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PROOF

RESEARCH PAPER

Effect of Parental Origin on Dry Feed Habituation and Intensive on-Growing Results in Pikeperch (*Sander lucioperca*) Offspring

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Abstract

In pikeperch culture, breeders are often sourced from natural stocks and possible benefits of using intensively cultured breeders to produce stocking material for intensive rearing purposes remain unknown. Therefore, the effect of parental origin on the success of pikeperch juvenile culture was investigated in present study. Two phases were investigated, weaning of pond-reared fry and initial on-grow of weaned juveniles, i.e. fingerling rearing phase. Two batches of 5-day-old larvae originating from intensively reared (CULTURE) and wild breeders (WILD) were stocked in two ponds for larval nursing. One month later, juveniles were harvested and stocked in five tanks per group for the evaluation of the success of habituation to intensive rearing conditions. At the age of 3 months, the 6-week trial on intensive on-grow performance was established. WILD fish exhibited a higher habituation success and survival during the period of habituation to the formulated diets than CULTURE fish. After 6 weeks of intensive on-grow, CULTURE juveniles exhibited a significantly higher specific growth rate. It seems that early domestication does not have positive effect on the weaning of pond-nursed juveniles. However, juveniles originating from cultured broodstock appear to be more appropriate stocking material for intensive on-grow.

Keywords: Domestication, pikeperch juveniles, RAS.

Introduction

Unlike farmed terrestrial animals, most cultured fish species do not originate from genetically improved stocks (Gjedrem, 2000; Teletchea & Fontaine, 2014). Occasionally, one life-stage of the biological cycle (usually breeders, or juveniles) are still sourced from natural stocks (Teletchea & Fontaine, 2014). A similar trend can be found in pikeperch (*Sander lucioperca*), a fish able to answer on rather high production costs in recirculation aquaculture system (RAS) due to its favourable flesh quality and attractiveness to the recreation fisheries and, consequently, significant and constant market demand (Ruuhijärvi & Hyvärinen, 1996; Kestemont, Xueliang, Hamza, Maboudou, & Toko, 2007; Wang, Xu, & Kestemont, 2007; Dalsgaard, Lund, Thorarinsdottir, Drengstig, Arvonen, & Pedersen, 2013). In this rather young culture wild breeders are often caught before or during the spawning season and then propagated to obtain stocking material (Rónyai, 2007; Müller-Belecke & Zienert, 2008 Khemis, Hamza, Messaoud, Rached, & M'Hetli, 2014). Some commercial-scale farms have recently been established and preliminary selection processes have been initiated on this species, which is an issue of interest for both farmers and researchers (Bertigny, 2013; Blonk, Komen, & Kamstra, 2014; Fontaine & Tsigenoupoulos, 2014). The majority of published results on pikeperch juvenile performance have not described the origin of fish in the context of the production background of their parents (Rónyai & Csengeri, 2008; Schulz, Huber, Ogunji, & Rennert, 2008; Bódis & Bercsényi, 2009; Wang *et al*., 2009). To our knowledge, there is just one study which evaluated fingerling performance in intensive conditions in this species with respect to their parental origin (Ljubobratović *et al*. 2015b). In this context, there is wide scope and interest to initiate studies that evaluate the possible consequences of parental origin and domestication processes on production performance parameters of offspring.

In order to produce pikeperch juveniles usable for intensive on-grow (i.e. accepting the commercial feed growers), two technological solutions have been described: 1) intensive larval rearing in RAS (Kestemont *et al*., 2007; Szkudlarek & Zakęś, 2007) and 2) extensive pond nursing and habituation of juveniles to formulated feeds and further rearing in RAS (Szkudlarek & Zakęś, 2002; Policar, Stejskal,

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Kristan, Podhorec, Svinger, & Blaha, 2013). The latter is not considered favourable for RAS production (seasonal periodicity and threatened bio-security). However, due to low farming effectiveness, expressed mainly in the variable numbers of juveniles produced in intensive system, habituation of pond-nursed juveniles still presents a significant share and perspective of production of stocking seeds for intensive aquaculture, which could be a favourable quality (Policar *et al*., in press). Adjusting extensively reared month-old juveniles to intensive on-grow conditions, requires habituation to two critical changes—environmental and nutritional. Extensive outdoor pond rearing is natural-like and implies a relatively small number of animals in a given area, while in the RAS, fish are reared in constant artificial conditions, where the stocking density is much higher. Thus, this transition period can be considered stressful for the young fish. Reviews on the changed behaviour between domesticated and wild fish argue about how these groups of fish respond to various stressful situations (Ruzzante, 1994; Huntingford, 2004). Therefore, it is of significant importance to evaluate if and how the habituation to an intensive system changes with respect to the fish origin.

