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Optimalization of rearing aspects in pond and intensive aquaculture
(GA JU 074/2013/Z)

Development and optimalization of intensive culture methods in pikeperch (Sander lucioperca) and Eurasian perch (Perca fluviatilis) in the Czech Republic
(NAZV QI 101C033)

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CONTENT

1. INTRODUCTION

Pikeperch, *Sander lucioperca* (L.) (Fig. 1) is currently one of the most promising fish species reared in European aquaculture (Müller-Belecke and Zienert, 2008; Policar et al., 2013b). This species is very popular with consumers (Dil, 2008) and sport anglers (Pivnicka and Rybar, 2001) thanks to its high-quality meat (Uysal and Aksoylar, 2005). Pikeperch grows fast under optimal conditions and it is possible to culture it in high densities using pellet feed (Policar et al., 2013b). The year-round pikeperch production is quantitatively and qualitatively erratic (Dil, 2008; Müller-Belecke and Zienert, 2008). On the basis of the above-mentioned facts, it is possible to predict an increase in production of pikeperch in European intensive aquaculture (Policar et al., 2013b).

Currently, about 85–90% of European production of marketable pikeperch comes from Russian, Kazakhstan and Estonian lakes. European capture fisheries of marketable pikeperch ranges between 9,000 to 15,000 tons (FAO, 2012b). However, this level of production has been decreasing. In the 1970's, the annual production from capture fisheries in Easter European lakes was about 40,000 tons of marketable pikeperch (Dil, 2008; FAO, 2012a), but this production has been reduced by fifty percent during the last 30–40 years. The main reason for this trend is overfishing and poor fishery management (Dil, 2008; Müller-Belecke and Zienert, 2008).

High popularity with consumers and sport anglers as well as decreasing capture production have led to an insufficient market supply mainly in Western Europe (France, Germany, Austria, Denmark, Belgium and Switzerland) and to an increase in price. Current wholesale price in Western Europe of pikeperch (0.7–2 kg) ranges from EUR 5 to 8 per kilogram and from EUR 6 to 9 per kilogram of fish weighing 2–4 kg (Dil, 2008). Retail price varies from EUR 13 to 15 (Tamazouzt, 2013). In the Czech Republic, an average retail price of marketable pikeperch is about CZK 290–350 (Zvonař, personal communication) which is approximately EUR 11.5–14.

The above-mentioned problems (poorly supplied market, overfishing and lower capture production) of pikeperch market in Europe have forced farmers to focus more on intensive culture of this fish species (Policar et al., 2011, 2013b). Nowadays, pond and intensive pikeperch culture produce only 5–7% (500–1,000 tons) of total production in Europe (FAO, 2012b). In Central and Eastern Europe (Czech Republic, Hungary, Ukraine, Bulgaria, Romania, Poland, Germany), pikeperch is usually reared in pond polyculture. Annual production of marketable pikeperch ranges between 300–500 tons in the mentioned countries. Pikeperch is an additional species cultured in pond polyculture with

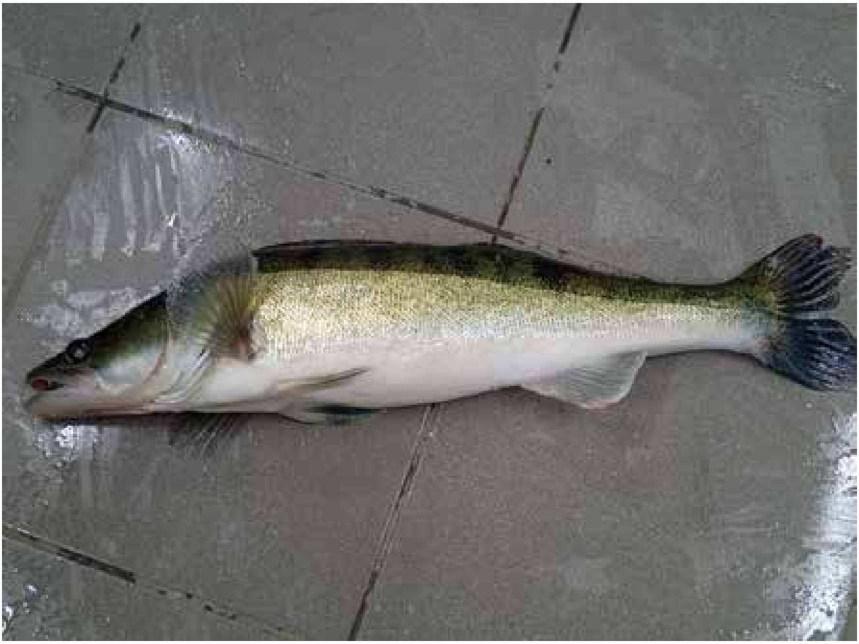

Fig. 1. *Marketable pikeperch, Sander lucioperca (L.), body weight 1,500 g (photo T. Policar).*

the main cultured fish species such as common carp (*Cyprinus carpio* L.), tench (*Tinca tinca* L.), grass carp (*Ctenopharyngodon idella* Valenciennes) and silver carp (*Hypophthalmichthys molitrix* Valenciennes). The main role of pikeperch in this system is to eliminate small cyprinids such as: topmouth gudgeon (*Pseudorasbora parva* Temminck and Schegel) roach (*Rutilus rutilus* Rafinesque), rudd (*Scardinius erythrophthalmus* Bonaparte) and bream (*Abramis brama* L.) (Wedekind, 2008; Adamek et al., 2012; Kratochvil, 2012).

Besides the traditional pond culture, pikeperch has been reared in recirculating aquaculture systems (RAS) in Western Europe in the last fifteen years (Policar et al., 2013b). Pikeperch culture in the RAS has used domesticated fish (Fontaine, 2009), out-of-season spawning (Zakes and Szczepkowski, 2004; Rónyai, 2007; Müller-Belecke and Zienert, 2008), pellet feed (Wang et al., 2009) and high fish densities (30–50 $kg.m^{-3}$; Wedekind, 2008). In the last several years, the intensive pikeperch aquaculture has been developed mainly in Denmark, Holland, Finland, France, Czech Republic, Austria, Germany, Romania, Bulgaria and Croatia (Van Mechelen, 2008; Philipsen, 2008; Policar et al., 2011, 2013b). At present, about 30 companies are producing marketable pikeperch under the RAS conditions (Aquapri and Lyksvad Fish Farm, Denmark; van Slooten Aquacultuur; Excellence fish; Lont en s van Barren and Viskweekcentrum, all based in Holland; Kidus; Savon-Taimen; Imatra Kala ja Kaviari, all based in Finland; LucasPerch and Asialor based in France (Fig. 2); Fish Farm Bohemia based in the Czech Republic; Fishzucht Pottenbrunn based in Austria; Osnabruck Pikeperch farm based in Germany; Sterlet-Timisoara farm based in Romania; Eko-Hidro-90 Ltd. based in Bulgaria; Aqua Campus based in Croatia). The current top RAS producer of pikeperch is a Danish company, Aquapri (www.aquapri.dk) which has been dealing with pikeperch since 2006. This company produced about one million pikeperch juveniles (with body weight of 1 g) and 100 tons of marketable fish (1.2–2 kg) in 2012 (Overton, personal communication, 2012). Only one company in the Czech Republic has been producing pikeperch in the RAS since 2011 (Junek, personal communication, 2011).

