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Feasibility of rearing brook char fingerlings in an intensive recirculating hatchery as a complementary species to rainbow trout

M. Buřič[1], J. Bláhovec[2], J. Kouřil[1]

[1]University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters, South Bohemian Research Center of Aquaculture and Biodiversity of Hydrocenoses, Vodňany, Czech Republic
[2]Trout farm Mlýny, Stachy, Czech Republic

ABSTRACT: Aquaculture, as the fastest growing agriculture sector, is currently focused on exploring the development of effective intensive recirculating systems (RAS). The use of intensive RAS requires a stable supply of fingerlings throughout the year. Salmonids are a highly important aquaculture species, with rainbow trout *Oncorhynchus mykiss* often reared in freshwater RASs. The dominant position of rainbow trout has triggered the investigation of a wider diversification of species, including brook char *Salvelinus fontinalis.* Brook char has the potential to be reared in facilities similar to those used for rainbow trout, but it is not known if brook char is suitable for hatching in an intensive recirculating hatchery system (RHS) to provide a consistent supply of fingerlings to an associated RAS roughly every three months. The present study evaluated the feasibility of producing brook char fingerlings in an RHS and compared results to those obtained with rainbow trout. A production cycle from eyed egg to fingerling was completed separately for rainbow trout, brook char, and parallel rearing of both species for the comparison of growth rate, feed conversion ratio, and the time to reach individual fingerling weight of 2 g. The results showed slower growth rate of brook char compared to rainbow trout reared under the same conditions and a significantly longer production cycle (~108 days), compared to rainbow trout (~74 days). Results suggest that brook char is not suitable for parallel rearing in facilities with primary rainbow trout production. The main practical problem is disruption of the production cycle which requires fingerling stocking at 3-month intervals.

Keywords: aquaculture; RAS; nursery; growth rate; salmonid

INTRODUCTION

Current trends in aquaculture are focused on the development and establishment of effective recirculating systems (RAS) for intensive rearing (Terjesen et al. 2013) to increase production in the face of prospective resource decline and environmental sustainability (Martins et al. 2010; Wilfart et al. 2013). The use of intensive RASs addresses the need for a consistent year-round supply of high quality fingerlings. The quality of fingerlings is determined by their origin with respect to potential contamination by a wide range of fish pathogens (Hastein et al. 2008). The stocking of fingerlings into RASs should include assessment of the certificate of origin, with health category I required (Jokumsen and Svendsen 2010; Council Directive 2006/88/EC) to prevent the transfer of fish diseases. A supply from a closed recirculating hatchery, preferably associated with the ongrowing

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facility, using controlled, non-surface water sources, will limit pathogen transmittance (Buric et al. 2015a).

Salmonids are important species for both mariculture and freshwater aquaculture, with rainbow trout *Oncorhynchus mykiss* Walbaum 1792 being the leading species (FAO 2014). Salmonids present an affordable supply of dietary protein rich in omega-3 fatty acids (EPA and DHA) (Wall et al. 2010; FAO 2014). The increasing demand for rainbow trout has led to an expanded effort to establish new RAS facilities throughout Europe (Terjesen et al. 2013), and triggered investigation into diversification of salmonid production. Suggested alternative species are Arctic char *Salvelinus alpinus* L., brook char *Salvelinus fontinalis* Mitchill 1814, and their hybrids (Dalsgaard et al. 2013; Svinger et al. 2013). The feasibility of rearing these species in RAS has been confirmed in past studies (Dalsgaard et al. 2013; Buric et al. 2015b). However, the suitability of brook char for intensive recirculating hatcheries has not been evaluated. The length of the fingerling production cycle is particularly important in the case of dual culture of brook char/rainbow trout. A longer growth period could disrupt production continuity in intensive RAS facilities primarily rearing rainbow trout, since they require stable fingerling stocking approximately every 3 months.

The present study evaluated the suitability of rearing brook char fingerlings in an intensive recirculating hatchery system to provide continual production for a neighbouring RAS system. The objectives were to compare survival, growth, feed conversion, and the length of production cycle of brook char and rainbow trout reared simultaneously, to provide similar conditions, as well as those reared at different times in the same system. The study investigated the potential for culture of rainbow trout and brook char in the same facility for diversification of fish production, without affecting the continuity of consecutive production cycles of both fingerlings and market-sized fish.