The present study aimed to evaluate the parental effect of an early domestication (first generation) on the farming effectiveness in pikeperch. The study involved two critical culture periods, specifically, habituation of pond-reared juveniles to intensive conditions and initial on-grow of 3-month-old juveniles. The performance of the fish was evaluated by forming a referent population from juveniles originating from wild breeders.

Materials and Methods

Breeders' Origin, Husbandry, Propagation Success and Pond Rearing of Juveniles

Virgin breeders were produced in the RAS at the H & H Carpio Fish Farming Ltd (Ócsard, Hungary) site and fed exclusively with formulated diets. Out of a total sample of 52,000 fish, the largest 2000 4-mo-old juveniles were selected and further reared. Once the fish reached a mean weight of 100 g, the largest 100 fish were finally selected for broodstock. Throughout their RAS rearing, fish were fed exclusively with commercial feed of pellet sizes 1 to 8 mm given according to the fish growth recommendation of the feed producer (Coppens International, The Netherlands). According to the manufacturer's information, the proximate composition of the feed SteCo SUPREME-10 of pellets sizes 3.0, 4.5, 6.0 and 8.0 mm was: 49% protein, 10% fat, 8.3% ash, 0.8%crude fibre, and 1.3% total phosphorus, while the feeds of 1.0, 1.5 and 2.0 mm pellet sizes were the identical to those used for the juvenile rearing in the present study. In October 2014, when the fish were 18 months old, one hundred individuals with body weights between 1 and 1.5 kg were stocked in a pond supplied with forage fish. In November 2014, a batch of fish were randomly chosen and transported to the outdoor earthen pond of the Research Institute for Fisheries and Aquaculture (NARIC HAKI) (Szarvas, Hungary). In mid-October, wild breeders were harvested from the oxbow of the Körös river and transported to the other earthen pond of the institute. Both ponds were stocked with prey fish at a ratio of 100% of pikeperch. Prey fish, with individual length 10-15 cm, consisted of bleaks (*Alburnus alburnus*), rudds (*Scardinius erythrophthalmus*), roaches (*Rutilus rutilus*), breams (*Abramis brama*), and common carps (*Cyprinus carpio*). These fish species are the common natural food for the pikeperch in most of the water bodies in Hungary and thus were stocked in the ponds as the food source of appropriate quality for pikeperch wintering. Following hormonal injection with human chorionic gonadotropin, breeders were artificially propagated in mid-April of the following year, during the natural spawning season. Each group of breeders was formed from males and females with similar individual body weight. Considering reproductive success, there were no significant differences in the mean 72-h post-fertilisation embryo survival (42.1 ± 33.8 and 30.5 ± 26.3%) and mean hatching rate (44.3 ± 42.9 % and 67.8 ± 34.3%) between the RAS and wild fish, respectively. Larvae were obtained from five wild and four RAS females and, upon hatching, stocked into two separate tanks. At 5 d post-hatch (DPH), 100,000 larvae from each group were stocked into two ponds (each group in one pond). Each pond was of equal shape, dimensions and area 0.14 ha situated one next to other, and biomanipulation of each pond was done by the same protocol—fertilising with cow manure; filling up the pond to the half of the maximal level 7 days prior to stocking; increasing the pond level to maximal two weeks after stocking and final harvest on the same day.