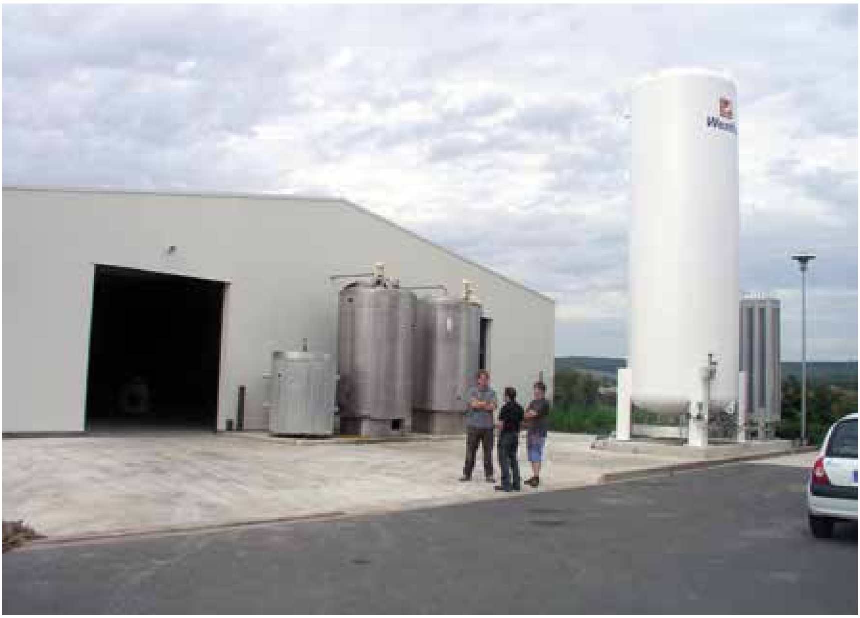

Fig. 2. *Production facility of company Asialor in France for production of marketable pikeperch, Sander lucioperca (L.) built in 2010 (photo T. Policar).*

One group of European pikeperch farmers works with a "closed production cycle" of pikeperch; it includes all fish stages (larvae, juveniles, marketable fish, broodstock). Broodstock are held under regulated environmental conditions (light and water temperature regime) to stimulate the gametogenesis. The main aim of this environmental stimulation is to achieve out-of-season spawning and subsequently, to produce larvae, juveniles and marketable fish year-round (Philipsen, 2008). The second group of European pikeperch farmers uses an open production cycle, which means that the farmers do not have broodstock; they purchase 8–10 g juveniles (van Slooten, personal communication, 2013).

Rearing of pikeperch in the closed production cycle is a very complicated and technologically demanding process, requiring high standards of zoohygiene, high water quality, proper nutrition (Zakes et al., 2006) and size-balanced population (Szczepkowski et al., 2011). Further, environmental and hormone stimulation of broodstock are required for spawning (Rónyai, 2007; Müller-Belecke and Zinert, 2008; Hemerlink et al., 2013; Kristan et al., 2013), plus egg incubation (Musil and Kouril, 2006; Policar et al., 2011) and nursing of larvae must be optimized to produce juveniles and marketable fish (Zakes et al., 2004, 2006; Kestemont et al., 2007; Wang et al., 2009; Lund and Steenfeldt, 2011). The entire rearing process is very challenging and expensive (Schram, 2008). Apart from high production costs, the complicated technological system (closed production cycle) also often results in low oocyte quality and, of course, decreased fertilisation (50–60%) and hatching rates (30–40%). It also is possible to have low quality larvae with a high frequency of body deformations. All these problems can be related to poor nutrition of broodstock in the closed production cycle (Policar et al., 2011).

For these reasons, since 2009 our team of scientists has been developing a process that combines pond culture (Fig. 3) and the RAS system (Fig. 4) for pikeperch production. This approach uses advantages of both pond culture and the RAS. Pond culture is used for broodstock, larvae and juvenile (up to the total length of 35–50 mm) production, providing optimal nutrition for all reared categories. It has a positive effect on broodstock reproduction, larvae viability and production of high quality juveniles. This technological process is not as expensive as production of pikeperch larvae in RAS (Policar et al., 2011). Intensive aquaculture is integrated when pond-cultured pikeperch juveniles are adapted to the RAS with subsequent intensive rearing of juveniles to marketable-size fish under intensive conditions (Policar et al., 2013a,b). This optimized intensive culture provides pikeperch with the best conditions for rapid growth and guarantees high efficiency of the whole rearing cycle (Zakes et al., 2006). According to our experience, it is advisable to apply this rearing technique (combination of pond and RAS culture) especially in countries with a high number of small ponds such as: the Czech Republic, Hungary and Germany.

Fig. 3. *Suitable pond for pikeperch, Sander lucioperca (L.) summer-fry production (photo T. Policar).*

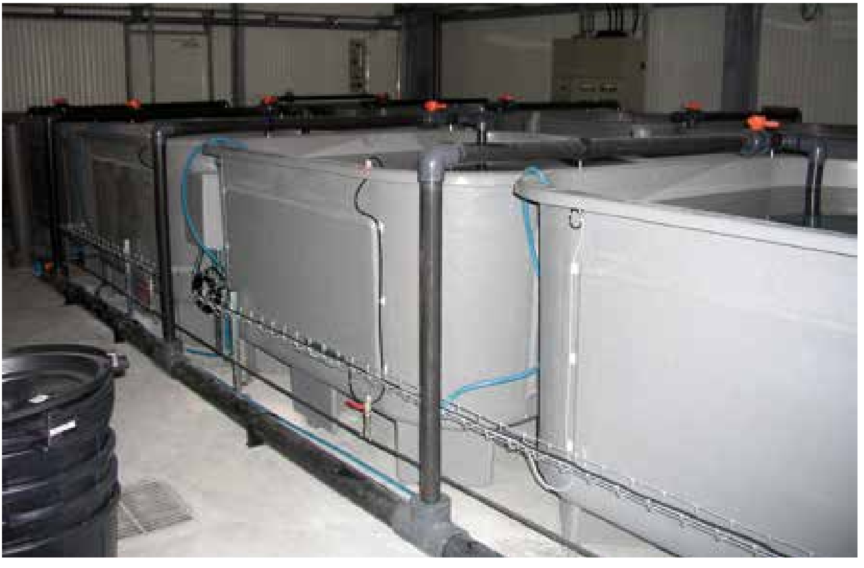

Fig. 4. *Suitable recirculating aquaculture system used for intensive culture of older pikeperch, Sander lucioperca (L.) in Asialor Ltd. company, France (photo T. Policar).*

2. AIM OF THE TECHNOLOGY

The primary objective of this publication is to describe the details of an optimized technological process which includes: 1) introduction of pond-cultured pikeperch juveniles (TL = 40–50 mm) into the RAS, 2) food and space adaptation of pond-cultured fish to the RAS, and 3) subsequent intensive culture of adapted fish in the RAS up to the body weight of 8 to 50 g. The next tasks were to observe and take care of health condition of fish before the stocking to RAS and during their intensive culture by using therapeutic and preventive treatments and to perform a regular sorting or size-grading so as to keep comparable-size fish in the culture system. An important component of the developmental process was to make a financial analysis to calculate the final product price i.e. an 8 g pikeperch juveniles. The last step was to make a market research and search for possible prospective buyers.

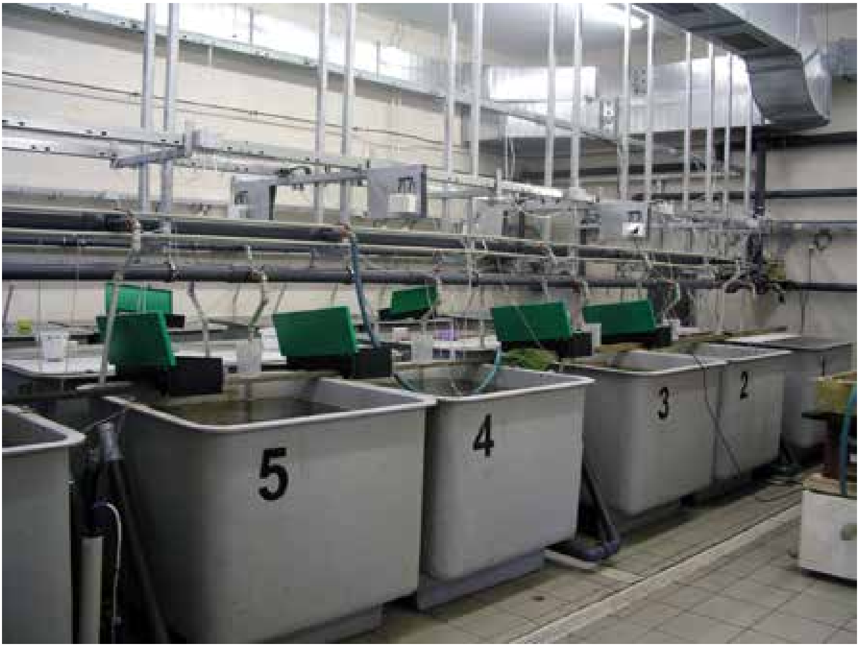

Fig. 5. *Recirculating aquaculture system of FFPW USB used for adaptation and intensive culture of juvenile pikeperch, Sander lucioperca (L.) (photo T. Policar).*

3. VERIFICATION OF THE TECHNOLOGY

The technological process was verified in 2012 at two Czech fish farms (Rybářství Nové Hrady, Ltd. and Fish Farm Bohemia, Ltd.) and in the research facilities (Faculty of Fisheries and Protection of Waters, University of South Bohemia – FFPW, USB) (Fig. 5). This technological process followed the methodology by Policar et al. (2011). Background for this technological process was provided by Stejskal et al. (2010) in the description of the combination of pond and RAS production system for marketable Eurasian perch (*Perca fluviatilis* L.).