MATERIAL AND METHODS

Hatchery system. The study was conducted at a small trout farm in South Bohemia (49°6'35.2''N, 13°45'10.2''E) in a recirculating hatchery system (RHS) that serves as the fingerling supply for a neighbouring Danish model RAS. The hatchery was developed for low fresh water demand (0.05 l/s) and energy consumption (1.6 kWh) with a production capacity of ~250–330 000 fingerlings per annum in four consecutive cycles (Buric et al. 2015a). The RHS consisted of a nursery system for egg incubation, hatching, and rearing through the change to exogenous feeding to the weight of ~0.5 g and a rearing system for ongrowing fish to 2–3 g.

Physical and chemical conditions. Physical and chemical water conditions are shown in Table 1. Data were obtained through bi-weekly collection of water samples from the RHS and analyzed in an accredited laboratory (Bioanalytika CZ, s.r.o., testing laboratory No. 1012). Oxygen saturation level (oximeter Oxi 3205 with CellOx® 325; WTW GmbH, Weilheim, Germany), pH (pH meter pH 330i with SenTix 41; WTW GmbH), and water temperature (KM12 digital thermometer; Comark Instruments, Norwich, UK) were monitored daily. The light regime was set at 12 h darkness and 12 h light using a timer. There were no significant differences in above parameters among trials.

Animals and rearing conditions. Three trials were completed during the study. Trial 1 was carried out with brook char, Trial 2 with rainbow trout, and Trial 3 consisted of parallel rearing of both species in the same system. Eyed eggs were obtained from certified disease-free farms (Troutex ApS, Fredericia, Denmark). The initial number of eyed eggs stocked in each trial is presented in Table 2. Eggs were placed in twelve incubation units of the nursery system where incubation, hatching, and the first seven days of free-living larvae took place. Dead eggs were removed daily. Larvae were then moved to 8 trays in which yolk absorption and the switch to external feeding were completed and larvae were grown to ~0.5 g. Dead and malformed specimens were removed daily. Feces and uneaten feed were removed from trays daily. At the weight of ~0.5 g, fry was stocked into 7 (Trials 1 and 2) or 6 circular tanks (Trial 3, three tanks per species) in the rearing system, for growth to the mean individual weight of ~2 g. Dead specimens were removed daily. The tanks were cleaned of feces and uneaten feed regularly, and the biofiltration/sedimentation unit was cleaned (sludge removal and cleaning of Bioblocs) on alternate days. Sodium chloride was added to systems to prevent the counteract of high nitrite concentrations, and micronized limestone was added to maintain a consistent pH.

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Table 1. Physical and chemical water parameters during Trial 1 (brook char), Trial 2 (rainbow trout), and Trial 3 (parallel rearing of both species) in the nursery and rearing system of recirculating hatchery. Data are mean ± standard deviation. Different alphabetic superscripts in the same row indicate significant differences at α = 0.05 (ANOVA)