Trial 1. Habituation of Pond-Reared Juveniles to the Intensive Rearing Conditions

The trial comprised two periods, namely, a 12-d habituation to dry feed and a 9-d post-habituation to dry feed. At 37 DPH, juveniles from each pond were harvested, transported to the indoor facility and stocked into a RAS consisting of ten, 80-L, black tanks. Five tanks were stocked with fish originating from wild breeders—WILD group (mean weight 0.345 ± 0.046 mg); and five tanks were stocked with juveniles originating from intensively reared breeders—CULTURE group (mean weight 0.449 ± 0.083 mg); resulting in five replicates per parental origin. Each tank was stocked with 500 fish. Just before stocking into RAS, a sample of 30 fish from each group was measured for individual weight (± 0.01 g) and total length (± 1 mm).

Trial 1. Period of Habituation to Dry Feed

One day after stocking into RAS, juveniles began habituation on the formulated diet. Dry feed habituation consisted of gradually changing the offered food from frozen bloodworms (*Chironomus* sp.) to the formulated diet of 1.0 mm pellet size Coppens SteCo Start Premium (Coppens International, Helmond, Netherlands; 54.0% protein, 15.0% fat, 1.0% crude fibre, 9.4% ash, 1.6% total phosphorus) for 12 d (38−50 DPH). Figure 1 shows the feeding protocol during the habituation.

Manual feeding with wet food (bloodworms and mixed bloodworms with formulated feed) was done by supplying four equal daily meals from 10:00−11:00, 14:00−15:00, 17:00−18:00 and 21:00−22:00 h. The dry formulated feed was provided by a mechanical belt feeder (4305 FIAP belt feeder; Aquacultur Fishtechnik, Germany) from 49 DPH onward for 18 h/day. At 51 DPH, fish were harvested from each tank, counted and separated into the following three fractions:

- starved—fish with obvious signs of starvation;
- big fish—dramatically larger compared to the majority of the population (assumed cannibals);
- habituated fish—fish without clear signs of starvation, with a size range similar to that of the majority of the population.

Separation was done by visual examination of the fish as explained by Horváth, Németh, Beliczky, Felföldi, and Bercsényi (2013). Thirty habituated fish from each tank were measured for individual wet weight (± 0.05 g) and photographed for length measurement.

Trial 1. Period Post-Habituation to Dry Feed

After grading, all habituated fish from each group were pooled together and further stocked into three tanks (three replications per parental origin) for 9 d of post-habituation rearing (51−59 DPH). Stocking density was 356 fish (4 g L^{-1}) in the CULTURE group tanks and 450 fish (3 g L^{-1}) in the WILD group tanks. During the period of post-habituation to dry feed, the feeding diet consisted exclusively of Coppens SteCo Start Premium, 1.0 and 1.5 mm pellet size formulated feed (Coppens International, Helmond, Netherlands). The feed was supplied by a mechanical belt feeder for 18 h/day. At 60 DPH, all the fish were removed from the tanks, counted and a sample of 30 fish per tank was measured for weight (± 0.05 g) and photographed for length determination. The total length of the fish was calculated using ImageJ 1.34 software (Bethesda, Maryland).

The tanks were cleaned twice daily at 08:00–09:00 and 20:00–21:00 h. At the time of each cleaning, the number of dead fish was recorded and valued as “detected mortality”. Fish were kept under stimulated photoperiodic regimes of light:dark (LD) 24:0 h and the light intensity measured at the surface of the tanks was 10–20 lux. Water flow in all tanks was set on one exchange per hour. Oxygen satiation and temperature were monitored daily, while the samples for examination of basic water quality parameters were recorded twice weekly, at the outflow of one randomly chosen tank from each group.

Trial 2. On-Grow Production Performance of Juveniles

Three weeks after the habituation trial (81 DPH), the fish were transferred to six, 275-L, grey tanks set in the same RAS where the fish were habituated on dry feed. At 92 DPH, three tanks were stocked with fish from the CULTURE and WILD group, respectively, resulting in triplication of each group. Each tank was stocked with 150 fish. The replicates