4. DESCRIPTION OF THE TECHNOLOGY

4.1. Stocking of pond-cultured pikeperch juveniles to the RAS

4.1.1. Technological process

The Bejkovna pond (surface area of 1.33 ha, GPS 48°48′12′′N; 14°48′53′′ E) was harvested on June 6 and the production was 86,000 pikeperch juveniles (TL = 41 ± 0.3 mm; W = 0.45 ± 0.05 g) (Fig. 6). Fish were graded and uniform-size were stocked into the RAS.

At the beginning of the harvesting, a sample of fish was taken and sent to a veterinary office for analysis using the methodology of Citek et al. (1997). Fish were infected with *Ichthyophtirius multifiliis*. Consequently, at harvest fish were treated during transport with a therapeutic bath (detailed description in section 4.4.) The health condition was inspected again before stocking into the RAS and any infection was not obserevd. Ideally, fish should be quarantined to include a common recirculating system without bio-filtration with a period of two or three days. This system should be used for observation and treatment of fish before their stocking to the RAS.

Juveniles sorted by size and without ectoparasites were put into RAS, which included 18 square tanks (size of 1 x 1 x 1 m) with water volume of 700 l. The RAS included a mechanical drum filter (IN-EKO Tisnov Ltd.), a retention tank (2,000L), three fluid-biofilters (4,000 l each), a ozonizer with a UV lamp (Ozon UV-C redox) and oxygenation column (Kovo Net Ltd.). The entire volume of the RAS was 28,100 litres.

Fig. 6. *Juvenile fish (summer-fry) pikeperch, Sander lucioperca (L.) stocked into RAS (photo T. Policar).*

All the fish were transferred from the transport tanks (WT = 17.7 ± 0.3 °C; oxygen saturation = 104 ± 23% and pH = 6.8) directly to the RAS. In total, 84,000 pikeperch juveniles were divided into 14 tanks. The 4 remaining tanks (total = 18 tanks) were subsequently used for rearing faster growing fish or cannibals (see 4.2.1.). The juvenile density was 8.6 individuals per litre and the fish biomass was 3.85 $kg.m^{-3}$. The water quality parameters at the beginning of acclimation were as follows: WT=19 °C; oxygen saturation = 90%; pH = 7.3; NO_2 = 0.15$mg.l^{-1}$; NO_3 = 58$mg.l^{-1}$; NH_4 = 0.16$mg.l^{-1}$; CHOD – chemical oxygen demand = 28$mg.l^{-1}$. The water inflow in each tank was 20 $l.min^{-1}$. An antifungal bath in NaCl with the concentration of 3 $g.l^{-1}$ (for details about effects of antifungal bath see section 4.4.) was applied in each tank. After that, space and feed adaptation began. The entire procedure of acclimating fish to new conditions, including the conversion from live to pellet feed is called weaning. Fish were initially fed bloodworm larvae (*Chironomus* sp.) and gradually a mixture of bloodworm and pellet feed (BioMar, Inicio Plus 1.1 mm) were introduced. The details of the weaning procedure are depicted in Fig. 7; water temperature was increased to 23 °C during the first 24 hours and a special photoperiod 15L/9D and light regime 100 lux were established.

Transport of fish and their stocking to the RAS (WT = 19 °C; oxygen saturation = 90%; 15L/9D; 100 lux), no feeding (1st day)

↓

Fish space adaptation to new environmental conditions in the RAS (WT = 23 °C; O2 = 100%; 15L/9D; 100 lux), no feeding (2nd day)

↓

Feeding with bloodworms (*Chironomus* sp.) only (3rd and 4th day)

↓

Feeding with mixture of bloodworms and pellet feed (BioMar, INICIO Plus 1.1 mm) in the ratio of 75 to 25% (5th and 6th day)

↓

Feeding with mixture of bloodworms and pellet feed (BioMar, INICIO Plus 1.1 mm) in the ratio of 50 to 50% (7th and 8th day)

↓

Feeding with mixture of bloodworms and pellet feed (BioMar, INICIO Plus 1.1 mm) in the ratio of 25 to 75% (9th and 10th day)

↓

Feeding with pellet feed (BioMar, INICIO Plus 1.1 mm) only (11th and 12th day)

↓

End of space and pellet feed adaptation (12th day)

Fig. 7. *Scheme of space and feed adaptation of juvenile pikeperch, Sander lucioperca (L.) in 12 days.*

No food was given during the first and second day so as to encourage subsequent feeding activity. During the feeding transition, the amount of bloodworms was decreased and the ratio of the pellet feed was increased every two days. Nutritional content of bloodworm and pellet feed are described in Tab. 1.

Tab. 1. *Nutritional content of bloodworm and 1.1 mm pellets BioMar, Inicio Plus during the weaning.*

Parameter	Bloodworm	Pellet feed
Size [mm]	9.13	1.1
Proteins[a]	65	55
Fat[a]	1	20
Digestible energy[c]	15.1	20
Fatty acids[b]		
12:0	0.1	0.2
14:0	3.2	5.2
15:0	2.2	0.4
16:0	20.3	16.4
17:0	1.6	0.2
18:0	6.6	2.5
20:0	0.7	0.2
22:0	0	0
14:1	1.5	0.1
16:0 (n-7)	13.9	7.8
17:1	2.1	0
18:1 (n-9)	15.1	12.9
18:1 (n-7)	4.6	1.7
20:1 (n-9)	0	3.8
22:1	0	6.2
24:1	0	0.4
18:2 (n-6)	13.6	22.6
18:3 (n-6)	0.6	0
20:4 (n-6)	2.4	0.3
18:3 (n-3)	3.4	2.4
18:4 (n-3)	0.4	2.4
20:5 (n-3)	7.7	7.3
22:5 (n-3)	0	0.6
22:9 (n-3)	0	6.6
Σ SFA	34.7	25
Σ MUFA	37.2	33
Σ PUFA	28.1	542.1
n-3	11.5	19.3
n-6	16.6	22.8
n-9/n-3	1.4	1.2

[a] percentage in dry matter, [b] percentage from fatty acids, [c] MJ/kg in dry matter

The daily feeding ratio (DFR) was *ad libitum* during the entire weaning and fish were fed every 30 minutes by hand from 6:30 till 21:30. The production parameters were:

Feed Conversion Ratio (FCR) = TAF/(FB - IB)

TAF total amount of feeding, FB final fish biomass and IB initial fish biomass (Stejskal et al., 2009a)

Survival (S, %) = NSF/NFB * 100

NSF means number of surviving fish and NFB means number of fish at the beginning.

Cannibalism (C, %) = (NFB - NDF - NSF)/NFB * 100

NDF means number of dead fish

Specific Growth Rate (SGR, %/day) = 100 * t^{-1}ln (FW - IW)

t means number of days, FW means final body weight and IW means initial body weight

Fultons Coefficient (FC) = 100 * TL^3/FW

TL means total length of fish (Policar et al., 2011, 2013b).

Body weight and total length of 10 fish (in each tank) were measured at the beginning and at the end of the weaning (Fig. 8). A common measuring tape with 1 mm increments and scale (Mettler, AE 200) with an accuracy 0.01 g were used. Fish were not anaesthetized during measurement.

