet stock, group S10 – pikeperch with sterlet stock comprising 10% of pikeperch biomass, group S20 – pikeperch with sterlet stock comprising 20% of pikeperch biomass)

Parameters	Group S	Group S10	Group S20
Pikeperch			
Final body weight (g)	18.9 ± 0.9[a]	19.4 ± 1.6[a]	18.7 ± 0.7[a]
Final body length (cm)	11.6 ± 0.1[a]	11.7 ± 0.3[a]	11.6 ± 0.2[a]
Daily growth rate DGR (g d^{-1})	0.30 ± 0.02[a]	0.27 ± 0.03[a]	0.25 ± 0.01[a]
Mean specific growth rate SGR (% d^{-1})	2.62 ± 0.09[a]	2.70 ± 0.12[a]	2.62 ± 0.08[a]
Feed conversion ratio FCR	1.19 ± 0.15[a]	1.16 ± 0.11[a]	1.13 ± 0.07[a]
Fulton's condition coefficient	1.17 ± 0.02[a]	1.17 ± 0.02[a]	1.20 ± 0.02[a]
Body weight variation coefficient CV (%)	33.5 ± 2.8[a]	31.4 ± 2.8[a]	28.5 ± 4.5[a]
Survival (%)	95.6 ± 0.8[a]	96.7 ± 1.8[a]	97.7 ± 0.9[a]
Sterlet			
Final body weight (g)	-	86.4 ± 7.1[a]	70.4 ± 2.7[b]
Final body length (cm)	-	21.4 ± 0.4[a]	20.5 ± 0.3[b]
Daily growth rate DGR (g d^{-1})	-	1.44 ± 0.12[a]	1.16 ± 0.06[b]
Mean specific growth rate SGR (% d^{-1})	-	4.63 ± 0.14[a]	4.26 ± 0.09[b]
Fulton's condition coefficient	-	0.88 ± 0.03[a]	0.82 ± 0.01[b]
Body weight variation coefficient CV (%)	-	17.7 ± 1.5[a]	18.8 ± 5.5[a]
Survival (%)	-	100.0 ± 0.0[a]	100.0 ± 0.0[a]

*Values in the same row with the same letter index do not differ significantly statistically (P > 0.05)

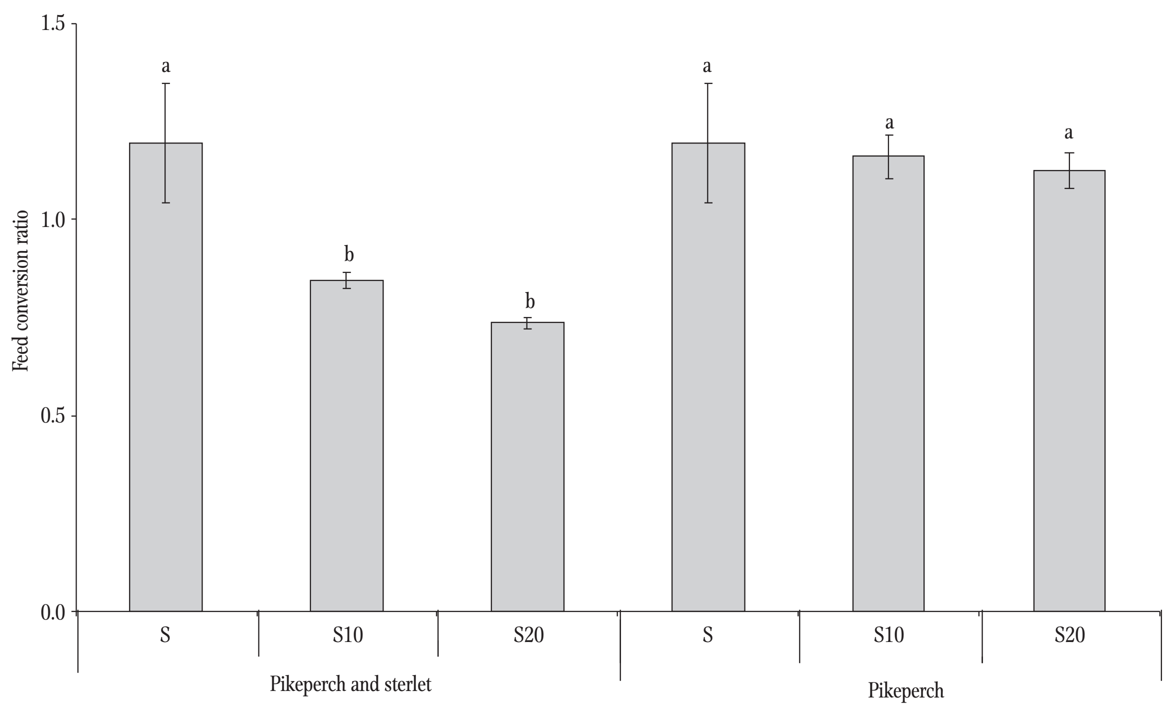

Figure 1. Feed conversion ratios of pikeperch (*S. lucioperca*) reared with sterlet (*A. ruthenus*) (mean values ± SD, n = 4) (group S – pikeperch without additional sterlet stock, group S10 – pikeperch with sterlet stock comprising 10% of pikeperch biomass, group S20 – pikeperch with sterlet stock comprising 20% of pikeperch biomass).