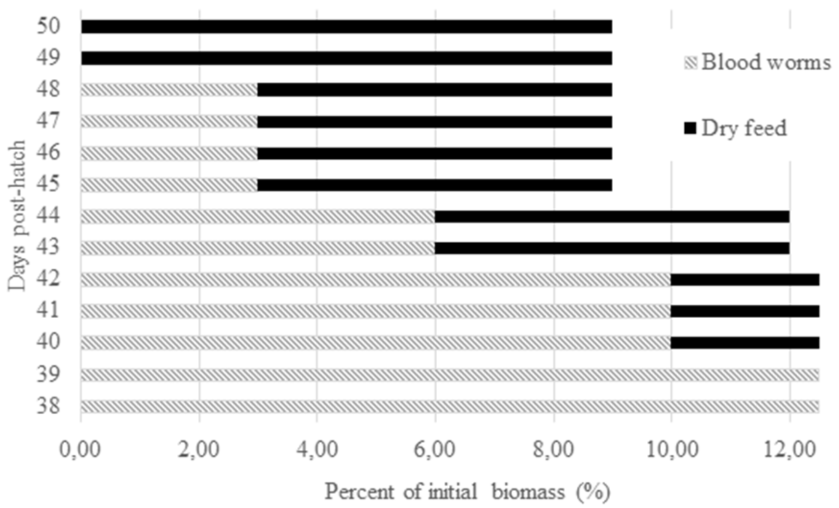

Figure 1. Feeding schedule during the period of habituation to the dry feed of pond-nursed pikeperch juveniles (38–50 days post-hatch).

were formed with respect to minimising the in-tank size variation.

During the trial, each feeding was performed until apparent satiation, i.e. until the ingestion of the feed particles visibly ceased. At the moment when non-ingestion of several pellets was observed, the feeding was stopped. The uneaten feed was not collected and reweighed, allowing only to evaluate the apparent feed conversion rate (AFCR) values. During the first 2-wk of the trial, the fish were fed three times daily, at 10:00–11:00, 14:00–15:00 and 21:00–22:00 h. It was noticed that the afternoon feeding was excessive, as the fish showed little or no interest in the feed. Therefore, in the following 4-wk of the trial, the fish were fed only twice daily, at 10:00–12:00 and 21:00–23:00 h. The fish were fed with 2.0 mm pellet size Coppens SteCo Pre Grower-14 (Coppens International, Helmond, Netherlands; 50.0% protein, 14.0% fat, 1.6% crude fibre, 7.8% ash, 1.0% total phosphorus) exclusively, for the first 4 wk. During the fifth week, the feed was gradually changed to 3.0 mm pellet size SteCo Supreme-10 (Coppens International, Helmond, Netherlands; 49.0% protein, 10.0% fat, 0.8% crude fibre, 7.9% ash and 1.3% total phosphorus) and further given exclusively during the sixth week of the trial. At the beginning and at the end of the trial, all the fish were measured for the individual body weights and 30 fish per tank were measured for individual total lengths. At 2 and 4 wk of the trial, a sample of 30 fish per tank was measured for individual body weight. Weight measurement was done to the nearest 0.05 g, while the length measurement was done to the nearest 1 mm.

The tanks were cleaned once daily, at 08:00–09:00 h. Fish were exposed to the LD 24:0 h photoperiod and the light intensity measured at the surface of the tanks was 0.8–1.2 lux. Water flow in all tanks was set at 75% exchange per hour. Temperature and oxygen content were measured 1 h after the morning meal and 5 d per week, at the outflow of all six tanks. Samples for the examination of basic water quality parameters were taken twice weekly at the outflow of one randomly chosen tank from each group.

Data Analysis and Statistical Procedures

Survival, cannibalism and growth rates were calculated as follows:

- detected mortality (%) = 100 $N_d \times N_i^{-1}$;
- survival (%) = 100 × $N_h \times N_i^{-1}$;
- cannibalism (%) = 100 × $N_m \times N_i^{-1}$;
- specific growth rate (SGR, % day^{-1}) = 100 × $(\mathrm{Ln}W_f - \mathrm{Ln}W_i) \times \Delta T^{-1}$;
- daily growth rate (DGR, g day^{-1}) = $(W_f - W_i)\ \Delta T^{-1}$;
- apparent feed conversion rate (AFCR g g^{-1}) = $F_t \times (W_f - W_i)^{-1}$;
- in-tank body weight coefficient of variation is CV_{weight} (%) = SD × mean tank body weight^{-1},

where:

N_i, N_d, N_h and N_m are the number of initially stocked, died, harvested and missing ($N_m = N_i$-N_d-N_f) fish, respectively;

W_i and W_f = initial and final mean individual body weights (g);

ΔT =duration of calculated period (days);

F_t = total given feed.