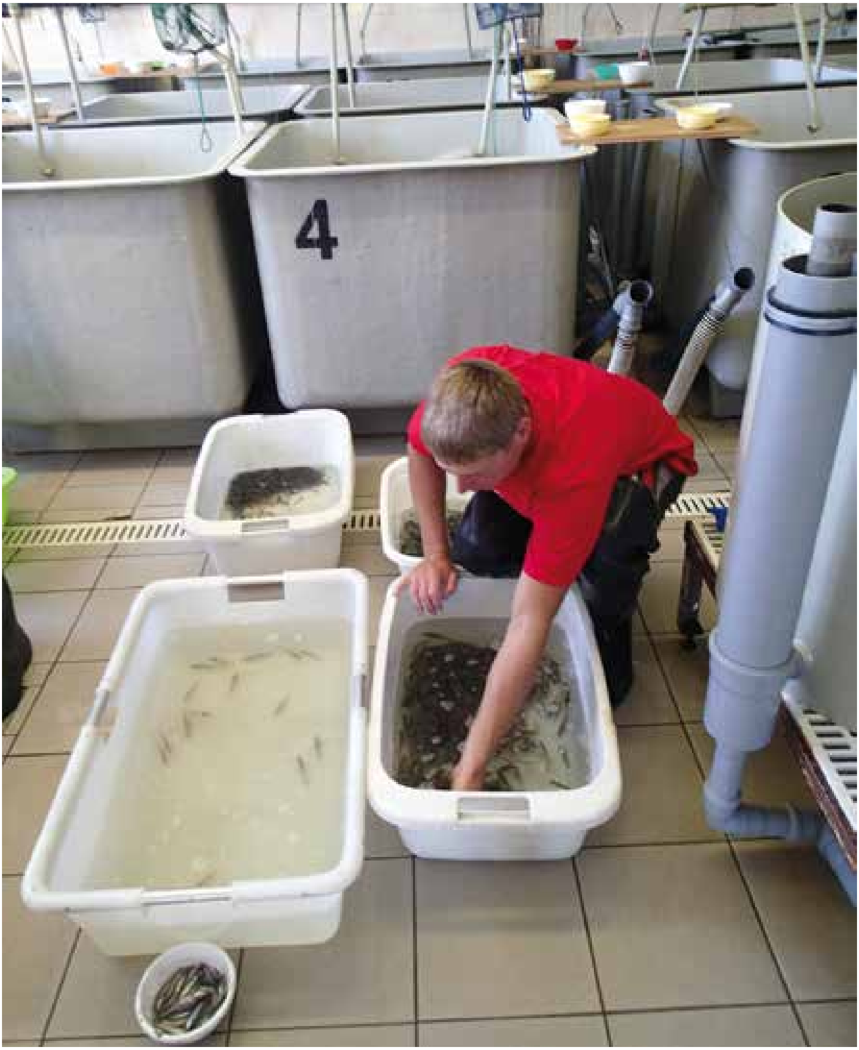

Fig. 8. *Manipulation of pikeperch, Sander lucioperca (L.) during intensive culture (photo T. Policar).*

Dead fish, uneaten feed, excrements and other sediment were removed from the tanks twice daily (at 8 a.m. and 14 p.m.). The dead fish were counted to assess mortality in each rearing period (NDF). Tank walls were brush-cleaned every 3 days (Fig. 9).

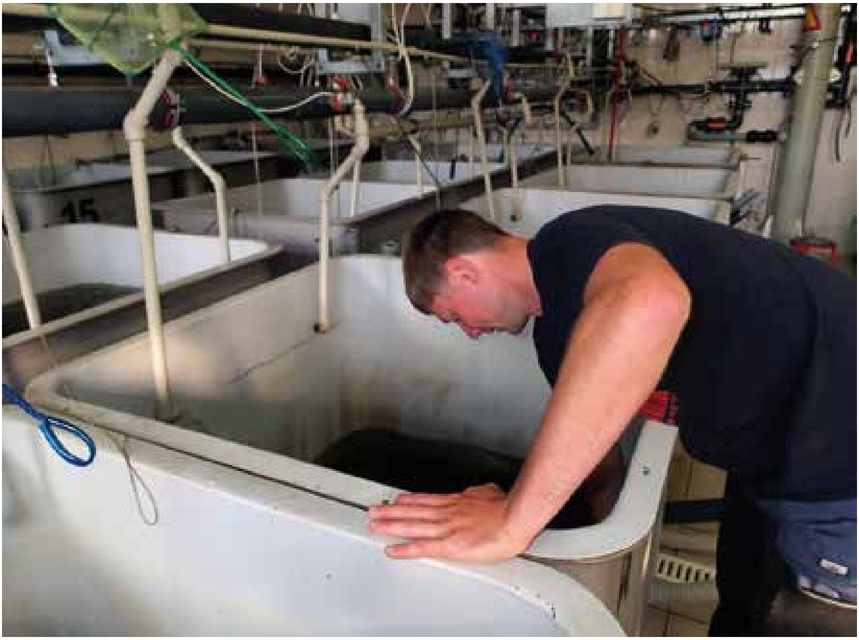

Fig. 9. *Cleaning of the tanks during intensive culture of pikeperch, Sander lucioperca (L.) (photo T. Policar).*

4.1.2. Results

After stocking, fish swam in shoals close to the tank bottom, then gradually during the 12-day adaptation, they began to swim in the upper part of water column. During the initial period of weaning, the juveniles fed somewhat reluctantly, but later they were more aggressive. After 5–10 days the fish rapidly reacted to the feed. Some of the fish attacked (by biting head and fins) each other during feeding but this behaviour did not lead to increased fish mortality. The mortality of reared pikeperch juveniles was low (a few individuals daily) at the beginning of the weaning. Later, several hundreds of fish died each day (from day 5 to 9 of the weaning). The fish that died were weak and did not eat. After day 10 of the weaning, mortality decreased and all surviving fish fed well. The results and production parameters assessed after weaning are presented in Tab. 2. The most important data from the weaning period were survival (S = 78 ± 5.5%), cannibalism (C = 5 ± 2%) and percentage of fish converted to pellet feed (97%). Cannibalism was low due to size grading before fish stocking to RAS. Very high Feed Conversion Ratio

(FCR = 4.7 ± 0.5 $g.g^{-1}$) was calculated after adaptation period. High value of FCR after this period was mainly caused by: 1) using of feed which had a higher water content (frozen bloodworms), 2) higher amount of uneaten feed and 3) higher fish mortality. Fish that had adapted to the intensive culture conditions were in good condition (FC = 0.67 ± 0.1).

Tab. 2. *Production parameters such as body weight, total length, SGR, survival, cannibalism, FCR and FC in pikeperch, Sander lucioperca (L.) juveniles assessed after the 12-day-long weaning.*

IW (g)	FW (g)	ITL (mm)	FTL (mm)	SGR (%/g)	S (%)	C (%)	FCR	FC
0.45 ± 0.05	0.70 ± 0.1	41 ± 0.3	47 ± 0.6	3.8 ± 0.2	78 ± 5.5	5 ± 2	4.7 ± 0.5	0.67 ± 0.1

IW – initial body weight; FW – final body weight; ITL – initial total length; FTL – final total length

4.1.3. Conclusion and recommendations for farmers

It is possible to efficiently convert pond-reared pikeperch juveniles to pellet feed with a high survival. The most important points of a successful weaning are:

a) careful and professional pond harvest and transport of fish to the RAS;
b) stocking of healthy size-graded fish;
c) optimal rearing conditions (high water quality);
d) fish can be stocked into the RAS with a 2–3 °C higher WT than in transport tanks.

4.2. Intensive culture of fully adapted pikeperch juveniles with a different average body weight 8; 25 and 50 g under the RAS conditions

4.2.1. Technological process

The following culture of pikeperch juveniles under the complete RAS (Fig. 10) conditions was divided into 3 phases [1st phase up to 8 g (Fig. 11); 2nd phase up to 25 g; 3rd phase up to 50 g (Fig. 12)] using different durations of culture phases, fish density and biomass (Tab. 3). Fish were prophylactically treated immediately after stocking into the tanks or handling during sampling and sorting, when a 3 g.l^{-1} bath of NaCl was used. Average water quality parameters were: WT = 24.7 ± 2.7 °C; oxygen saturation = 101 ± 5%; pH = 7 ± 0.3; NO_2 = 0.24 ± 0.07 mg.l^{-1}; NO_3 = 65 ± 8.07 mg.l^{-1}; NH_4 = 0.18 ± 0.0207 mg.l^{-1}; CHOD = 30 ± 5.5 mg.l^{-1}. Light regime was established at 15L/9D and water inflow in each tank was about 25 l.min^{-1}.

