EFFECTS OF TAGGING ON MIGRATION BEHAVIOR, SURVIVAL AND GROWTH OF HATCHERY-REARED ATLANTIC SALMON SMOLTS – AN EXPERIMENTAL STUDY

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We examined the effects of four different tagging methods (PIT, anchor T-tag, Carlin tag, and dummy radio transmitter) on the survival, behavior and growth of salmon smolts during their downstream migration in semi-natural circular channels during a natural migration period in spring 2013. Survival of smolt was high and tagging wounds healed well in all tagging groups. Tag loss rates were generally low, but highest in the dummy radio transmitter group (2.5%). Length and weight of the tagged and untagged smolts did not differ at the end of the experiment. Smolts tagged with Carlin tag started their migration later than PIT-tagged fish. Additionally, smolts with Carlin tag or dummy radio transmitter showed less overall migration activity than fish with PIT tag. The results supported the perception that tagging by different tag types affected salmon smolt migration and performance rather similarly during the period of migration with no prominent negative consequences.

1 INTRODUCTION

Securing the survival of downstream migrating smolts is one the key factors for re-establishment of salmon populations in regulated rivers. Information of smolt behavior and migration success is used for planning mitigation measures, such as downstream migration routes passing weirs and powerhouses. Such information is usually based on tagged fish. Therefore, understanding tagging effects on smolts is important for making relevant conclusions and recommendations for mitigation measures. Tagging of the fish has been done since the late 1800s to provide information on fish stock identity, movements and migration, abundance, age and growth, mortality, behavior and stocking success [1, 2]. Early tagging studies were undertaken with external tags based on the recapture of tagged fish [1] and during last decades technical developments have brought up a variety of new tag types based on telemetry, which has enabled tracking of fish without recapture.

The ability to attach the tag to the experimental fish with high tag retention and without negative effects on the fish physiology or behavior is the key for any successful tagging study [3]. However, the known fact is that tagging can have negative effects on tagged fish and tag retention rates can vary between and even within tag types. To this end, it is important to understand how tag induced effects differ between tag types when analyzing research results and planning management and conservation measures for fish stock.

Different tagging methods are used to study behavior and success of downstream migration of Atlantic salmon smolts (later ‘smolts’). Effects of conventional and more recent telemetry tags to the smolts have been

studied previously, but only few of them have compared possible effects between tag types. However, this topic should be of high priority for gaining reliable knowledge, because smolts may be sensitive to tagging due to their physiological changes during smoltification [4]. The aim of this experiment was to examine how four commercially available tag types (PIT, anchor T-tag, Carlin tag, and dummy radio transmitter) affect smolts during their downstream migration. Our selected tag types are commonly used in studies of smolt migration in regulated rivers. We were interested in quantifying the potential effects of different tag types on migration performance and growth of smolts. In addition, we investigated tagging mortality and tag loss rates between the tag types.

2 MATERIAL AND METHODS

Two year old smolts used in this experiment were of Oulujoki hatchery stock origin and they were reared by standard rearing methods (Det Norske Veritas Quality system certificate No. 2000-HEL-AQ-833, SFS_EN ISO 9001) in the Kainuu Fisheries Research Station of the Natural Resources Institute Finland (64°23´20´´N, 27°30´23´´E). The experimental fish were measured and tagged on 20-23 May 2013. The fish were dip-netted randomly from a larger batch of smolts and anaesthetized with buffered MS-222 solution (<100 mg/l), one fish at a time. The fish were measured for total length and body weight, and thereafter tagged immediately. The experiment included 800 smolts in total, divided into groups of 160 fish for every treatment (four tag-treatments and one untagged control group). There were no differences in the total length (mean 21.2 cm) or body weight (mean 90.2 g) of the fish between the treatments (ANOVA $F_{[4,795]} = 2.158$, $P = 0.072$ and $F_{[4,795]} = 1.541$, $P = 0.188$, respectively).

