MIGRATORY BEHAVIOR OF ASCENDING ADULT SALMON (SALMO SALAR) IN THE OUTLETS OF HYDROPEAKING POWER PLANTS

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The effect of dams on natural river ecosystems has been damaging. Dams change both the geomorphology and hydrology of rivers. For the anadromous fish species, like the Atlantic salmon (Salmo salar), dams are also migratory barriers. In situations when it is not possible to remove a migratory barrier, a fishway or a by-pass channel is constructed to allow fish-passage. For the planning of fish-passage structures it is important to know the patterns of fish behaviors below the dam: when fish are actively finding the way upstream. Upstream migration may also be guided by environmental factors, like changes in discharge. In this study we used telemetry to study the migration patterns of ascending adult salmon in two large rivers in Finland, Rivers Kemijoki and Iijoki. Altogether 121 salmon were captured during their spawning run, tagged with telemetry tags, and released below six hydropower stations in small groups. Stationary telemetry antennas were used to observe fish behavior below the dams. A clear pattern was found as fish moved upstream below the dam at higher discharge during daylight and descended downstream at lower discharge and darkness. The effect of temperature was less significant. Our results add to knowledge needed in re-building of salmon stocks in regulated rivers.

1 INTRODUCTION

Hydropower is an important source of renewable energy. The adverse effects of hydropower, in addition to hydrodams, result from the effects of flow regulation. Flow regulation changes the natural flow regime both on the seasonal and also on a more short-term basis. Several previous papers study the environmental factors affecting the spawning run patterns of salmon. The artificial migration barriers, like hydropower dams, cause delay in the upstream migration. The behavior of salmon in the power station outlets, where discharge situations are typically very complex, is not understood well.

The two important salmon rivers flowing into Baltic Sea in Northern-Finland, Rivers Kemijoki and Iijoki, once supported wild salmon populations. Both rivers were dammed for hydropower production after the World War II. Now after decades from closing the migration routes the original salmon stocks have been either lost (River Kemijoki) or maintained in hatchery (River Iijoki). Both rivers, however, still maintain potential for salmon reproduction, and an ongoing long-term project for re-building the salmon stocks has been initiated. The task is challenging as there are multiple hydropower dams in both rivers below the remaining spawning and nursery areas.

In this study we used radio tracking to study the behavior of adult Atlantic salmon during their upstream migration in two regulated rivers, Rivers Kemijoki and Iijoki. The patterns of upstream movements from the outlet to the close vicinity of the hydropower station above were studied in six hydropower stations, three in each river. The objectives of the study were to examine the effects of environmental factors (sunrise/sunset and rapid flow changes) on upstream migration pattern during the daily 24-h cycle and on a longer daily basis during the whole migration period.

2 MATERIAL AND METHODS

Both study rivers flow into the Bothnian Bay, Baltic Sea, in the northern Finland (Fig. 1). River Kemijoki is the longest river in Finland with the length of 550 km and catchment area of 51127 km2. The length of the main channel of the River Iijoki is 340 km and catchment area is 14 319 km2. The flow in the both rivers is regulated for hydropower production. The daily mean discharge during the study variated in the River Iijoki between 79-348 m3s-1 (the mean water discharge 174 m3s-1), in the River Kemijoki between 100-983 m3s-1 (the mean 402 m3s-1). The both rivers, have five hydropower dams in both rivers, equipped with Kaplan turbines, before the migrating salmon can reach the remaining spawning and nursery areas. Water from the turbines is directed to the outlet channels which are constructed outside the original river channel. These channels are man-made, principally u-shaped and considerably deep. The upstream migrating adult salmon swim to the outlet when searching the route upstream. Salmon migration was studied in the outlets of six hydropower plants: Kierikki, Maalismaa and Pahkakoski in the River Iijoki and Ossauskoski, Petäjäskoski and Valajaskoski in the River Kemijoki (Fig. 1, Table 1). There are no fishways in these hydrodams.

Alltogether 121 salmon were tagged with radio transmitters (mean total length 77 cm (range 47-111 cm), mean mass 5.1 kg (range 0.9-15.1 kg), 64 males and 57 females. Salmon were caught by long-handled hand net, seine or a trap from the estuaries of the study rivers during they were ascending to the river. Coded gastric telemetry-tags were used (Lotek Wireless, Inc, models MCFT2-3A and MCFT2-3BM, the tag models weighting 16 and 8 g in air, respectively). Tag size was selected according to the size of salmon. A transmitter was implanted intragastrically to anaesthetised (MS-222, 100 mg l -1) fish by pushing the transmitter through the oesophagus into the stomach with an applicator made of plastic tube, whereby the antenna wire was guided out through the fish's mouth. Before and after tagging fish were allowed to recover in net cages 1-2 days. Then the fish were transferred in 1 m3 oxygenated containers, transported, and released about two to three kilometers downstream from each of the six hydropower-stations (19 – 22 salmon per station). The tagged fish were tracked by automatic receivers (Lotek wireless Inc, model SRX_DL3) equipped with five (River Iijoki) or eight (River Kemijoki) underwater antennas and a six-element aerial Yagi-antenna.