Fig. 10. *Juvenile pikeperch, Sander lucioperca (L.) in rearing tank during intensive culture (photo T. Policar).*

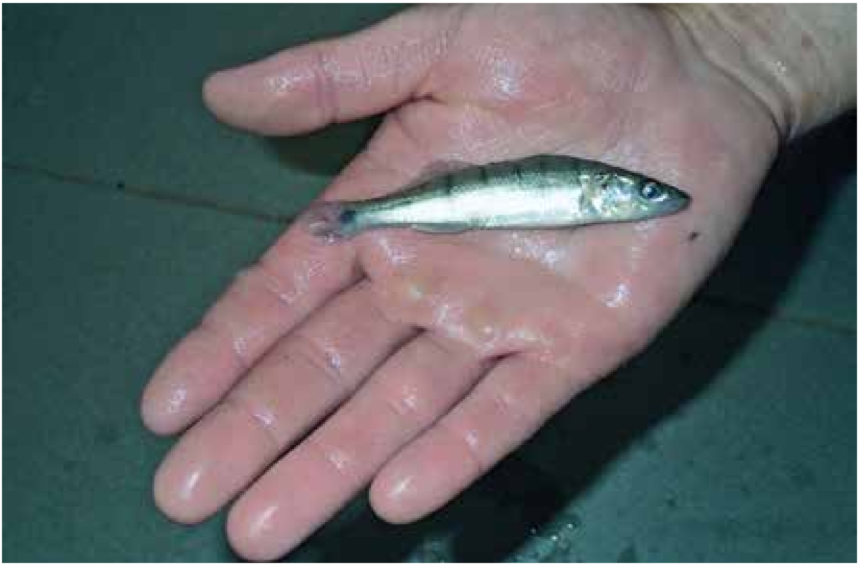

Fig. 11. *Juvenile pikeperch, Sander lucioperca (L.) cultured up to average weight of 8 g (photo M. Blecha).*

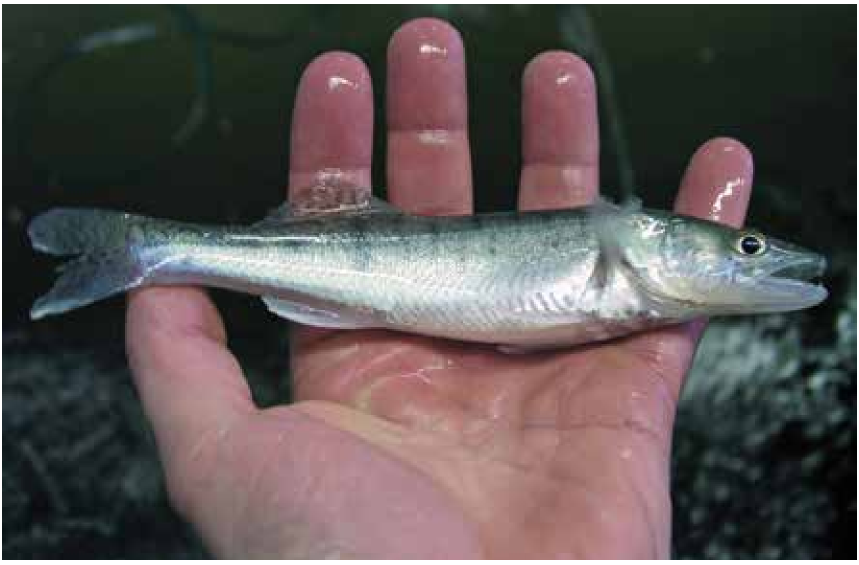

Fig. 12. *Juvenile pikeperch, Sander lucioperca (L.) with average weight of 50 g at the end of intensive culture (photo T. Policar).*

Tab. 3. *Duration of each pikeperch Sander Lucioperca (L.), rearing period, average fish biomass and density at the beginning and at the end of each rearing period in 700-L tanks (average ± S.D.)*

Rearing period	Length of rearing (days)	Initial fish biomass (g)	Initial fish density (n)	Final fish biomass (g)	Final fish density (n)
I. period (0.7–8.2 g)	65	3,283 ± 320	4,680	34,038 ± 1,680	4,151 ± 205
II. period (8.2–25.1 g)	40	9,840 ± 580	1,245	30,145 ± 875	1,201 ± 35
III. period (25.1–50.6 g)	45	19,200 ± 400	800	38,658 ± 365	764 ± 7

A very important procedure during each rearing phase was to size grade the fish (1^{st} phase every 10 days; 2^{nd} and 3^{rd} phase every 21 days). The sorting permitted removal of cannibals (Fig. 13) (more information about this issue see section 4.3.). All cannibals were cultured in 4 separated tanks.

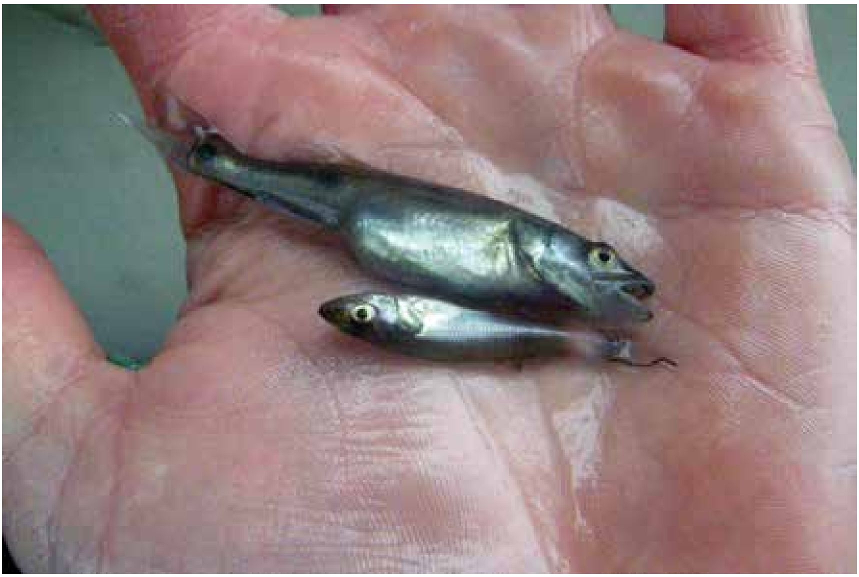

Fig. 13. *Comparison of the size of cannibalistic (above) and non-cannibalistic (below) pikeperch, Sander lucioperca (L.) individuals (photo T. Policar).*

The first feed was given approximately 5 hours after sorting. Fish were fed with BioMar Inicio Plus and Efico Sigma 570 pelleted feed. The pellet size, kind of feed, DFR and the feeding technique are listed in Tab. 4. The pellet feed was applied by hand (every 30 minutes during the day-light period) and by belt feeders (during the entire day-light period). Hand feeding was used to achieve better distribution of the pellets among all fish in the tanks. This procedure led to a more uniform size-balanced fish population in tanks. At the end of each rearing phase, the production parameters were counted. It was conducted in the same manner and according to the same formula as in section 4.1.1.

