Examensarbete
i ämnet biologi

2013:4

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Passage effektivitet och vandringsbeteende hos lekvandrande Atlantlax i en ”Ice-Harbor” fisktrappa

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Keywords: passage efficiency, salmon, fish ladder, telemetry, power station

Program: Jägmästarprogrammet
Kursnamn: Master degree thesis in biology at the Department of wild life, fish and environmental studies

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30 hp, A2E
Kurskod EX0708

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Umeå 2013

Abstract

Due to exploitation of the world's rivers, the upstream migration of anadromous species is frequently delayed or even prevented. To mitigate these problems and allow fish to migrate past obstacles, structures such as fish ladders have been developed. However, recent studies show that many of the present fish passage facilities are deficient. Monitoring and evaluation of passage facilities is therefore crucial to enable necessary adjustments. In this study I have examined the passage efficiency and the migration behavior for upstream migrating Atlantic salmon (*Salmo salar L.*) passing a recently built fish ladder in the river Umeälven. 104 salmon were caught, tagged and released in the spillway close to the fish way entrance during the 2012 spawning run. Tagged fish were monitored with several radio telemetry loggers and PIT-antennas (Passive Integrated Transponder). The result revealed a passage efficiency of 78% and a mean delay of 30 days, post-tagging, before passage. Salmon tagged earlier in the season delayed longer before passing the fish way. The majority of salmon visited the entrance pool several times (mean 11.3 visits) before ascending and the time spent in the entrance pool were in general high (mean 2.4 days). The activity in and out from the entrance pool followed a diel rhythmicity but was independent of discharge in the bypass channel. The ladder was visited in average 1.5 times before the final ascent, which took on average 17.7 hours. A delay was observed in the upper part of the ladder in front of the VAKI-system, used to count passing fish. Once past the VAKI-system, there seems to be no problem for the fish to reach river Vindelälven. I also report that the migration pattern passed the fish way did not differ between native salmons from the Ume/Vindelälven stock and strayers with a genetic origin from the Luleälven stock

Sammanfattning

Till följd av exploatering av världens vattendrag, blir uppströms migrerande fiskar ofta uppehållna eller till och med hindrade. För att minska problemen och möjligöra för fisk att passera förbi antropogena hinder har anordningar som fisktrappor byggts. Emellertid, så visar ny forskning att många av dessa fiskpassageanläggningar är bristfälliga. Uppföljning och utvärdering av nämnda anläggningar är därför avgörande för att möjliggöra nödvändiga justeringar. I denna studie har jag utvärderat passageeffektiviteten och rörelsemönstret under en vandringssäsong för uppströms migrerande lax (*Salmo salar L.)* i en fisktrappa belägen i Umeälvens nedre del. 104 laxar fångades, märktes och släpptes i närheten av fisktrappans entré under lekvandringen 2012. Märkt fisk följdes därefter bland annat med hjälp av flera radio-telemetriloggrar och PIT-antenner (Passiva Integrerade märken). Resultatet visade en passageeffektiviteten på 78 % och en 30 dagars (medeltal) fördröjning mellan märkning och passage av fisk trappan. Fisk som märktes tidigt under säsongen uppvisade längst fördröjning. Majoriteten av laxarna som passerade trappan besökte entré-poolen flera gånger (medeltal 11.3 besök) innan den slutgiltiga forceringen och generellt så spenderade laxarna mycket tid i entré-poolen (medeltal 2.4 dagar). Passage in och ut från entré-poolen följde en daglig rytm men var däremot oberoende av om det spilldes i utskovet. Trappan besöktes i medeltal 1.5 gånger före den slutgiltiga forceringen, vilket i medeltal tog 17.7 timmar. En fördröjning kunde ses i trappans övre del framför VAKI-utrustningen som installerats för att automatiskt räkna passerande fisk. Jag fann även att det inte fanns någon signifikant skillnad i beteendet och passage mönstret för älvsegen fisk kontra fisk av annan stamtillhörighet

Introduction

Damming and hydroelectric exploitation of the running waters holding migratory fish species generally cause severe problems for fish to move up-and downstream to reach their spawning areas or the sea for continuous growth (Roscoe and Hinch 2010; Bunt et al. 2011; Kemp 2012). For salmonids has a reduced connectivity (Sheer and Steel 2006) been shown to prevent or delay up- and downstream migration in rivers (Rivinoja et al. 2001; Karrpinen et al. 2002; Marschall et al. 2011) followed by an increased mortality (Blackwell and Juanes 1998; Budy et al. 2002). Several methods and devices such as fish ladders, elevators and nature-like fish ways have been developed to mitigate these problems and enable migrating fish to reach their destinations (Clay 1995; Castro-Santos and Haro 2010). However, a lot of the present fish way facilities aren't adequate (Brown et al. 2013), mostly since they suffer from low attraction rate and therefore don't allow fish to pass as desired (Bunt et al. 2011; Noonan et al. 2011).