All tagging operations were conducted at standard laboratory conditions and according to animal experiment legislation in Finland (license EVISA-2458-04.10.03-2011). The untagged (UT) fish were anaesthetized and measured without tagging. The PIT-tagged (PT) fish were tagged with half duplex PIT tags (Texas Instruments Inc., size 23 mm x 4 mm) that was implanted into the body cavity through 5-10 mm incision. PIT tags were also inserted to all fish in other tag-treatments, because the monitoring of salmon migration and performance during the experiment was based on PIT-tracking (see detailed information below). The anchor T-tagged (TT) fish were equipped with the anchor T-tag (Hallprint, model TBA, 65 mm). The anchor T-tags were inserted below the dorsal fin with the applicator. The Carlin-tagged (CT) fish were tagged by inserting the Carlin tag (Graphium Inplastor, Sweden) below the dorsal fin with two hypodermic needles. The dummy radio transmitter tagged (RT) fish were tagged by implanting the dummy transmitters (manufactured by Advanced Telemetry System Inc., size and weight as the model F1410, weight 0.5-3.3% of the fish weight in air) into the body cavity through 13-15 mm incision between the abdominal and pectoral fins. Antenna of the dummy transmitters was run through hypodermic needle out of the body cavity and incision was closed with one suture.

After tagging, fish were randomly placed in eight indoor tanks (water volume 700 l) with 20 fish from each treatment. The fish from the recovery tanks were transported on 24 May 2013 to the eight outdoor semi-natural circular channels. Each channel (length 28.5 m, width 1.5 m, water depth average 33 cm) with directional water flow (c. 0.11 m s^{-1}) was equipped with four PIT reader antennas. The automatic recording system logged detected tags IDs and date and time from each antenna [see details 5]. PIT-data (www.pit.net) software package was used to calculate individual number and direction of antenna bypasses per hour during the experimental period. Hourly data were used to determine migration parameters for each individual. We determined: (i) the day when the threshold value (48 rounds around the channel in three successive day) of downstream migration was reached; (ii) the day when maximal movement to downstream direction was observed (total n of rounds around the channel was highest); (iii) maximal downstream movement per day (total n of rounds around the channel); (iv) overall movements during the experiment (total n of rounds around the channel); and (v) overall downstream movement during the experiment (total n of rounds to downstream direction around the channel). The experiment continued until 25 June. At the end of the experiment total length and body weight of the fish were measured, and condition of the incision was checked. The channels support benthic invertebrates providing a natural food supply thus artificial food was not provided for fish. Daily water temperature (Figure 1) was sampled by temperature loggers (Thermochron iButton® Temperature Logger DS1922L, Onsolution Pty Ltd, Australia).

Tagging effects on growth and migration characteristics of fish were analyzed using nested analysis of variance and generalized linear mixed-effects models, respectively, in the R statistical environment [6].

3 RESULTS AND DISCUSSION

Survival of smolts was close to 100% in all treatments. Only three fish (one TT and two CT) were found dead and the fate of one UT-fish remained unknown because it was not found at the end of study. In addition, tag retention rates were high in all treatments: no PIT tags were lost during the study period and highest tag loss rate was in RT-fish (2.5% of the dummy transmitters). Incision of the PIT tag was well-healed in all tag-treatments, but other tag types showed slight inflammation at the end of the experiment (10.6-29.4%). However, tagging did not have any effect on growth of smolts during the experimental period.

Downstream migration of smolts in the experimental streams started on average in mid-June when the water temperature had increased over 11 °C (Figure 1). The smolts thus followed a typical downstream migration timing of smolts in the rivers of the northern Baltic Sea area [7]. Smolts of CT-treatment started their downstream migration on average one day later than the fish in the other treatments. Overall downstream movement and maximal migration activity of smolts were lower in CT- and RT-treatments.

In conclusion, despite some differences observed between the treatments the use of different tag types to monitor smolt migration resulted in rather uniform and with comparable outcomes. The present experiment was run, however, under simple semi-natural arenas with e.g. no predation or flow-related disturbances typical in natural lotic systems. Forthcoming studies should focus on the impacts of multiple simultaneously operating pressures on smolts tagged with different tag types.