Tab. 4. *Daily feeding ratio (DFR), kind of pellet, pellet size and feeding techniques applied during the rearing phases of pikeperch intensive culture to different body weights.*

Rearing phase	DFR (%)	Kind of feed	Pellet size (mm)	Feeding technique
1st phase (0.7–8.2 g)	12–15	Inicio Plus	1.5 and 2	by hand : belt feeder 1 : 1
2nd phase (8.2–25.1 g)	5–7.5	Inicio Plus	2	by hand : belt feeder 1 : 1
3rd phase (25.1–50.6 g)	1.5–3	Inicio Plus Efico Sigma 570	2 and 3	belt feeder

4.2.2. Results

Production parameters at the end of each rearing phase are described in Tab. 5. The pikeperch juveniles achieved a very good specific growth rate in the first phase (3.9%.day^{-1}) and in the second phase (2.8%.day^{-1}), but a somewhat lower SGR was observed after the third phase (1.7%.day^{-1}). It was caused by bigger size of the fish and unstable water temperature during this phase. The good SGR positively affected absolute increment of the fish biomass in the tanks which ranged between 19.5–30.8 kg. High survival (88.7–96.5%) during each rearing phase was also observed. Survival was the lowest during the first rearing phase, primarily because of a high cannibalism of 7.5%. On the other hand, cannibalism was lower during the second and third phases (1.5–2.5%). To explain that, smaller pikeperch juveniles (up to 5–8 g) are able to prey on the same size individuals but bigger juveniles (10 g and bigger) are not able to do so. Fast growth of the cultured pikeperch juveniles was associated with a very good feed conversion rate (FCR), only 0.93 during the first phase, but higher during the second (1.5) and third phases (1.7) was caused by an unstable water temperature regime and therefore lower feeding activity of the cultured pikeperch juveniles. Generally, condition values (FC = 0.82–0.89) were good during all phases. At the end of each phase, very high content of perivisceral fat was observed in fish. This finding showed unbalanced nutritional composition of the used feed. Therefore, it is possible to say that the BioMar feed which was used in this study was not optimal for intensive pikeperch juvenile culture.

Tab. 5. *Production parameters such as body weight, total length, SGR, survival, cannibalism, FCR and FC in pikeperch (Sander lucioperca) juveniles assessed after each rearing phase.*

Rearing phase	IW (g)	FW (g)	ITL (mm)	FTL (mm)	SGR (%/ day)	S (%)	C (%)	FCR	FC
1st phase	0.7 ± 0.1	8.2 ± 0.6	47 ± 0.6	97.3 ± 10.1	3.9 ± 0.3	88.7 ± 5.3	7.5 ± 2.5	0.93 ± 0.15	0.89 ± 0.15
2nd phase	8.2 ± 0.6	25.1 ± 5.6	97.3 ± 10.1	145 ± 10	2.8 ± 0.3	96.5 ± 3	2.5 ± 0.75	1.5 ± 0.1	0.82 ± 0.2
3rd phase	25.1 ± 2.7	50.6 ± 12.2	145 ± 10	182.5 ± 12.3	1.7 ± 0.2	95.5 ± 1	1.5 ± 0.5	1.7 ± 0.25	0.83 ± 0.18

In total, 58,114 fish were produced at the end of the first phase (initial stock comprised 65,520 ind.), during the second phase it was 4,804 fish (initial stock 4,980 ind.) and in the third phase the production amounted to 3,056 fish (initial stock 3,200 ind.). The pikeperch juveniles from the third phase were used for the study which focused on survival of intensively cultured pikeperch juveniles under the pond conditions during the winter time (Choteborsky, 2013).

4.2.3. Conclusion and recommendations for farmers

Rearing of pond-cultured pikeperch juveniles readily adapted to conditions of intensive aquaculture, demonstrating its feasibility. It is important to provide fish with the following rearing conditions: water temperature 23–24 °C, oxygen saturation about 100%, pH 7, CHSK approximately 30 $mg.l^{-1}$, minimum values of nitrites, nitrates and ammonium. The initial stocking density should be at the level of 6.7 $ind.l^{-1}$. An appropriate pellet feed represents a very important factor with respect to intensive culture of pikeperch juveniles. According to our experience, the pellet feed by BioMar is satisfactory but not optimal. Next, the pellet feed should be served both by hand and belt feeders during the first two phases. This combined method leads to better distribution of pellets to all fish in a tank and results to a size-balanced population. Daily cleaning of tanks is important to maintain a healthy environment.

4.3. Sorting of fish

4.3.1. Technological process

Regular sorting represents a very important procedural step in intensive culture of pikeperch juveniles. The purpose of sorting is to separate faster growing and cannibalistic individuals (Fig. 14) from other juveniles and thereby eliminate losses caused by predation of cannibals.

Fig. 14. *Cannibalistic pikeperch, Sander lucioperca (L.) individual which was separated during sorting of fish in intensive aquaculture rearing (photo M. Blecha).*

Basic information about the size grading or sorting was mentioned in section 4.2.1. The first sorting was done after pond harvest and before stocking juveniles into RAS. Subsequent sorting was conducted after weaning. Even after the population was size-balanced before the weaning, growth disparity produced several cannibals in each tank during weaning. Therefore, size sorting was applied again. During the first phase, sorting was done every 10 days and afterwards (from the TL = 100 mm; W = 8–9 g), subsequently, it were carried out at 21-day intervals.

Fish were not anaesthetized during grading, hand sorters function more effectively when fish are active (Fig. 15). A 20-min salt bath of 3 $g.l^{-1}$ was administered immediately after sorting and stocking of fish into the tanks. Salt treatment has a positive effect on health of percid fish cultured in RAS (Kestemont et al., 2008).

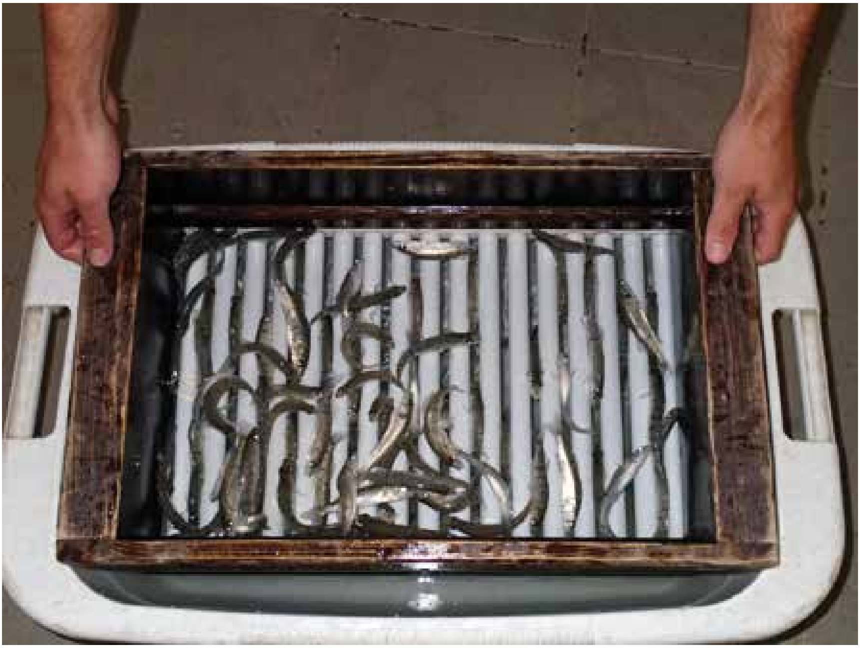

Fig. 15. *Sorting of pikeperch, Sander lucioperca (L.) juveniles with hand sorter during intensive culture (photo T. Policar).*

4.3.2. Results

Size-grading with hand sorters requires some skill, but it is more rapid than individually measuring. Fish should not be fed the day before the sorting. According to our experience, it is advisable to start the sorting in the morning because the process is time-consuming. Three persons are required to sort several tens of thousands of fish (sorting carried out within work described by this publication comprised 58,000–86,000 fish). One worker catches the fish, cleans the tanks and then re-stocks the fish back to the tanks. Two workers sort and record data (information concerning fish biomass, number of fish in tanks, average weight of fish). This working group is able to sort 58,000–86,000 fish in 6 to 8 hours. Because the sorting takes quite a long time and it is not possible to feed fish during the process, it is advisable to divide the process in two days, or to use more people to shorten the process. The main disadvantage of the alternative is that it requires additional experienced staff. Another possibility is to use an automatic sorting machine (Fig. 16). This machine is relatively expensive and can increase the cost so as to be unprofitable, especially in small RAS (annual production of 50,000 juveniles).