There are numerous types of fish ladders. All have the same purpose, which is to break an obstacle into several passable pools with different water surface elevations. Monitoring and evaluation of these ladders are crucial to ensure that they work properly and allow fish to pass as supposed (Clay 1995; Williams 1998; Pelicice and Agostinho 2008). However, according to Roscoe and Hinch (2010) many of the performed evaluations are poor with inaccuracies question formulations. A fish ways passage efficiency is quantitative description of its performance and commonly used during evaluations. It is generally explained as the number of fish that successfully pass relative to the number of fish that attempt to pass (Castro-Santos and Haro. 2010; Roscoe and Hinch. 2010). Methods measuring efficiency thus provide important knowledge about the success rate for fish that successfully pass and attempt to pass but fail (Bunt et al. 1999; Larinier et al. 2005; Castro-Santos and Haro. 2010). In addition, the migration behavior of salmon on their return from the sea to the rivers for spawning is complex and not fully understood. Telemetry is considered to be a very useful tool to achieve a quantitative evaluation (Roscoe and Hinch 2010; Bunt et al. 2011) and has been used in several studies to assess the movement patterns of salmon individuals, in relation to the ambient environmental conditions during their migration through fish ways (Gowans et al. 1999; Rivinoja et al.2001; Karrpinen et al. 2002). Previous studies has revealed that discharge is an important factor when explaining the fish swimming behaviour below dams and power station outlet (Gowans et al. 1999; Rivinoja et al. 2001; Thorstad et al. 2005a) while water temperature is important in both the timing of fish arrival and the rate of passage (Smith 1994; Northcote 1998; Gowans et al. 1999). Other external factors which may influence the migration are water turbidity, atmospheric pressure, variations in concentrations of dissolved ions, cloud cover and odor (Banks 1969; Bendall 2012).

Salmonids are known for their precise homing after continuous growth in the sea. However, some individuals enter non-native rivers instead of returning to their native river (Candy et al. 2000; Jonsson et al. 2003). This fact highlight one problem when designing telemetry studies to evaluate the individuals upstream behavior since some fish that do not belong to a specific natural river system only migrate upstream to explore the river. These individuals are commonly called strayers and this behavior help fish to find new habitats (Milner and Bailey 1989). However, straying may be a threat to native stocks since human-mediated interbreeding between previously discrete populations can reduce the fitness of populations by homogenizing unique gene pools and thus disrupting local adaptations (Allendorf et al. 2001; Jonsson et al. 2003).

The upstream migration of salmon (*Salmo salar L.*) in the problematic flow-regulated lower part of the river Umeälven has previously been studied (Rivinoja et al. 2001; Lundqvist et al. 2008) since the fish have problems to bypass a complex confluence area to reach and pass an upstream fish way to find their spawning areas in the tributary river Vindelälven. These results showed several obstacles in the bypass channel, signifying an average loss of 70 % potential spawners over the years. 30% of the loss where related to the most upper part of the fish way consisting of a fish ladder. Year 2008 a project aiming to improve migration conditions for salmonids past the regulated river section was initiated. Parts of the bypass channel were reconstructed and the old fish ladder was replaced with a new modernized fish ladder that became operational in the year 2010.

In the scope of the restoration project, it is necessary to verify the degree of functionality of the passage by assessing the fish ways passage efficiency and the behavior of ascending fish.

The main objective of my study was to investigate the fish ways efficiency and assess the migratory pattern and behavior for adult Atlantic salmon passing the fish way. Based on individual telemetry and PIT-data were the following questions asked: 1) What is the fish ways passage efficiency? 2) How much time does it take for the salmon to pass the fish way? 3) How does the salmon enter, ascend and leave the fish ladder? 4) Is there any difference in swimming behavior between strayers and native salmon?