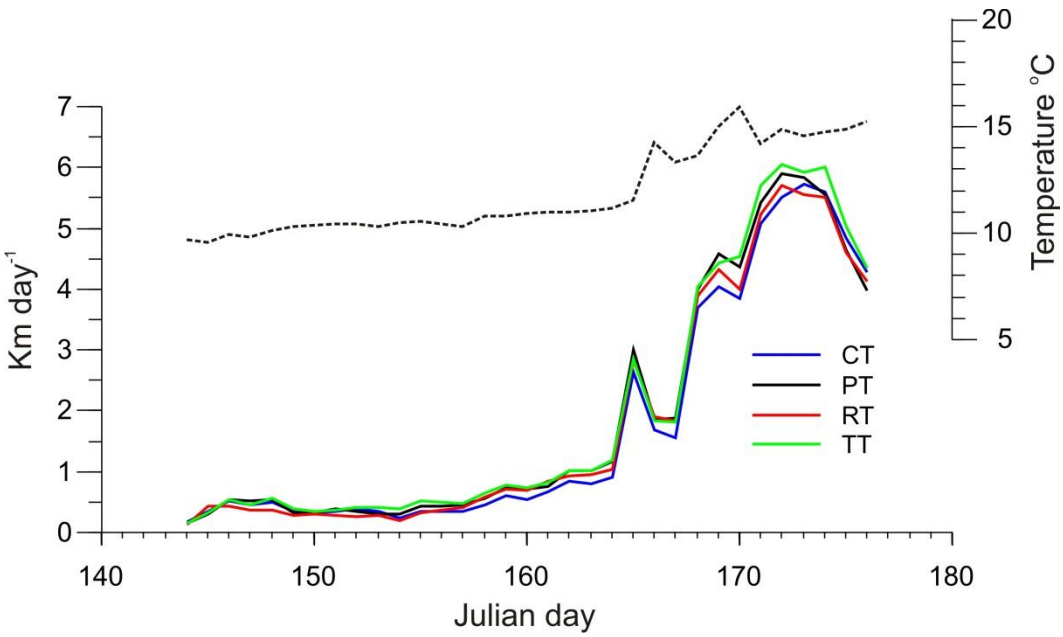

Figure 1.Average daily water temperature during the experiment (24.5.-25.6.2013, i.e. Julian days 144-177) and the average daily migration speed of smolts in the different tag treatments (PT = PIT tagged, TT = anchor T-tag +PIT, CT = Carlin tag+ PIT, RT = dummy radio transmitter+PIT).

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REFERENCES

[1] McFarlane G.A., Wydoski R.S. and Prince E.D., "External tags and marks: historical review of the development of external tags and marks", *American Fisheries Society Symposium*, Vol. 7, (1990), pp. 9-29.

[2] Lucas M.C. and Baras E., "Methods for studying spatial behaviour of freshwater fishes in the natural environment", *Fish and Fisheries*, Vol. 1, No. 4, (2000), pp. 211-220.

[3] Bridger C.J. and Booth R.K., "The effects of biotelemetry transmitter presence and attachment procedures on fish physiology and behavior", *Reviews in Freshwater Science*, Vol. 11, No. 1, (2003), pp. 13-34.

[4] McCormick S.D., Hansen L.P., Quinn T.P. and Saunders R.L., "Movement, migration, and smolting of Atlantic salmon (*Salmo salar*)", *Canadian Journal of Fisheries and Aquatic Sciences*, Vol. 55, No. S1, (1998), pp. 77-92.

[5] Vainikka A., Huusko R., Hyvärinen P., Korhonen P.K., Laaksonen T., Koskela J., Vielma J., Hirvonen H. & Salminen M., "Food restriction prior to release reduces precocious maturity and improve migration tendency of Atlantic salmon (Salmo salar) smolts", *Canadian Journal of Fisheries and Aquatic Sciences*, Vol. 69, No. 12, (2012), pp. 1981-1993.

[6] R development Core Team http://www.r-project.org

[7] Jutila E., Jokikokko E. and Julkunen M., "The smolt run and post-smolt survival of Atlantic salmon, *Salmo sala*r L., in relation to early summer water temperatures in the northern Baltic Sea", *Ecology of Freshwater Fish*, Vol. 14, No. 1, (2005), pp. 69-78.