MORPHOLOGICAL CHANGES IN ARTIFICIALLY REARED ONE YEAR OLD SEA TROUT (*SALMO TRUTTA* L.) DURING SPRING

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Abstract
Morphological parameters and their changes common for artificially reared one year old sea trout were examined from January to May the year 2013 to determine whether these parameters indicated the smoltification in one year old sea trout and whether these fish achieved smolts stage. Fish were reared in flow-through and recirculation systems in hatcheries based on three different rivers (Brasla, Daugava, Venta basin). Sea trout were examined in the Latvia University of Agriculture, Faculty of Veterinary Medicine, Institute of Food and Environmental Hygiene and in the Institute of Food Safety, Animal Health and Environment BIOR, Laboratory of Aquaculture and Fish Pathology. To appreciate fish growth stage condition index, hepatosomatic index, spleen index was calculated and silvering level was evaluated. The fish condition index decreased in all hatcheries and flow-through and recirculation rearing systems from January to April and increased in May. Spleen index was the most stable parameter and did not change a lot showing that fish did not have migratory stress in April and May. Silvering level increased from January to April but suddenly the increase became slower in May without reaching the top level. These results made us to consider that one year old sea trout parrs released in May 2013 probably did not become smolts before release and they had to stay in river for one additional year until reaching pronounced smolt stage.
Key words: smoltification, condition index, silvering, hepatosomatic index, spleen somatic index.

Introduction

Spring is the time when juvenile salmonids such as sea trout start parr-smolt transformation called smoltification. The main purpose of smoltification for salmonids is to perform physiological adaptation to be ready for environment change from fresh water to salt sea water. It is very important for future survival and growth in salt water (McCormick, 2013). There are several physiological factors which can be taken into account for determination of smoltification – different blood parameters, gill Na+ K+-ATPase activity (Zaugg and McLain, 1972) and several morphological parameters such as fish length, weight, condition index, silvering etc. (Quigley et al., 2006; McCormick et al., 2007).

The most visible morphological sign of smoltification is silvering which is caused by deposition of guanine in derma and under fish scales. However, there are some salmonid species, which migrate to sea without any visible signs. It is detected that certain level of weight and age has to be reached for several species before migration to sea and adaptation to salt water (Stoskopf, 1993). It was assumed that it is better to release bigger smolts because they are more adult to protect themselves from predators (Salminen and Kuikka, 1995); however, it has been studied that purposeful raising of temperature in fish farm to promote growing of fish parr, can negatively affect smoltification – inhibit raising of gill Na+ K+-ATPase activity (Zaugg and Wagner, 1973; Ewing et al., 1979; Handeland et al., 2000). During smolitification different important physiological changes perform in the body of fish, for instance, reserves of body lipids and especially level of triglycerides rapidly decrease. A decrease in lipid content is a reason for reduction of condition index (CI) (Sheridan, 1989). Spleen somatic index (SSI) used to determine stress level in fish, shrinks due to contraction of spleen smooth muscles in stress conditions (Gerwick et al., 1999). Hepatosomatic index (HSI) changes according to season and fish nutritional status. It is affected by parasite infections and water pollution (Montenegro, González, 2012).

Fish growth depends on feeding and water quality. The most important factors of water quality for fish rearing are water temperature, oxygen saturation and pH. Optimal water pH for sea trout rearing is 6.0, but not higher than 8.5, and oxygen concentration should be above 7 mgL^{-1} (Peterson et al., 1972; Маликова и Иозепсон, 1987). Unfortunately, additional warming of water, which would be necessary for promotion of fish growing is not economically viable in flow-through rearing systems (Mitāns, 2001).

Physiological appreciation of smoltification is usually quite expensive and time-consuming; therefore, morphological evaluation is more applicable, because it is cheaper and simplier to perform.

The aim of the sea trout restocking in Latvia is improvement of natural salmonid resources mainly to compensate the negative effect of hydroelectric power station cascade on river Daugava and other anthropogenic factors. Till now in Latvia smoltification is determined just by fish weight, and other parameters are not taken into account. Besides, there is insufficient amount of studies about sea trout growth, development and smoltification in conditions common for the environment of Latvia. Many theories are based on theoretical presumptions and not on scientifically approved facts. The aim of the research was to start improve current situation and to appreciate the morphological changes of one year old sea trout in spring to assess their physiological readiness for migration to sea.

Materials and Methods

The study took place in the Latvia University of Agriculture, Faculty of Veterinary Medicine, Institute of Food and Environmental Hygiene and in the Institute of Food Safety, Animal Health and Environment BIOR, Laboratory of Aquaculture and Fish Pathology in 2013. In total of 1482 one year old sea trouts were examined in the investigation. Fish were reared in different hatcheries based on three rivers of Latvia – hatchery A (river Venta basin), hatchery B (river Brasla) and hatchery C (river Daugava). In all these hatcheries fish are reared in flow-through systems, but in the hatchery C fish are reared also in recirculation system. Fish were examined once every two weeks from January to February but from March to May once a week. In May, fish with appropriate weight were released in natural environment. Morphological factors were determined for fish individuals of different weight and size. We measured fish fork length (length from anterior-most part of the fish to the end of the median caudal fin rays) and fish were weighed. Then section was performed and fish liver and spleen were weighed. We visually evaluated sea trout body silvering and calculated CI (Formula 1), HSI (Formula 2) and SSI (Formula 3).