Parameter	Trial 1	Trial 2	Trial 3
Nursery system			
Water temperature (°C)	12.07 ± 1.88[a]	11.75 ± 1.52[a]	12.41 ± 1.85[a]
pH	7.34 ± 0.38[a]	7.21 ± 0.36[a]	7.29 ± 0.25[a]
Total ammonia (mg/l)	0.78 ± 0.62[a]	0.67 ± 0.64[a]	0.73 ± 0.69[a]
Nitrite (mg/l)	0.45 ± 0.48[a]	0.39 ± 0.47[a]	0.41 ± 0.42[a]
Nitrate (mg/l)	8.09 ± 2.57[a]	8.22 ± 2.75[a]	9.22 ± 3.55[a]
Biological oxygen demand (mg/l)	1.07 ± 0.26[a]	1.00 ± 1.00[a]	1.16 ± 0.33[a]
Chemical oxygen demand (mg/l)	1.92 ± 0.77[a]	1.95 ± 0.68[a]	2.03 ± 0.65[a]
Suspended solids (mg/l)	5.36 ± 2.44[a]	4.61 ± 2.09[a]	4.96 ± 2.31[a]
Chlorides (mg/l)	51.97 ± 20.62[a]	49.88 ± 22.60[a]	55.42 ± 18.12[a]
Phosphorus (mg/l)	0.27 ± 0.24[a]	0.26 ± 0.22[a]	0.27 ± 0.23[a]
Alkalinity (mmol/l)	1.79 ± 0.33[a]	1.81 ± 0.40[a]	1.77 ± 0.36[a]
Hardness (mmol/l)	1.09 ± 0.22[a]	1.14 ± 0.22[a]	1.12 ± 0.24[a]
Rearing system			
Water temperature (°C)	11.17 ± 1.31[a]	10.91 ± 0.98[a]	11.74 ± 1.59[a]
pH	7.41 ± 0.34[a]	7.39 ± 0.36[a]	7.26 ± 0.32[a]
Total ammonia (mg/l)	0.65 ± 0.50[a]	0.67 ± 0.44[a]	0.70 ± 0.54[a]
Nitrite (mg/l)	0.31 ± 0.20[a]	0.30 ± 0.24[a]	0.28 ± 0.27[a]
Nitrate (mg/l)	26.00 ± 13.09[a]	24.27 ± 14.51[a]	25.87 ± 15.11[a]
Biological oxygen demand (mg/l)	1.00 ± 1.00[a]	1.00 ± 1.00[a]	1.30 ± 0.53[a]
Chemical oxygen demand (mg/l)	1.90 ± 0.52[a]	2.00 ± 0.54[a]	1.95 ± 0.38[a]
Suspended solids (mg/l)	4.79 ± 2.47[a]	4.85 ± 2.89[a]	4.38 ± 1.99[a]
Chlorides (mg/l)	62.99 ± 41.61[a]	64.31 ± 32.75[a]	67.98 ± 36.55[a]
Phosphorus (mg/l)	0.88 ± 0.95[a]	0.79 ± 0.90[a]	0.83 ± 0.87[a]
Alkalinity (mmol/l)	1.74 ± 0.28[a]	1.69 ± 0.41[a]	1.79 ± 0.33[a]
Hardness (mmol/l)	1.34 ± 0.33[a]	1.28 ± 0.35[a]	1.29 ± 0.32[a]

During the study, pelleted feed (0.4–1.1 mm) (INICIO Plus G; Biomar A/S, Brande, Denmark) was supplied to the freely floating fry. Feed was provided manually at 2-hour intervals in the nursery system, and every three hours in the rearing system. Before feeding, any uneaten feed (if any occurred) from the previous feeding was removed. In the first 10 days after the switch to exogenous feeding, the fry were fed in excess to trigger foraging activity. Subsequently, the daily ration was maintained in accordance with fish appetite, leaving a minimal amount of uneaten feed. During rearing in the circular tanks, the daily feed ration was based on fish biomass and appetite, and was in the range of 2.0–5.5% biomass.

Fish growth and feed conversion. The growth of stock was monitored via weekly or bi-weekly random sampling of specimens from each tray or circular tank. Fish were weighed to the nearest 0.01 g using an electronic balance (Kern & Sohn

Table 2. Number of rainbow trout and brook char eyed eggs stocked in Trials 1–3

Trials	Rainbow trout	Brook char	Stocking date
1	0	100 000	5/1/2012
2	100 000	0	6/2/2011
3	40 000	40 000	21/12/2012

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GmbH, Balingen, Germany). The first weighing was conducted at the beginning of exogenous feeding. The production cycle was completed when mean individual weight exceeded 2 g.

Feed conversion ratio (FCR) was calculated as

$$FCR = w_k/w_p$$

where:
w_k = amount of feed (kg)
w_p = obtained biomass weight increment (kg)

Specific growth rate (SGR) was calculated as

$$SGR = (\ln(w_t) - \ln(w_i)) \times 100/T \quad \text{(% per day)}$$

where:
w_t = weight at time t (g)
w_i = initial weight (g)
T = time (days)

The calculation followed the 1980 Report of the EIFAC, IUNS and ICES Working Group on Standardization of Methodology in Fish Nutrition Research (EIFAC Technical Paper EIFAC/T36).