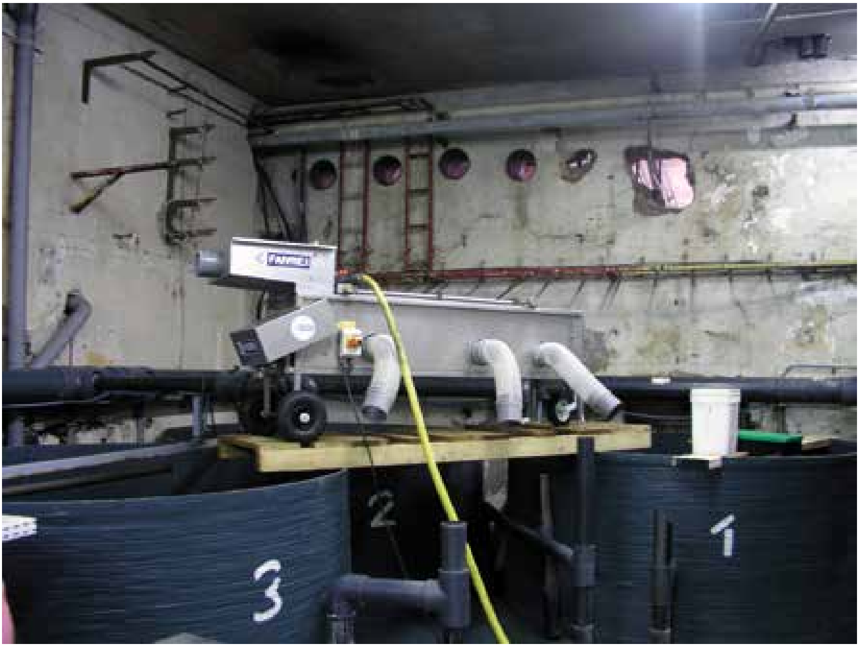

Fig. 16. *Automatic sorter used in commercial intensive farms of Eurasian perch, Perca fluviatilis (L.) and pikeperch, Sander lucioperca (L.) in Lucas Perch Ltd. company, France (photo T. Policar)*

4.3.3. Conclusion and recommendations for farmers

Size sorting is a very important step in intensive culture of pikeperch juveniles. It facilitates the rearing of a size-balanced population, eliminates cannibals, increases survival of cultured fish and profit of the operation. Optimal frequencies of sorting are: fish with the body weight from 0.5 to 8 g every 10–12 days; fish with the body weight from 8 to 50 g every 21 days.

4.4. Control of fish health, preventive and therapeutic baths in intensive culture

4.4.1. Technological process

As already described in section 4.1., fish should be sampled for fish health analysis at the time of the pond harvesting. Depending on the diagnosis, appropriate treatment can be applied. During this test, *Ichthyophtirius multifiliis* was diagnosed. Therefore, the 8-hour-long treatment bath in 35.2% formaldehyde at the concentration of 15 ml.m^{-3} was applied in the transport box. In the Czech Republic treatment with a formaldehyde bath must be prescribed by a veterinarian because formaldehyde is an unregistered medical substances. No maximum residue limit (MRL) for treated market fish has been defined for formaldehyde. The maximum residue limit determines the maximum amount of an active ingredient which can be allowed in edible tissue of a given fish species. In the absence of MRL, fish cannot be used for human consumption until the longest protection period – in this case 500-day degrees (Kolarova and Svobodova, 2009). It is also necessary to follow the safety rules with toxic substances because formaldehyde is a carcinogenic substance.

The control of fish health was made once a week during intensive culture of pikeperch juveniles and ectoparasite occurrence and health conditions were determined in at least 7 individuals from all used tanks. Special attention was given to condition of the skin and gills (Citek et al., 1997). When ectoparasites were found, possible treatment was discussed with a veterinary surgeon. In this particular case, a formaldehyde bath at the concentration of 0.015 ml.l^{-1} was suggested.

According to our experience, low formaldehyde concentration (0.015 ml.l^{-1}) has no negative effect on the functioning of biological filters, even if it is applied 2–3 times a week. We tested the effect of formaldehyde on function of the biological filters in 2010 and 2011. We found no serious changes in ammonium and nitrites concentrations when quality of water was examined according to Stejskal et al. (2009b) and Kroupova et al. (2013) in different places of the RAS. The values of ammonium and nitrite concentrations were stable for 3–4 days after the formaldehyde application. These results are in agreement with the results of Yanong (2012) who claimed that formaldehyde bath did not affect the biological filtration function.

When a bacterial infection was found, a therapeutic bath in Chloramin T at the concentration of 0.02 g.l^{-1} was applied in rearing tanks with fish for 20 minutes. Water inflow was stopped during the bath. Fish were transferred to other rearing tank and all water was drained from the RAS after the treatment.

This treatment was repeated every 4 days till the end of the occurrence of the bacterial infection.

A preventive antifungal bath of NaCl at the concentration of 3 g.l^{-1} for 20 minutes was applied after every manipulation (sampling and sorting) and the water containing the salt solution was diluted in the entire RAS. The salt solution at the concentration of 3 g.l^{-1} or lower has no negative effect on biological filtration and, on the contrary, increased concentration of sodium chlorine has a positive effect on fish health (Kestemont et al., 2008; Yanong, 2012).

4.4.2. Results

Slight infections with *Ichthyophtirius multifillis* and *Chilodonella cyprinid* were found twice during the entire culture. *Dactylogyrus sp.* was diagnosed once. Bacterial disease of gills and fins appeared one month after the weaning. Preventive and therapeutic baths were applied.

According to the veterinary surgeon's recommendation, a long-term therapeutic formaldehyde bath at the concentration of 0.015 ml.l^{-1} was applied. This treatment was used only in exceptional cases because formaldehyde is an aggressive and carcinogenic chemical and its possible usage has to be discussed with and permitted by a veterinarian.

To eliminate and stop the bacterial infection of gills and fins, a short-term therapeutic bath in Chloramin-T at the concentration of 0.02 g.l^{-1} for 20 minutes was applied. It is possible to use Chloramin T repeatedly after discussing the issue with a veterinarian.

Application of NaCl (concentration of 3 g.l^{-1} for 20 minutes) baths as a preventive treatment against fungal infection has proved very useful. Salt preventive bath was applied after every manipulation (sorting and sampling) with fish and it was subsequently diluted in the whole RAS system without any problem.

4.4.3. Conclusion and recommendations for farmers

Preventive examinations of fish health represent the basis for successful and economically effective intensive culture of pikeperch in the RAS conditions. However, every therapeutic treatment should be discussed with a veterinarian. To make safer treatment for the whole tank stock, a tolerance test (application of the treatment only to a few individuals at first) should be conducted beforehand. All mentioned therapeutic treatments can be recommended as effective and safety protection of intensively cultured pikeperch juveniles in RAS.

4.5. Calculation of production costs and final price of a 8 g pikeperch juveniles completely adapted and cultured in RAS conditions

4.5.1. Technological process

Production costs of combined culture of pikeperch juveniles up to the body weight of 8 g were recorded in detail. It was impossible to calculate the market price of 25 and 50 g juveniles because the culture of these fish was performed in the same RAS as other experimental fish.

The calculation of the production costs was divided into four parts:

1. direct production costs of pond-reared juveniles;
2. direct production costs connected with the RAS culture;
3. indirect production costs connected with the RAS culture;
4. depreciation of tangible assets connected with the production of pikeperch juveniles in RAS.

4.5.2. Results

All the direct production costs (CZK 97,020) connected to production of pond-cultured juveniles involved:

- Pikeperch broodstock (CZK 10,500): 10 pairs: 30 kg x CZK 350 = CZK 10,500;
- Reproduction of broodstock (CZK 26,940): hormones = CZK 7,500; staff salary: 2 persons x 7 days x 3 hours x CZK 300 = CZK 12,600; water supply: 30 m^3 x CZK 61.2 = CZK 1,840; other costs: syringes, anaesthetics, bathtubs, artificial spawning nests, disinfection of fish and incubated eggs = CZK 5,000. Total = CZK 26,940;
- Pond preparation (CZK 6,560): 1,600 kg of compost = CZK 2,000; staff salary: 2 persons x 5 hours x CZK 300 = CZK 3,000; transport of material: 120 km x CZK 13 = CZK 1,560.
  Total = CZK 6,500;
- Stocking of larvae into ponds (CZK 4,560): transport of material: 120 km x CZK 13 = CZK 1,560; staff salary: 2 persons x 5 hours x CZK 300 = CZK 3,000. Total = CZK 4,560;
- Pond culture and juvenile harvesting (CZK 48,460): rent of 4 ha of ponds for 2 months: 4 x 2 x (7,000/12) = CZK 4,700; pond control and sampling: 5 x 2 persons x 5 hours x CZK 300 = CZK 15,000; pond harvesting: 4 x 2 persons x 8 hours x CZK 300 = CZK 19,200; material for pond harvesting = CZK 8,000. Total = CZK 48,460.