Material and methods

Study site

River Umeälven is a highly exploited boreal humus river, running from the Scandinavian mountain ridge in a southeast direction to the coast in the Bothnian Sea in the northern parts of Sweden (annual mean flow c. 430 m^3s^{-1}). The river is highly exploited and Stornorfors hydropower, located c.32 kilometer upstream the coast, is the last dam before the river empties into the Bothnian bay. With a production of 2256,073 GWh/year and a maximum a capacity of c.1000 m^3 s it has the highest production capacity of all hydropower facilities in Sweden. Migrating fish aiming for river Vindelälven are supposed to bypass the power station through an c. 8 km long stream section, i.e. the old riverbed (from no one referred to as the bypass channel), and a c. 350 meter long fish ladder model “Half-Ice Harbour ladder” (see NMFS 2011). The bypass channel is open and provided with water during May 20^{th} until October 1^{st}. In order to increase the bypass channels attractiveness towards the turbine outlet and optimize for salmon to migrate upstream in the bypass channel the flow varies (c. 23 or 50 m^3/s) on a weekly basis between June 15 and September 4^{st} (Rivinoja et al. 2001). For the remaining time and especially late in the migration season flow is kept at c. 10 m^3 s^{-1}. During this study the above flow schedule was followed relatively accurately (Figure 1).

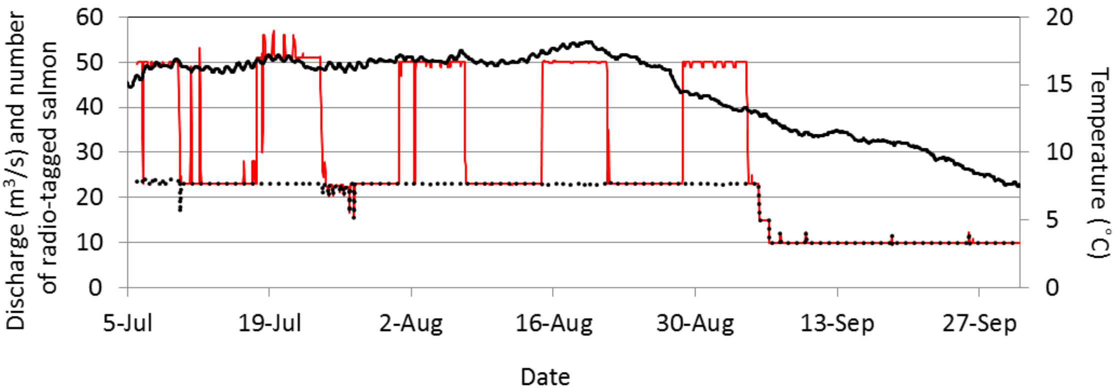

Figure 1 Discharge in the bypass channel (red solid line) and in the fish ways entrance pool (black dotted line) during the study period 2012 based on data received from Vattenfall AB; water temperature measured downstream the fish way entrance (fat solid black line).

The fish ladder rises 22 meters in altitude and is comprised of, from the entrance and upwards; one larger entrance pool, 77 smaller pools (3.5x3.0x1.9 m) and an exit control section (from now on referred to as the "exit zone"). Each pool is connected by a bottom orifice (0.4x0.4 m) and an overflow (1.5 m width). In the upper part of the ladder is a VAKI-system (e.g. an automatic fish counting system) installed. To pass the system the fish is supposed to move through a small tunnel. Water flow within the ladder is maintained at 1.2 m^3/s. To increase the fish ways attraction rate the entrance is supplied with auxiliary water (min-max 9-22 m^3/s) depending on time of the migration period (Figure 1). This attraction flow is de-energised after passing a small turbine before it empties in the entrance pool (Figure 2).