Data are presented as the mean ± standard deviation (SD). Prior to analysis, all the percentage variables were arcsin-transformed. The distributions of the variables were tested with one-sample Kolmogorov-Smirnov tests. Differences between the groups were analysed using an independent t-test, for data with a normal distribution, and the Mann-Whitney U test, for data with unknown distribution. The significance level was set at $P \leq 0.05$. Analyses were performed using SPSS 22.0 software (IBM, New York, NY, USA).

Results

The only significant difference in the assessed water quality parameter during the trials was in the pH value, being lower at the outflow of CULTURE group. Water quality parameters are presented in Table 1.

Habituation to Intensive Conditions of Pond-Reared Juveniles

At the end of the pond nursing phase (37 DPH), signs of cannibalism were seen among the CULTURE fish as there were individuals substantially larger than the majority of the population. The mean initial weight, length and coefficient of variation in the CULTURE group were higher compared to the WILD group. During the period of dry feed habituation, the WILD fish exhibited a significantly higher survival and habituation, while the CULTURE fish showed a significantly higher growth but, simultaneously, a significantly higher cannibalism. On the contrary, during the period post-habituation to dry feed, a significantly higher survival was recorded in the CULTURE group, while in the WILD fish, both growth and cannibalism were significantly higher (Table 2).

On-Grow Production Performance of 3-Month-Old Juveniles

During the on-grow trial, the CULTURE fish showed a significantly higher growth performance compared to WILD fish (Table 3).

Significant differences were found between the two groups regarding final weight, SGR, DGR and AFCR, and all favoured the CULTURE group. Growth was constantly higher in the CULTURE fish and the first significant difference in the SGR was

Table 1. Water quality parameters during the trials

Parameter	Culture	Wild
Trial 1 – Habituation of pond-nursed fry to intensive rearing conditions		
Temperature during habituation to dry feed (°C)	21.8 ± 0.9	
Oxygen saturation during habituation to dry feed (%)	82.7 ± 3.6	85.3 ± 3.5
Temperature after habituation to dry feed (°C)	23.6 ± 0.6	
Oxygen saturation after habituation to dry feed (%)	83.7 ± 1.2	83.0 ± 1.8
Ammonium-nitrogen (mg L^{-1})	0.36 ± 0.25	0.36 ± 0.24
Nitrite-nitrogen (mg L^{-1})	0.03 ± 0.01	0.03 ± 0.01
pH	8.2 ± 0.1	8.2 ± 0.1
Trial 2 - On-grow production performance of juveniles		
Temperature (°C)	24.1 ± 0.8	
Oxygen saturation (%)	78.2 ± 5.3	83.1 ± 3.4
Ammonium-nitrogen (mg L^{-1})	0.46 ± 0.20	0.43 ± 0.26
Nitrite-nitrogen (mg L^{-1})	0.06 ± 0.01	0.06 ± 0.01
pH	7.9 ± 0.1*	8.0 ± 0.1*

Data in the row significantly different between each other are marked with an asterisk in the superscript

Table 2. Performance parameters of pond-reared pikeperch juveniles with different parental origin during the habituation to intensive rearing conditions (38–59 days post-hatch)

Parameter	WILD[a]	CULTURE[b]	P-value
Period of habituation to dry feed (38–50 days post-hatch)			
Initial body weight	0.345 ± 0.046	0.449 ± 0.083	/
Initial CV_{weight} (%)	13.2	18.5	/
Initial total length (mm)	35.0 ± 2.0	38.1 ± 2.7	/
Survival (%)	76.8 ± 4.5	67.3 ± 6.4	0.005
Detected mortality (%)	3.8 ± 1.9	2.2 ± 0.7	0.130
Cannibalism (%)	19.4 ± 5.3	30.4 ± 3.5	0.005
Habituation success (%)	54.1 ± 2.6	42.8 ± 2.8	<0.001
Final body weight (g)	0.48 ± 0.04	0.90 ± 0.05	<0.001
Final total length (mm)	40.3 ± 0.8	47.3 ± 1.7	<0.001
Final CV_{weight} (%)	29.7 ± 3.6	23.3 ± 3.8	0.027
SGR (% day^{-1})	2.7 ± 0.6	5.7 ± 0.5	<0.001
Period post-habituation to dry feed (51–59 days post-hatch)			
Survival (%)	62.5 ± 2.7	86.1 ± 0.9	<0.001
Detected mortality (%)	9.2 ± 4.8	3.9 ± 2.1	0.162
Cannibalism (%)	21.3 ± 6.6	9.9 ± 2.6	0.013
Final body weight (g)	1.14 ± 0.06	1.31 ± 0.12	0.095
Final total length (mm)	51.3 ± 1.7	55.6 ± 1.5	0.032
Final CV_{weight} (%)	39.3 ± 2.3	29.9 ± 1.5	0.004
SGR (% day^{-1})	9.6 ± 0.6	4.2 ± 1.0	0.001