Data analysis. Data were analyzed using STATISTICA software (Version 12.0, 2013). Results were examined for normal distribution (Kolmogorov–Smirnov test) and homoscedasticity (Levene test). ANOVA tests were used to compare FCR and SGR. Chi-square test (χ^2) was used for comparison of production cycle length and survival rate. The null hypothesis was rejected at $\alpha = 0.05$. Data are presented as mean ± standard deviation.

RESULTS

Growth and survival. A higher growth rate was observed in both parallel and separately reared rainbow trout (Figure 1). Faster growth was due to higher SGR in rainbow trout; however observed SGR did not significantly differ among groups (ANOVA, F = 0.412, P = 0.526). Specific growth rate for parallelly reared brook char was 3.43 ± 0.94% per day, for separately reared brook char 3.23 ± 1.51% per day, for parallelly reared rainbow trout 4.75 ± 2.29% per day, and for rainbow trout reared separately it was 4.19 ± 1.38% per day. When differences between species were analyzed without consideration of rearing conditions, significantly higher SGR was found for rainbow trout (4.47 ± 1.94% per day) than brook char (3.31 ± 1.32% per day) (ANOVA, F = 4.222, P = 0.048) (Figure 2, Table 3).

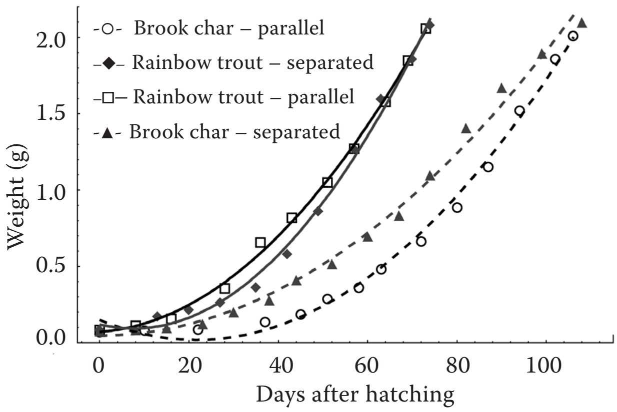

Figure 1. Growth rate of rainbow trout and brook trout in parallel and separated stocks reared in the recirculating hatchery

Non-significant differences were found in survival rates (χ^2 = 2.967, P = 0.085). Survival of brook char stock (66.85 and 77.91% in separate and parallel rearing, respectively) was more affected by cannibalism. Mortality of rainbow trout stock (survival rate 82.44 and 79.12% in separate and parallel rearing, respectively) was primarily associated with physical deformities in the period from hatching to the switch to exogenous feeding.

Feed conversion. The FCR of parallelly reared brook char was 0.72 ± 0.05, of separately reared brook char 0.73 ± 0.08, of parallelly reared rainbow trout 0.73 ± 0.04, and of rainbow trout reared separately it was 0.72 ± 0.05. No significant differences were shown (ANOVA, F = 0.036, P = 0.851). FCR analyzed only

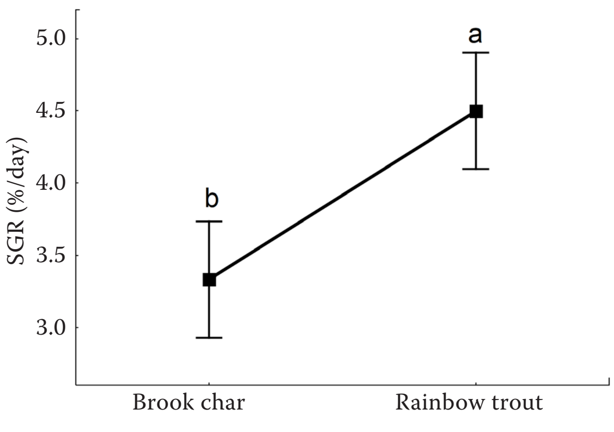

Figure 2. Specific growth rate (SGR) reached in the rainbow trout and brook trout stocks in parallel and separated rearing in the recirculating hatchery. Significant differences are highlighted by different alphabetical superscripts (ANOVA, α = 0.05)

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Table 3. Brook char and rainbow trout biometric data from parallel rearing and separate rearing