Table 2

Oxygen consumption and ammonia excretion in the pikeperch (*S. lucioperca*) stock reared with sterlet (*A. ruthenus*) (group S – pikeperch without additional sterlet stock, group S10 – pikeperch with sterlet stock comprising 10% of pikeperch biomass, group S20 – pikeperch with sterlet stock comprising 20% of pikeperch biomass)

Groups	Oxygen consumption (mg O_2 kg^{-1} h^{-1})			Ammonia excretion (mg TAN kg^{-1} h^{-1})		
	Mean*	Maximum*	Minimum*	Mean*	Maximum*	Minimum*
Group S	$271.0^a \pm 29.1$	$301.4^a \pm 27.1$	$237.9^a \pm 29.1$	$7.3^a \pm 2.5$	$14.1^a \pm 1.0$	$1.7^a \pm 0.1$
Group S10	$242.7^a \pm 21.8$	$275.2^a \pm 9.8$	$211.0^a \pm 28.3$	$7.1^a \pm 2.8$	$14.8^a \pm 4.7$	$1.9^a \pm 1.3$
Group S20	$270.3^a \pm 11.9$	$295.7^a \pm 12.7$	$238.7^a \pm 17.0$	$7.8^a \pm 3.1$	$13.5^a \pm 1.6$	$2.2^a \pm 0.9$

*Values in the same column with the same letter index do not differ significantly statistically ($P > 0.05$)

groups were similar. The feed rations applied in our experiment were those recommended for pikeperch (Zakęś et al. 2006, Kozłowski et al. 2010), and the feed coefficient values were similar to those reported in other studies (Zakęś et al. 2003, Kozłowski et al. 2009). Despite this, a portion of the feed was not consumed, and it would have been wasted. The additional sterlet stock resulted in significantly improved feed utilization, which is evidenced by the reduced feed coefficients. In effect, the added value of the sterlet biomass was obtained with the same quantity of feed.

The possibility of rearing pikeperch and sterlet in polyculture is possible primarily because of the behavioral differences of these two species and the different feeding strategies they employ; pikeperch gathered in the near-surface water layer near the feeder and mainly took feed from the water column (Kozłowski et al. 2008), while sterlet occupied the near-bottom water layer. This is why these two species did not compete directly for feed. The pikeperch consumed fed floating in the water column, while the feed they did not eat sank to the bottom where sterlet ate it. Pikeperch mortality during rearing was low (3.3-4.4% of the initial stock) and appeared to be associated primarily with mutually inflicted injuries (type II cannibalism; Baras et al. 2000). The fish exhibited mostly injured caudal fin and caudal peduncles. The present results are confirmed by previous studies that indicated that losses to cannibalism are low when larger material is of similar size (Zakęś 2009, 2012, Kozłowski et al. 2010). No instances of mutual aggression between the pikeperch and sterlet were observed, which is probably linked with the similar sizes of the fishes. Aggressive behavior in sterlet is limited to prey of relatively small size because of the relatively small mouth of this species.

Introducing the additional fish stock influenced the aquatic environment. In the current experiment, the sterlet stock played a very useful role by removing surplus feed and most of the solid pikeperch excrement. This reduced rearing tank maintenance work, and in the current experiment the unconsumed feed had to be removed from the monoculture tank daily, but only once per week in the tanks stocked with the polyculture. This is especially important with fish such as pikeperch that are sensitive to any kind of manipulation in the tanks. Similar observations have been described when rearing juvenile pike and Siberian sturgeon, *Acipenser baerii* Brandt in a recirculating system (Szczepkowski and Szczepkowska 2006) and when rearing sturgeon in a pond in which these fish cleaned the bottom of detritus (Kolman 1998).

The additional fish stock also had an impact on the concentrations of oxygen and ammonia nitrogen in the rearing tanks. The mean oxygen consumption and ammonia excretion values did not differ among the groups studied, which indirectly indicates that the levels are similar in both species. Since total fish biomass was higher in the polyculture stocks, the total oxygen consumption and ammonia excretion in these tanks was also higher. At the end of the experiment, OC in the polycultures was higher by 21.4% in group S10 and 45.9% in group S20 in relation to group S. This is because of the necessity of covering additional oxygen consumption and the removal of excreted ammonia nitrogen. Another shortcoming of rearing two species in one tank is the necessity of sorting them when rearing is finished.

The results of the experiment indicate that the addition of sterlet to the basic pikeperch stock during rearing in a recirculating system resulted in substantially better feed utilization and reduced the labor intensity of tank maintenance.

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