[a]WILD – juveniles originating from wild breeders; [b]CULTURE – juveniles originating from indoor reared breeders; CV – in-tank individual body weight coefficient of variation; initial weight, length and CV_{weight} were calculated based on the sample of 30 fish from each of the groups; SGR – specific growth rate; period of habituation to dry feed: number of replications n = 5, number of fish per replication n = 500; period post-habituation to dry feed: number of replications n = 3, number of fish per replication - CULTURE n = 356, WILD n = 450.

noticed at 4 wk of the trial, 120 DPH (3.7 ± 0.0 and 3.3 ± 0.1% day^{-1} in the CULTURE and WILD fish, respectively, Figure 2).

Discussion

The cultured parental origin of month-old pond-reared juveniles did not lead to increased success of habituation to formulated feed compared to fish of wild origin. The main reason for lower habituation success in the CULTURE fish could be the significantly higher cannibalism rate during the period of habituation to the dry diet. Literature results are inconsistent regarding the correlation between artificial selection and agonistic behaviour in fish. While some studies found that domestication reduces aggression (Robinson & Doyle 1990; Ruzzante & Doyle, 1991, 1993), others observed increased agonistic behaviour among domesticated fish compared to wild ones (Swain & Riddell, 1990; Mesa, 1991). Cannibalism is an inevitable phenomenon in the culture of predatory fish (Kubitza & Lovshin, 1999; Kestemont *et al*., 2003) and rather high losses due to cannibalism have been reported in pikeperch during the transition from live to inert diets in both post-larvae (Ljubobratović *et al*., 2015a) and juveniles (Szkudlarek & Zakęś, 2002). Thus, loss due to cannibalism could be characterised as a sign of

Table 3. Performance parameters of pikeperch juveniles with different parental origin after 6 weeks of intensive on-grow (92–134 days post-hatch)

Parameter	Wild[a]	Culture[b]	P-Value
Initial body weight (g)	5.6 ± 0.0	7.0 ± 0.0	<0.001
Initial CV_{weight} (%)	13.0 ± 0.3	12.9 ± 0.4	0.605
Initial total length (cm)	8.7 ± 0.4	9.8 ± 0.5	0.039
Final body weight (g)	15.0 ± 1.8	26.0 ± 0.2	<0.001
Final CV_{weight} (%)	37.0 ± 4.6	31.8 ± 1.3	0.135
Final total length	12.6 ± 0.2	14.5 ± 0.3	0.001
SGR (% day^{-1})	2.3 ± 0.3	3.1 ± 0.0	0.001
DGR (g day^{-1})	0.22 ± 0.04	0.45 ± 0.00	0.001
AFCR (g g^{-1})	1.4 ± 0.1	1.0 ± 0.0	0.01
Survival (%)	99.1 ± 0.8	98.4 ± 0.8	0.362

[a]WILD – juveniles originating from wild breeders; [b]CULTURE – juveniles originating from indoor grown breeders; CV_{weight} – in-tank individual body weight coefficient of variation; SGR – specific growth rate; DGR – daily growth rate; AFCR – apparent feed conversion rate; number of replications n = 3; number of fish per replication n = 150.