Sampling date	Brook char					Sampling date	Rainbow trout				
	dps	dph	SGR	W	FCR		dps	dph	SGR	W	FCR
Parallel rearing											
21/12/2012	0	–15	–	< 0.07	–	21/12/2012	0	–9	–	< 0.08	–
05/01/2013	15	0	–	0.07	–	07/01/2013	25	8	–	0.08	–
15/01/2013	25	10	–	0.08	–	15/01/2013	25	16	8.67	0.16	start
27/01/2013	37	22	0.70	0.09	start	27/01/2013	37	28	6.63	0.36	0.753
11/02/2013	52	37	3.12	0.14	0.703	04/02/2013	45	36	7.58	0.66	0.726
19/02/2013	60	45	2.79	0.19	0.784	11/02/2013	52	43	3.04	0.82	0.772
25/02/2013	66	51	5.51	0.27	0.655	19/02/2013	60	51	3.12	1.05	0.639
04/03/2013	73	58	4.27	0.36	0.808	25/02/2013	66	57	3.20	1.27	0.730
09/03/2013	78	63	5.55	0.48	0.697	04/03/2013	73	64	3.14	1.58	0.715
18/03/2013	87	72	3.59	0.66	0.686	09/03/2013	78	69	3.09	1.85	0.741
26/03/2013	95	80	3.61	0.89	0.719	13/03/2013	82	73	2.72	2.06	0.756
02/04/2013	102	87	3.75	1.15	0.648						
09/04/2013	109	94	3.99	1.52	0.696						
17/04/2013	117	102	2.50	1.86	0.767						
21/04/2013	121	106	1.94	2.01	0.736						
Separate rearing											
05/01/2012	0	–29	–	< 0.07	–	06/02/2011	0	–13	–	< 0.08	–
03/02/2012	29	0	–	0.07	–	19/02/2011	13	0	–	0.08	–
11/02/2012	37	8	–	0.08	–	04/03/2011	26	13	5.64	0.17	–
18/02/2012	44	15	2.41	0.10	–	11/03/2011	33	20	3.20	0.21	start
26/02/2012	52	23	3.15	0.12	–	18/03/2011	40	27	2.95	0.26	0.794
05/03/2012	59	30	6.38	0.20	–	26/03/2011	48	35	3.96	0.36	0.706
13/03/2012	67	38	4.39	0.28	start	02/04/2011	55	42	6.75	0.58	0.660
19/03/2012	73	44	6.33	0.41	0.558	09/04/2011	62	49	5.65	0.86	0.676
27/03/2012	81	52	2.98	0.51	0.751	17/04/2011	70	57	4.86	1.27	0.690
04/04/2012	89	60	3.79	0.70	0.724	23/04/2011	76	63	3.82	1.60	0.739
11/04/2012	96	67	2.53	0.83	0.670	30/04/2011	83	70	2.18	1.86	0.763
18/04/2012	103	74	3.94	1.10	0.721	04/05/2011	87	74	2.84	2.08	0.764
26/04/2012	111	82	3.12	1.41	0.727						
04/05/2012	119	90	2.14	1.67	0.802						
13/05/2012	128	99	1.41	1.89	0.796						
22/05/2012	137	108	1.14	2.10	0.804						

dps = days post-stocking, dph = days post-hatching, SGR = specific growth rate (% per day), W = mean specimen weight (g), FCR = feed conversion ratio

for species, without regard to rearing conditions, did not significantly differ (ANOVA, $F = 0.043$, $P = 0.837$) between rainbow trout (0.73 ± 0.04) and brook char (0.72 ± 0.06) (Table 3).

Production cycle length. The production cycle length was calculated as the time required to reach individual weight > 2 g from egg stocking in the hatchery (dps) or from hatching (dph). The production cycle was significantly longer for brook char under both conditions than for rainbow trout for dps ($\chi^2 = 47.284$, $P < 10^{-6}$) and for dph ($\chi^2 = 30.539$, $P < 10^{-6}$).