The total production of pond-reared pikeperch juveniles amounted to 86,000 fish and total costs for this production represented CZK 97,020. The price of pond-reared juveniles was CZK 1.13 per fish. Only, one pond was used for juvenile production, but it is advisable to use more ponds (there are 4 in this model calculation). One of the disadvantages of pond culture is an unstable production due to several natural and unpredictable conditions and situations (flood, fish predators, oxygen deficits etc.). Therefore, we recommend the use of more ponds for stable annual production of pikeperch juveniles.

All the direct production costs (CZK 391,739) connected with RAS culture comprised:

- Staff salary (CZK 234,000): 2 persons x 6 hours x 65 days x CZK 300. Total = CZK 234,000;
- Feed (CZK 52,735): 995 kg of feed x CZK 53. Total = CZK 52,735;
- Pure oxygen used for oxygenation of water in the RAS (CZK 40,978): 4 x CZK 10,244. Total = CZK 40,978;
- Electrical energy (CZK 16,779): CZK 12,496 + CZK 283 + 2 x CZK 2,000. Total = CZK 16,779;
- Water supply used for filling and cleaning of used RAS (CZK 13,097): daily water exchange was 9% of the total RAS volume: 2.6 m^3 x 65 days = 169 m^3; cleaning of the system 5 m^3 weekly x 9 weeks = 45 m^3; (169 m^3 + 45 m^3) x 61.2 CZK/m^3. Total = CZK 13,097;
- Amortization of tangible assets (CZK 4,000): air pump CZK 2,000 + scales CZK 2,000. Total = CZK 4,000;
- Used material (CZK 30,150): a vet fee and therapeutic treatment CZK 5,500; nets CZK 3,000; aeration stones CZK 1,000; filtration medium CZK 12,000; netting for the mechanical drum CZK 7,500; buckets CZK 800; bathtubs CZK 1,000; anaesthetics CZK 350. Total = CZK 30,150.

Indirect production costs connected with the RAS culture (CZK 13,200): phone fee CZK 1,200; office supplies CZK 500; cleaning service CZK 2,500; accountant's salary 20 x CZK 450 = CZK 9,000. Total = CZK 13,200.

Depreciation of tangible assets connected with the production of pikeperch juveniles in RAS (CZK 70,000): depreciation of the building CZK 40,000; depreciation of the RAS CZK 30,000. Total = CZK 70,000.

The total production costs for the production of 58,000 fish amounted to CZK 571,959 (direct production costs for pond-reared juveniles 17%, direct production costs connected with the RAS culture 68.5%, indirect production costs connected with the RAS culture 2.3%, depreciation of tangible assets connected with the production of pikeperch juveniles in the RAS culture 12.2%). Total production cost for cultured pikeperch juveniles with the body weight 8 g was calculated as CZK 9.9 per one fish in total production of 58,000 fish.

4.5.3. Conclusion and recommendations for farmers

The pikeperch culture implemented according to this methodology is characterised by rather high production costs (CZK 9.9 per fish), however, production is stable, and predictable and yields a high-quality product. The produced pikeperch juveniles are mainly intended for further rearing in RAS and not for stocking into open waters or production ponds. The main reason is the price of pikeperch juveniles. A current price of 5–15 g pond-reared pikeperch (used as a stocking material for open waters or ponds) ranges from CZK 3 to 7 in the Czech Republic. On this ground, pond farmers prefer pond-cultured pikeperch juveniles. However, the RAS farmers are willing to pay even more (CZK 15 to 20 or more per one fish) for quality stocking material. Therefore, described pikeperch production technology can be very effective and profitable for RAS fish farmers.

4.6. Possibilities of selling and next using of 8 g pikeperch juveniles

4.6.1. Technological process

The European pikeperch market was analysed in order to discover market demands, potential customers and current price of juvenile pikeperch with body weight 8 grams. Almost all European pikeperch RAS farmers were addressed and asked whether they would be interested in the produced fish (8 g pikeperch juveniles), how many fish they would be willing to buy and how much they would pay for them. After that, incomes and expenses were defined and possible profitability of the entire production was calculated.

It had be noted that no fish were sold and all of the fish were used for further experiments, research and education of bachelor's, master's and doctoral students in FFPW, USB.

4.6.2. Results

Positive reaction and interest of eight farmers from Belgium, France, Netherlands, Denmark, Bulgaria and the Czech Republic were received. Detailed information concerning the hypothetical price and amount of demanded fish is presented in Tab. 6. Total demand for juvenile pikeperch amounted to 93,000 fish and we only produced 58,000 fish. The farmers offered a purchasing price for one 8 g pikeperch juvenile ranging from EUR 0.6 to 0.8 exclusive of VAT. If we sold all our produced fish for EUR 0.8 per fish, we would earn EUR 45,800 exclusive of VAT (approximately CZK 1,145,000 exclusive of VAT). After calculating all incomes and expenses, the hypothetic profit of this culture would be about CZK 573,041 (profit per 1 fish was CZK 9.9). This profit was achieved with two workers after using of combined culture with four 1ha ponds during 2 months period and the RAS with water volume of 28.1 m^3 for 65–77 days. We can mention that this type of aquaculture is able to get very good economic profit in fish farms at present.

Tab. 6. *List of companies interested in buying 8 g pikeperch juveniles including the demanded amount of fish and price.*

Company, country	Amount of demanded fish [ind.]	Price per fish [EUR]
Eko-Hidro-90, Bulgaria	20,000	0.8
Inagro vzw, Roselare, Belgium	3,000	0.8
Aquapri, Frederiksvaerk, Denmark	3,000	0.8
Van Slooten Aquacultuur, Urk, Holland	20,000	0.75
Asialor farm, Dieuze, France	20,000	0.7
Excellence fish, Horst, Holland	15,000	0.6
Maatschap Lont en Baaren, Hippolytushoef, Holland	6,000	0.6
Švarc-chov ryb na oteplené vodě, Velká Bystřice, CZE	6,000	0.6

4.6.3. Conclusion and recommendations for farmers

The results of the European market analysis showed high demand of RAS farmers for 8 g pikeperch juveniles and their willingness to pay quite a high price for one fish (EUR 0.6–0.8 per fish). According to our findings, the profit of 8 g pikeperch juvenile production could amount approximately to CZK 9.9 per fish if the stated technology was followed.

5. THE ECONOMIC BENEFITS OF THIS TECHNOLOGY

The financial analysis of the entire production cycle of 8 g pikeperch juveniles showed potential profitability of the introduced production method. If our technological process was followed, it would bring profit to farmers amounting approximately to CZK 9.9 per one produced 8 g pikeperch juvenile. It is not a problem to produce hundreds of thousands of pond-reared pikeperch juveniles in average Czech pond fish farm. If the intensive aquaculture will be developed in this farm, production of 8 g pikeperch juveniles might represent tens to hundreds of thousands of fish. This production (100,000–300,000 8 g juveniles) could yield profit of about CZK 990,000–2,970,000.

6. USE OF THE TECHNOLOGY IN THE PRODUCTION FIELD IN THE CZECH REPUBLIC

This verified technology of adaptation of pond-cultured pikeperch juveniles and their following intensive culture in RAS was and will be used especially in the Fish Farm Bohemia Ltd. The mentioned fish farm will produce tens of thousands of juvenile pikeperch due to application of this technology every year. The Fish Farm Bohemia Ltd. will use most of the produced pikeperch juveniles for its production of marketable fish and broodstock. The goal of the fish farm is to produce about 2–5 tons of marketable pikeperch in 2016–2018 and sell a small part of juvenile production to other regional fish farmers.

We suppose that this technological process could increase production of marketable pikeperch in the Czech Republic. It could lead to a better offer of pikeperch in the market as well as increased consumption of fish in the Czech Republic.

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