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Danish Model Recirculating System for Salmonids in the Climate of Mid-Europe: Advantages, Possibilities, Limitations

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ABSTRACT - The first Danish model recirculating aquaculture system (RAS) for salmonids was built in the Czech Republic in 2007. Surprisingly, there are lacking similar farms also for other fish species. A large skepticism is ingrained within traditional fishermen focused mainly on carp production. We therefore monitored the function and local specific issues for evaluating RAS in the mid-European conditions. The greatest difference compared with the place of Danish model RAS origin is winter season operating, characteristic by 3-4 months of ice coverage and water temperature ranging between 0.9-3.0 °C. However, the use of tested RAS in local Czech Republic conditions was evaluated as very effective, and more beneficial than traditional flow-through systems (FTS) for salmonids. Bio-filtration was effective despite of low temperature and able to remove an amount of metabolits produced in winter season. Compared to FTS placed on the same site, RAS is independent of often seasonal water quality changes caused by land use, sudden weather changes (thaw), flow variation (floods or summer drought), variable content of dissolved matter and possible disease transfer from a river. More stable conditions of water quality, compared to FTS, resulting in better fish condition and growth. Higher increments, feed conversion ratio, and Fulton's condition coefficient were reached in RAS compared to adjoining FTS. However, the long winter period breaks down the total possible production. In general, this question is only one limitation, excluding the primary cost of the RAS, of similar systems in mid-European conditions. The potential production can be largely increased by covering RAS and using oxygenation. Nevertheless, the RAS is functional also in the presented state. The propagation, developing and building of new RAS means to use of more effective techniques and to invest to the future in the frame of sustainable development in aquaculture.

Methodology

Study site

- Danish model recirculating aquaculture system (RAS) and flow-through system (FTS) for salmonids in Souther region of Czech Republic (Loc: 49°6'35.2"N, 13°45'10.2"E).
- Climate: Mid-European, foreland of the Bohemian Forest, ice coverage from 3 to 4 months, average air temperature (2010) 6,4°C; average (on study site) water temperature 6,3°C

Tested system

- Overall volume: ~ 1000m^3 ; inlet water: ~ 3$l.s^{-1}$
- Maximal capacity: 50 tons; Calculated possible production: 100 tons
- Fish stock during the study (13-20 tons): rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta m. fario*), siberian sturgeon (*Acipenser baeri*), russian sturgeon (*A. gueldenstaedti*)

Fig. 1. The flow through system (FTS) and recirculating system (RAS) at the study site.

Data sampling and analysis

Fish growth and condition – monthly realized measurements of length and weight increments, continuous control of stocked fish, feeding control.

Physical and chemical conditions – Bi-monthly sampling of RAS water and analysis of NH_4^+, NO_2^-, NO_3^-, BOD, COD_{Mn}, suspended solids.

- Samplings were carried out on three sample sites: prior to the biofilter, past the biofilter, and inlet to fish tanks.
- Daily measurements of dissolved oxygen level, pH, and water temperature.

Data analysis – Data were edited and analyzed using software Statistica 9.0 (StatSoft, Inc.).

Results

- RAS offers more stable conditions (temperature, flow, water quality) and higher temperature throughout the year compared to FTS (Fig. 2.).
- RAS enables better fish growth (compared to FTS) via higher feed conversion ratio and better condition (Table 1.).
- Winter season is limiting in fish production – 3.5 months was RAS covered by ice (low feeding – Fig. 3., higher work difficulty).
- The functional state of biofilter is conserved also during winter by routine cleaning.
- Spring and autumn critical period (increase of toxic nitrites and ammonia, increase of BOD) was checked when temperatures varied from 10 to 12 °C (Fig. 4., Fig. 5.).
- Nitrates increased continuously with increasing intensity of feeding (and temperature) (Fig. 6.).

Table 1. Comparison of Fulton's condition coefficient (CF) and Feed conversion ratio (FCR) between the Danish model recirculaitng system (RAS) and the Flow through system (FTS) for rainbow trout on the same site. Data are presented as mean ± SD. Statistically significant differences (ANOVA, Tukey post-hoc test, $p < 0.05$) are marked with different superscripts.