DISCUSSION

The production of salmonids using intensive RAS technology is expected to grow in the future (d'Orbcastel et al. 2009; Terjesen et al. 2013). The main cultured freshwater salmonid has been the rainbow trout (FAO 2014). The increasing demand for salmonid meat, as an aquaculture product with exceptional culinary and health value (Dewailly et al. 2007; Wall et al. 2010), has led farmers to consider product diversification for better satisfying this demand. Possible alternatives to rainbow trout are brook char and Arctic char, along with their hybrids (Fischer et al. 2009; Svinger et al. 2013). The potential for rearing primary and complementary species simultaneously in the same facility, for continual production of both species, is being explored.

Intensive RAS assumes the continuous rearing of fish at various stages of development to sustain a year-round harvest at approximately 3-month intervals. This requires that species should have a similar length (less than 3 months) of production cycle. The present study chose brook char as an available adjunct species, since it has been identified as potentially suitable for RAS with an ongrowing rearing period similar to that of rainbow trout (Fischer et al. 2009). The production cycle can be maintained only with a stable supply of fingerlings at approximately 3-month intervals. For this purpose, a recirculating hatchery with the potential to complete five production cycles per year has been developed (Buric et al. 2015a). To assess the feasibility of using brook char in such an intensive production process, we first determined rearing time to fingerling stage in two single species time-separated production cycles. The third trial comprised brook char in parallel with rainbow trout in the same system to compare performance of both species in identical conditions of physical and chemical RAS parameters. All parameters were appropriate for salmonid culture in RAS (Summerfelt et al. 2004; Colt 2006; Davidson et al. 2014), and no negative impact on fish health was observed.

Survival, growth rate, and feed conversion were assessed as key factors influencing production cycle length. Growth rate, expressed as SGR, for both brook char and rainbow trout reached higher levels than has been reported for rainbow trout in previous studies (Pedersen et al. 2012; Unger and Brinker 2013). Rainbow trout showed significantly higher mean SGR than brook char, while FCR values were similar for both species. This may be attributed to higher feed intake (fish were fed to satiation) of rainbow trout along with the high FCR. The FCR values were similar or superior to those previously reported for the tested species (Bailey and Alanara 2006; Fischer et al. 2009; Pedersen et al. 2012), possibly due to manual feeding at frequent intervals, strictly controlled amount of uneaten feed, and use of high quality feed. Generally, the ability to utilize higher amounts of feed per day produces more rapid growth of fish stock. The survival rate did not significantly differ between species, despite the observed higher cannibalism in brook char.

A shorter production cycle was found for rainbow trout (73 and 74 dph in parallel and separate rearing, respectively) than for brook char (106 and 108 dph in parallel and separate rearing, respectively). This was exacerbated by a longer time from stocking of eyed ova to hatching in brook char (15 and 29 days in parallel and separate rearing, respectively) compared to rainbow trout (9 and 13 days in parallel and separate rearing, respectively). The relevant value is the rearing time from hatching, since the hatching period is largely influenced by degree days (d°) to hatching (brook char 330 and 280 d°; rainbow trout 260 and 250 d° in parallel and separate rearing, respectively). Brook char exceeded the required production cycle length for assurance of stable production of fingerlings at 3-month intervals.

Rainbow trout was confirmed as a suitable species for intensive rearing in the RHS. On the other hand, brook char cannot be recommended for a continuous supplying of fingerlings to intensive RASs with continual production cycles, due to interruption in the continuity of production and therefore increased production costs. It is likely to be more cost effective to rear brook char in a detached facility.

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REFERENCES

Bailey J., Alanara A. (2006): Effect of feed portion size on growth of rainbow trout, Oncorhynchus mykiss (Walbaum), reared at different temperatures. Aquaculture, 253, 728–730.

Buric M., Blahovec J., Kouril J. (2015a): Back to the roots: the integration of a constructed wetland to a recirculating hatchery – a case study. PLoS ONE, 10, e0123577.

Buric M., Blahovec J., Kouril J. (2015b): Feasibility of open recirculating system in temperate climate – a case study. Aquaculture Research, doi: 10.1111/are.12572.

doi: 10.17221/8663-CJAS

Colt J. (2006): Water quality requirements for reuse systems. Aquacultural Engineering, 34, 143–156.