CI was calculated by the following formula (Berrill et al., 2006):

$$CI = \frac{W}{L^3} \cdot 100, \quad (1)$$

where
CI -condition index;
W-fish weight, g;
L- fork length, cm.

HIS was calculated by the formula (Nikolsky, 1963):

$$HSI = \frac{W_L}{W_F} \cdot 100, \quad (2)$$

where
HSI – hepatosomatic index;
W_L – liver weight, g;
W_F – fish weight, g.

SSI was calculated by the formula (Nikolsky, 1963):

$$SSI = \frac{W_S}{W_F} \cdot 100, \quad (3)$$

where
SSI – spleen somatic index;
W_S – spleen weight, g;
W_F – fish weight, g.

Silvering was evaluated using scale from 0 to 4 (Birt and Green, 1986, modified by Rutkovska) (Table 1).

Table 1

Evaluation of silvering level

Scale	Description
0	Parr. No signs of silvering, clearly visible parr marks.
1	Parr. Slightly silvery colour. Visible parr marks, some signs of silvering.
2	Smolt like Parr. (50% silvering). Silvery colour and visible parr marks.
3	Smolt like Parr. (75% silvering). Silvery colour and only slightly visible parr marks.
4	Smolt. Silvery colour, black fin margins. No visible parr marks.

The water temperature data were obtained from hatcheries daily temperature measurements.

Average and standard deviation (SD) was calculated for the data obtained. To compare parameters' changes from month to month, differences between hatcheries of different rivers and differences between flow-through system and recirculation system in hatchery C, T-test for comparison of two separate samples was used (Sokal and Rohlf, 2000).

Results and Discussion

The water temperature data obtained from hatcheries showed that in the beginning of the study water temperature in hatchery A was 0.2 °C, and it started to increase from the beginning of April. On May 1, water temperature reached 9.5 °C and at the end of the research it was 16.0 °C. In the hatchery B water temperature was 2.5 °C in January and did not change significantly until April 24 when it started to increase. On May 1, it reached 6.4 °C and on May 10, it was 8.2 °C. In the hatchery C flow-through system water temperature was 2.0 °C in January, then it lowered to 1.0 °C in February. Temperature started to increase from April 19 and on May 1 it reached 7.5 °C, and in the middle of May it was 16.5 °C. In the hatcheries C recirculation system water temperature was 8.0 °C in January and it started to increase in April reaching 14.0 °C at the end of the research.

Table 2

One year old sea trout condition index in spring

Fish farm/ rearing system	Month				
	January	February	March	April	May
A/ flow-through	1.08 ± 0.08	1.03 ± 0.09[a]	1.03 ± 0.10	1.06 ± 0.12[b]	1.08 ± 0.08
B/ flow-through	1.16 ± 0.09	1.08 ± 0.10[a]	1.05 ± 0.10	1.06 ± 0.11	1.08 ± 0.06
C/ flow-through	1.17 ± 0.13[c]	1.15 ± 0.11[c]	1.04 ± 0.10[ac]	1.07± 0.14[c]	1.14± 0.07[ac]
C/ recirculation	1.24± 0.12[c]	1.22 ± 0.12[c]	1.16± 0.12[ac]	1.15 ± 0.14[c]	1.32 ± 0.11[ac]

[a] significant difference $p<0.01$ in comparison with previous month
[b] significant difference $p<0.05$ in comparison with previous month
[c] significant difference $p<0.01$ between rearing systems of hatchery C

Table 3

One year old sea trout hepatosomatic index in spring

Fish farm/ rearing system	Month				
	January	February	March	April	May
A/ flow-through	1.68 ± 0.32	1.59 ± 0.71	1.36 ± 0.28[b]	1.30 ± 0.30	1.63 ± 0.21[a]
B/ flow-through	1.61 ± 0.31	1.65 ± 0.32	1.62 ± 0.29	1.63 ± 0.31	1.38 ± 0.21[a]
C/ flow-through	2.08 ± 0.37[c]	1.91 ± 0.42[bc]	1.82 ± 0.28[c]	1.70 ± 0.35[ac]	1.37 ± 0.14[a]
C/ recirculation	1.66 ± 0.36[c]	1.63 ± 0.28[c]	1.47 ± 0.28[ac]	1.41 ± 0.23[c]	1.27 ± 0.25[b]

[a] significant difference $p<0.01$in comparison with previous month
[b] significant difference $p<0.05$in comparison with previous month
[c] significant difference $p<0.01$ between rearing systems

When analyzing results obtained in the spring of 2013, it can be seen that CI varied between fish farms and months (Table 2). From January it gradually decreased reaching its lowest level in March and then increased again. This could be seen in all fish farms. It can be explained by the water temperature, which affects a feed consumption. In winter water temperature is low; therefore, fish feed less than in warm water but still they have their lipid reserves which gradually are being spent. Accordingly, fish had the poorest condition in March. Then, water temperature increased and fish fed more and fish condition improved again. It can be seen that fish from recirculation system had steadily significantly higher CI than fish from flow-through systems but still CI slightly decreased from January to even April and then sharply increased in May. Water temperature in this system in winter was higher than in flow-through systems.