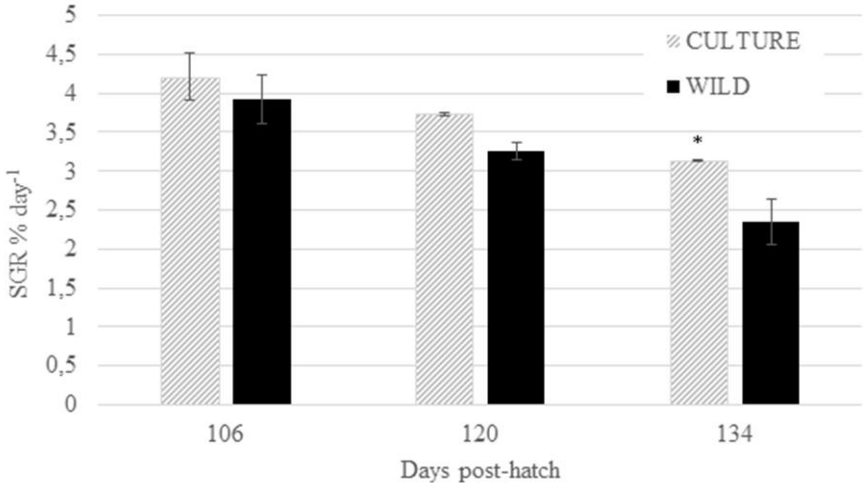

Figure 2. Specific growth rates of pikeperch juveniles of different parental origin during the 6 weeks (92–134 days post-hatch) on-grow trial after each 2 weeks of rearing. CULTURE – juveniles originating from indoor reared breeders; WILD – juveniles originating from wild breeders; SGR – specific growth rate. Columns marked with an asterisk are significantly different (P≤0.05).

agonistic behaviour in this species. Our results during the period of habituation to dry feed, suggest that CULTURE fish displayed stronger agonism when compared with the WILD group. However, in the subsequent post-habituation period, cannibalism was significantly lower in this group. It implies that until the fish accepted dry feed, agonistic behaviour was increased in the fish originating from intensively reared breeders, while once the dry feed was accepted these fish exhibited a calmer behaviour.

Nevertheless, there are facts to consider in interpreting above mentioned findings. At the beginning of the trial, signs of cannibalism were noticed in the CULTURE group that was not observed in the WILD fish. Even though substantially larger fish were extracted before the trial was established, initial individual body weight variation remained higher in the CULTURE (18.5%) compared to WILD group (13.2%). Beside the origin, there might be additional reason for such different outcomes of extensive larval nursing. Although the ponds were of equal dimensions, biomanipulation technology and position, due to non-replicated ponds, the effect of pond itself cannot be excluded. In this context it should be mentioned that our study did not aim to compare effectiveness of pond and tank rearing methods in pikeperch on-growing rearing, but only to evaluate the possible effect of parental origin on the post-pond culture. This difference in size heterogeneity could influence the cannibalism in the habituation period. Conversely, at the start of post-habituation, density (shown as the number of fish per litre) was higher in the WILD (four fish per litre) compared to the CULTURE group (three fish per litre). However, according to previous studies on the effect of stocking density during the habituation period in pikeperch (Szkudlarek & Zakęś, 2002; Molnar, Hancz, Molnar, & Horn 2004; Policar *et al.*

2013; Ljubobratović, Kucska, Sándor, Péteri, & Rónyai, 2016), it may be implied that this factor does not have a significant effect on the cannibalism.

In terms of growth, the noticed differences between habituation and post-habituation phases follow the same pattern as that reported for cannibalism during these two periods. Therefore, it seems that increased cannibalism finally led to the increased growth, with the smallest individuals most likely preyed. Regarding the above-mentioned distracting factors that could influence this part of the study and the differing outcomes of the two periods of the first trial, we cannot provide a definitive conclusion on the direction the effect of an early domestication has on the success of habituation on intensive conditions in pond-reared juveniles. Thus, it might be considered that for this part of pikeperch culture, technology has a stronger influence over the origin. Nevertheless, additional studies are needed to draw the final conclusions.