Council Directive 2006/88/EC of 24 October 2006 on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals. Official Journal of the European Union, L 328, 14.

d'Orbcastel E.R., Blancheton J.-P., Belaud A. (2009): Water quality and rainbow trout performance in a Danish Model Farm recirculating system: comparison with a flow through system. Aquacultural Engineering, 40, 135–143.

Dalsgaard J., Lund I., Thorarinsdottir R., Drengstig A., Arvonen K., Pedersen P.B. (2013): Farming different species in RAS in Nordic countries: current status and future perspectives. Aquacultural Engineering, 53, 2–13.

Davidson J., Good C., Welsh C., Summerfelt S.T. (2014): Comparing the effects of high vs. low nitrate on the health, performance, and welfare of juvenile rainbow trout Oncorhynchus mykiss within water recirculating aquaculture systems. Aquacultural Engineering, 59, 30–40.

Dewailly E., Ayotte P., Lucas M., Blanchet C. (2007): Risk and benefits from consuming salmon and trout: a Canadian perspective. Food and Chemical Toxicology, 45, 1343–1348.

Fischer G.J., Held J., Hartleb C., Malison J. (2009): Evaluation of brook trout production in a coldwater recycle aquaculture system. Aquacultural Engineering, 41, 109–113.

FAO (2014): The State of World Fisheries and Aquaculture. Opportunities and Challenges. FAO, Rome, Italy.

Hastein I., Binde M., Hine M., Johnsen S., Lillehaug A., Olesen N.J., Purvis N., Scarfe A.D., Wright B. (2008): National biosecurity approaches, plans and programmes in response to diseases in farmed aquatic animals: evolution, effectiveness and the way forward. OIE Revue Scientifique et Technique, 27, 125–145.

Jokumsen A., Svendsen L.M. (2010): Farming of freshwater rainbow trout in Denmark. DTU Aqua, National Institute of Aquatic Resources, Charlottenlund, Denmark.

Martins C.I.M., Eding E.H., Verdegem M.C.J., Heinsbroek L.T.N., Schneider O., Blancheton J.P., d'Orbcastel E.R., Verreth J.A.J. (2010): New developments in recirculating aquaculture systems in Europe: a perspective on environmental sustainability. Aquacultural Engineering, 43, 83–93.

Pedersen L.-F., Suhr K.I., Dalsgaard J., Pedersen P.B., Arvin E. (2012): Effects of feed loading on nitrogen balances and fish performance in replicated recirculating aquaculture systems. Aquaculture, 338, 237–245.

Summerfelt S.T., Davidson J.W., Waldrop T.B., Tsukuda S.M., Bebak-Williams J. (2004): A partial-reuse system for coldwater aquaculture. Aquacultural Engineering, 31, 157–181.

Svinger V.W., Policar T., Steinbach C., Polakova S., Jankovych A., Kouril J. (2013): Synchronization of ovulation in brook char (Salvelinus fontinalis, Mitchill 1814) using emulsified d-Arg(6)Pro(9)NEt sGnRHa. Aquaculture International, 21, 783–799.

Terjesen B.F., Summerfelt S.T., Nerland S., Ulgenes Y., Fjaera S.O., Reiten B.K.M., Selset R., Kolarevic J., Brunsvik P., Baeverfjord G., Takle H., Kittelsen A.H., Asgard T. (2013): Design, dimensioning, and performance of a research facility for studies on the requirements of fish in RAS environments. Aquacultural Engineering, 54, 49–63.

Unger J., Brinker A. (2013): Feed and treat: What to expect from commercial diets. Aquacultural Engineering, 53, 19–29.

Wall R., Ross R.P., Fitzgerald G.F., Stanton C. (2010): Fatty acids from fish: the anti-inflammatory potential of long-chain omega-3 fatty acids. Nutrition Reviews, 68, 280–289.

Wilfart A., Prudhomme J., Blancheton J.-P., Aubin J. (2013): LCA and emergy accounting of aquaculture systems: towards ecological intensification. Journal of Environmental Management, 121, 96–109.

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Corresponding Author

Miloš Buřič, Ph.D., University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters, South Bohemian Research Center of Aquaculture and Biodiversity of Hydrocenoses, Zátiší 728/II, 389 25 Vodňany, Czech Republic

Phone: +420 387 774 601, e-mail: buric@frov.jcu.cz