In our study it could be seen that fish did not lose their body lipids in May; on the contrary, CI increased. In other studies with Atlantic salmon (*Salmo salar* L.) situation was different - CI decreased during smoltification (Sheridan, 1989; Quigley et al., 2006), but there are other studies with sea trout where CI increased during parr-smolt transformation (Tanguy et al., 1994; Quigley et al., 2006). D.T.G. Quigley et al. (2006) suggests that increase in CI can be connected with non-proportional growth of the caudal peduncle or with not so intensive lipolysis.

A different situation was observed with HSI, where no common tendencies could be seen (Table 3). In every fish farm tendencies were different. In the fish farm A, HSI decreased from January to April and then sharply increased in May. In the fish farm B, HSI was more or less stable until it rapidly decreased in May. In the fish farm C, HSI decreased from January to May. Moreover, it happened in both recirculation and flow-through rearing systems. There was significant difference between HSI of both rearing systems of the fish farm C from January to April. It was not so easy to find the reason for these fluctuations of HSI. There were no signs of seasonal changes in flow-through systems or we could not find connection with changes of CI. Studies of other researchers have shown that HSI changes according to season and fish nutritional status. It is affected by parasite infections and water pollution (Montenegro and González, 2012). We could consider the possibility of water pollution in flow-through systems, but we have no clear evidence of that because water quality was not controlled at that time. We could see that there was significant difference between HSI of fish from flow-through and recirculation systems of the hatchery C. The water quality in recirculation system is good with no fluctuations of pollutants. Underground water was used in this system and all tests made have indicated a good water quality. Unfortunately, during this study water quality analysis had not been made in hatcheries and we can just rely on previous data of water quality

Table 4

One year old sea trout spleen somatic index in spring

Fish farm/ rearing system	Month				
	January	February	March	April	May
A/ flow-through	0.14 ± 0.05	0.17 ±0.06	0.14± 0.06	0.13± 0.05[a]	0.12 ±0.04
B/ flow-through	0.20± 0.08	0.20 ±0.08	0.21± 0.08	0.20± 0.07	0.19± 0.07
C/ flow-through	0.15± 0.06	0.16 ±0.06	0.14± 0.07[ac]	0.13± 0.04[c]	0.14± 0.04
C/ recirculation	0.15± 0.06	0.17 ±0.07	0.16± 0.05[c]	0.16± 0.05[c]	0.16 ±0.05

[a] significant difference $p<0.01$in comparison with previous month
[c] significant difference $p<0.01$ between rearing systems

Table 5

One year old sea trout silvering level in spring

Fish farm/ rearing system	Month				
	January	February	March	April	May
A/ flow-through	1.55	2.11	2.56	2.70	2.67
B/ flow-through	1.36	1.68	2.35	2.60	2.70
C/ flow-through	1.54	2.14	2.37	2.64	2.96
C/ recirculation	1.96	2.36	2.79	2.74	2.95

provided by hatcheries. Therefore, in the hatchery C the reason of HSI decrease could be seasonal changes – the raise of water temperature. The temperature increase initiated HSI decrease.

More stable situation was detected for SSI (Table 4). There was not significant fluctuation of SSI in fish farms B and C (recirculation system). Some changes can be seen in the fish farm A from March to April and in the fish farm C flow-through system from February to March.

In fish organisms changes caused by stress are coordinated through the hypothalamus which leads to contraction of smooth muscle in the spleen (Thomas, 1990). Analyses revealed that fish did not have migratory or other stress in any of studied hatcheries during April and May. These months are the time of year when smoltification has to appear. Studied sea trout did not have stress during smoltification or they had not become smolts yet, as smoltification is associated with stress.

In all fish farms a level of silvering slightly increased during spring period, but it didn't reach a maximum level – 4 (Table 5).

Our results coincide with previous studies of other researchers, showing that there are not as visible changes in sea trout as it is detected for salmon during smoltification (Soivo et al., 1989; Debowski et al., 1999). Some researchers think that it may be connected with very intensive growth of sea trout during spring (Fahy, 1990; Bohlin et al., 1993; Tanguy et al., 1994).

Conclusions

CI of one-year old sea trout decreased from January to April and then started to increase. SSI was quite stable and did not decrease in April and May. There could be seen silvering in one year old sea trout in spring, but it is not clear whether these fish managed to become smolts in the end of first year of life. The low silvering level and absence of migratory stress indicated that most part of one year old sea trout did not reach smolt stage and it would be necessary to continue rearing for one more year until fish become two years old. More investigations have to be done to evaluate the possible HSI connection with smoltification.

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