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul
C_F	RAS	1.72±0.13^a	1.76±0.12^a	1.83±0.15^a	2.01±0.17^a	1.93±0.16	1.90±0.07	2.01±0.01
	FTS	1.64±0.12^b	1.65±0.13^b	1.74±0.14^b	1.89±0.16^b	x	x	x
FCR	RAS	x	0.4259	0.6899	0.7522	0.7469	0.8005	0.7868
	FTS	x	negative	0.7380	0.8099	0.8126	0.8347	0.8157

Fig. 4. Ammonia and nitrite concentration in RAS throughout the year. Black arrows mark the NH_4^+ and NO_2^- increase probably due to change of bacterial strains on biofilter. Gray arrow marks the increase due to limiting conditions (high temperature and feeding).

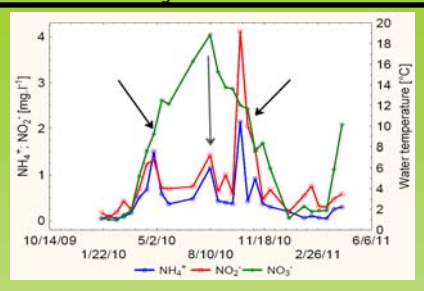


Fig. 7. Biofiltration units.

Fig. 2. Higher water temperature in recirculating system (RAS) compare to flow through system (FTS) at the same site.

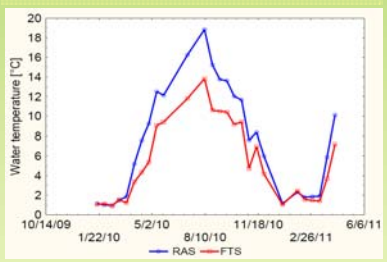


Fig. 3. The water temperature (temp), average feed amount per day (feed), and pH in RAS during the study.

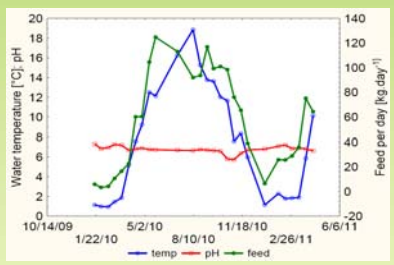


Fig. 5. Biological oxygen demand (BOD), chemical oxygen demand (COD_{Mn}), and temperature (temp) during the study in RAS. Black arrows mark the BOD increase probably due to change of bacterial strains on biofilter.

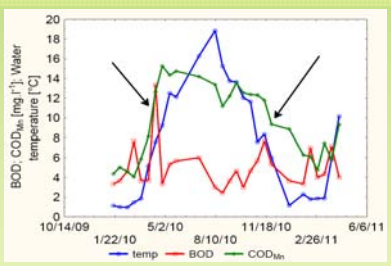
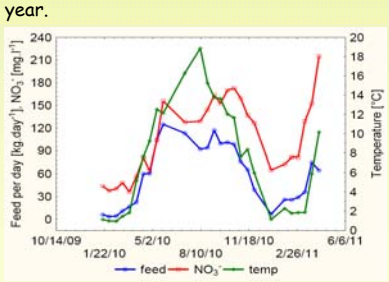


Fig. 8. Rearing channel and the specimens of rainbow trout reared in RAS during the study.

Fig. 6. Nitrate concentration, average feed amount per day (feed), and temperature (temp) in RAS throughout the year.



Conclusions

Usefulness in Mid-European climate

- Advantages – no disease transfer by inlet water, better growth than in FTS, reduced amount of discharged sludge, stable conditions not affected by floods or drought, not affected by land use and wastewater discharges, possible use of Danish model RAS for other species (brook trout, brown trout, sturgeon, pike-perch, perch).
- Limitations – expensiveness, high energy demand.
- Critical points – pH maintaining, water temperature over 19°C, autumn decrease and spring increase of water temperature (10-12°C) connected with increased amount of toxic nitrites and ammonium.

Winter season

- Disadvantages – low feeding intensity, high work difficulty, negative effect of long winter season on rainbow trout health.
- Possitive effect – better conditions than in FTS, „refreshing" of the biofilter and reduction of nitrates before a new growing season.

Possibilities and suggestions

- Covering RAS by a hall with oxygen and temperature treatment, new species testing, increasing the knowledge.

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