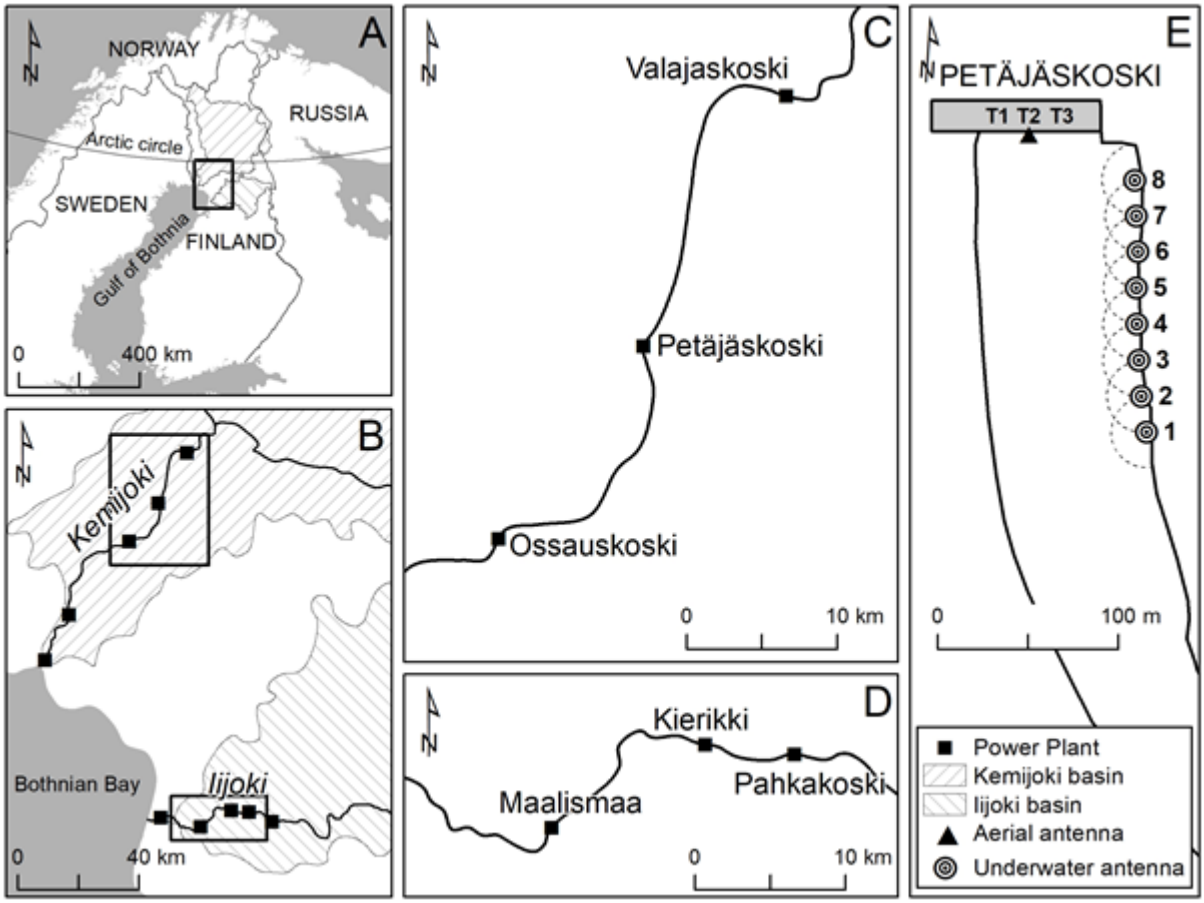

Figure 1. Location of the rivers (A) and location of the hydropower plants (B-D). The frame E in the right shows the setup of the telemetry antennas using the Petäjäskoski power plant as an example.

3 RESULTS AND DISCUSSION

Out of 121 salmon 15 never migrated upstream to the observation area. The number of ascends made by the remaining 106 salmon was in total 39 187. Salmon made on average 370 attempts to ascend upstream to the dam, although individual variation was high (1-1553 ascends). The time from release to the last observation, i.e. the time remained in the reservoir making attempts upstream, was on the average 63 days (SD=32) with a minimum of one day to a maximum of 129 days. The mean time spent in the observation area below the dam was 50 m 44 s (SD = 2 h 27 m 24 s).

The results of the present study showed that migrating adult salmon repeatedly moved upstream and downstream in front of the hydropower dam apparently to find the way upstream. These movements were affected by both by changes in discharge and day length as salmon moved downstream at night when the discharge at the power station decreased and up to the power station when the discharge again increased at daytime. Temperature had no effect on these daily movements but probably has a longer term effect in regulating the timing of migrations. In fact, when rebuilding the salmon stocks into these hydropower rivers the different timing of migrations and migratory behaviour of salmon should be taken into account; the large salmon returned earlier than small salmon, especially small males. Small fish also made less attempts to move upstream at the power stations than large fish.

In the case of several dams before spawning grounds, as in our study rivers, it is essential to minimize the delay, i.e. the subsequent up and down movements, in upstream migration. The migrating salmon were attracted to the high flow from the turbines, and unless considerable amount of the flow can be guided to the by-pass, the fishway entrance should be near the turbine flow. Here all possible remedial measures should be taken to guide the salmon. The most abundant migrations periods were the high flow situations during daylight. The results add to the knowledge needed in re-building of salmon stocks in regulated rivers, especially to the construction of fishways.