Although the indications about the effect of early domestication on the dry feed habituation procedure are not totally conclusive, the effect is somewhat evident during the on-grow of 3-mo-old juveniles. The CULTURE fish exhibited a constantly higher SGR, which reached a level of significance at 4 wk of the trial and the mean DGR was double compared to the WILD fish. Although not totally convincing, previous results on older pikeperch juveniles indicated a similar effect of early domestication on growth, even in the fish originating from extensively cultured breeders compared to wild ones (Ljubobratović *et al*. 2015b). In comparison, the effect of early domestication in sea bass (Millot, Péan, Leguay, Vergnet, Chatain, & Bégout, 2010) on the stress response in fish originating from wild and domesticated breeders, showed the evident improvement of growth after only one generation of domestication, which was attributed to a higher appetite rather than better feed utilisation. Based on results of this study, the same cannot be supposed for pikeperch juveniles, considering that the amount of given feed depended on the interest the fish had for the feed, and no significant differences were noticed in the offered food between the groups (Figure 3). Nevertheless, although the feed utilisation in the CULTURE group seemed to be better, only the AFCR values were calculated, providing just an informative feature.

The growth parameters achieved in the on-growing trial of the present study are in agreement with previous on-growing studies in pikeperch juveniles of similar size. The mean SGRs in our study were 3.1 ± 0.0 and 2.3 ± 0.3% day^{-1} in the CULTURE and WILD group, respectively. Zakęś, Kowalska, Czerniak, and Demska-Zakęś (2006) reported a mean SGR of 2.45 ± 0.05% day^{-1} in the optimal treatment at 22ºC in a 6-wk study. Wang *et al*. (2009) published a mean SGR of 2.0 ± 0.04% day^{-1} in the optimal variant at 28ºC in an 8-wk investigation, while Kozłowski, Zakęś, Szczepkowski, Wunderlich, Piotrowska, and Szczepkowska (2010) obtained a mean SGR of 3.61 ± 0.03% day^{-1} at 24.4ºC in a 12-wk trial. Hence, it may be concluded that the rearing conditions in the present study were suitable for intensive on-grow of pikeperch juveniles.

To conclude, this study represents the first evaluation of the effects of early domestication in pikeperch on two parts of juvenile culture. Habituation to the intensive rearing conditions of pond-nursed month-old juveniles originating from intensively reared breeders did not lead to increased efficacy of this technological procedure compared to fish of wild origin. Due to distracting factors, prior to stronger conclusion, the additional studies are strongly suggested. However, on-grow performance of 3-mo-old juveniles appears to be significantly improved even after one generation of domestication.

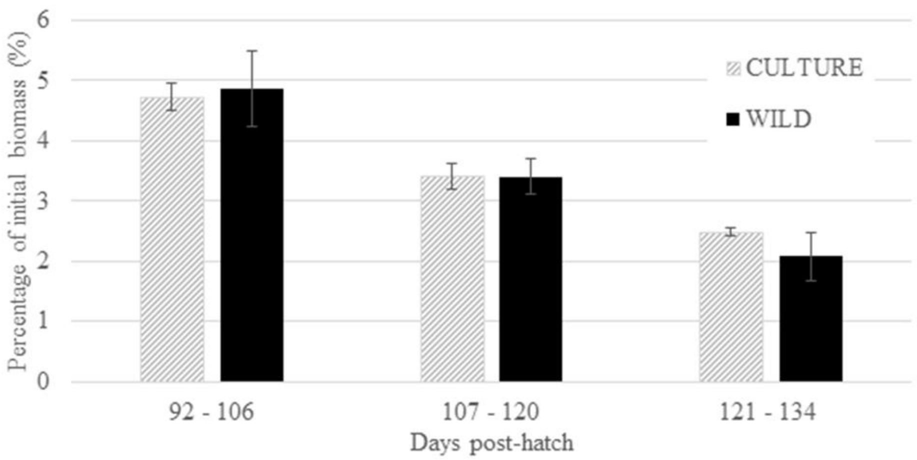

Figure 3. Mean daily feed supply during 6 weeks of pikeperch juvenile on-grow (92–134 days post-hatch).
CULTURE – juveniles originating from indoor reared breeders; WILD – juveniles originating from wild breeders; Fish were fed three times a day during the first 2 weeks and twice a day during the last 4 weeks of the trial. Each feeding was done until the apparent satiation. There were no significant differences between the groups.

In this context, the present study suggests that a comprehensive breeding program on this species would substantially increase the efficacy of pikeperch on-grow in RAS.

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