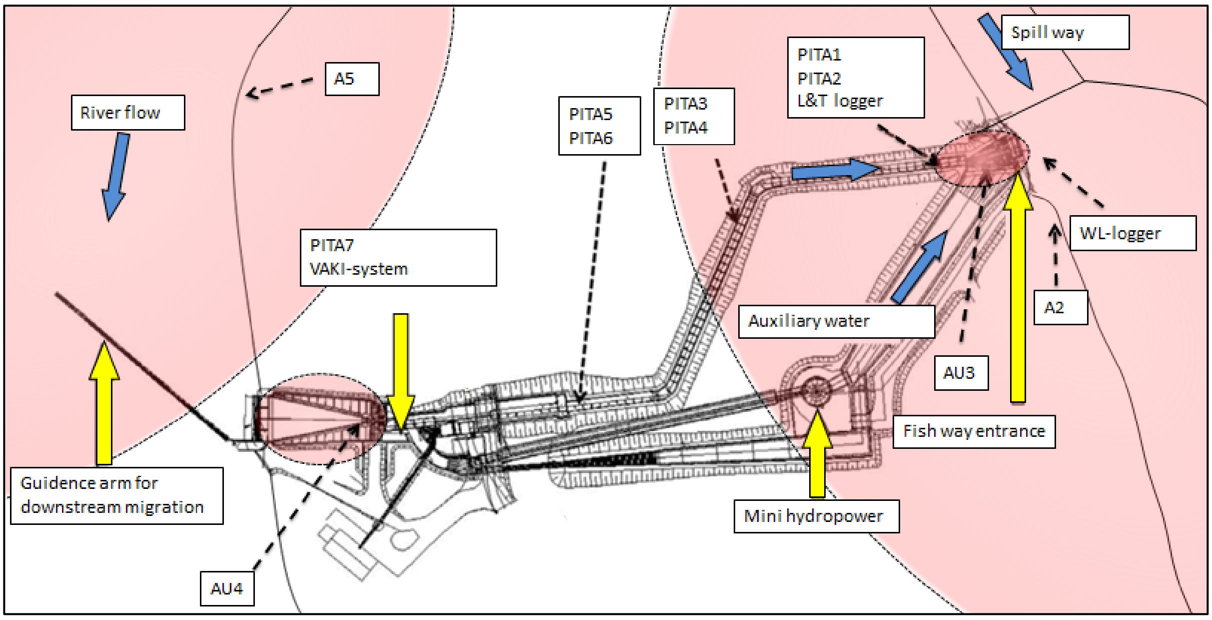

Figure 2 Map of the fish ladder at Norrfors, the automatic radio loggers' (A3, AU4, AU5 and A6) catchment areas (red dashed circles), the seven PIT-antenna pairs (PITA1-7) position in the fish ladder and the placement for the loggers measuring water level (WL) and temperature and luminosity (L&T).

Data for average hourly discharge in the small side turbine, the ladder, and in the spillway was received from the hydropower company Vattenfall AB. Additional flow information was stored every hour by a water level logger (HOBO U20-001-01) outside the fish way entrance. A regression analysis show that the correlation between the received discharge data and collected depth data from the water level logger is high (R2= 0.95). Water temperature and luminosity was measured every 10 minutes in the first pool above the entrance pool by an automatic light and temperature logger (HOBO UA-002-64) on a depth of c. 1 m.

Tagging of fish

At six different occasions during the period July 6th to August 21th there were 103 (63♀, 40 ♂) salmon tagged with both PIT-tag and gastric radio-tag, additional one female was tagged August 7th but then only with gastric radio-tag (Table 1). Fish length ranged from 39 to 116 cm (mean size 89.7 ± 2.2). The genetic analyses indicated that radio-tagged salmon most likely belonged to two different salmon stocks (Nilsson 2012). The majority of the radio-tagged (87%), belonged to the river Ume/Vindelälven stock, the other significant component was salmon originating from the river Luleälven (13%).

Table 1 Date and number of radio-and PIT-tagged upstream migrating Atlantic salmon caught, tagged and released downstream fish ladder and later recorded at one or more telemetry/PIT antennas during migration season 2012 in Norrfors. Size limits shows mean, minimum and max values for each nominal group. Affiliation shows the distribution of fish belonging to Ume/Vindelälven and Luleälven, respectively, for each nominal group.
[1]One female was only tagged with radio-tag.
[2]Seven individuals were released c. 1000 m downstream the spillway

Tag date	06-jul	11-jul	18-jul	02-aug	07-aug	21-aug	Tot.
N	23	7	17	28	15[1]	14[2]	104
Female:Male	18:05	06:01	10:07	15:13	08:07	07:07	64:40
Size (cm)	90 (73-106)	95 (77-105)	94 (70-116)	89 (75-112)	86 (75-104)	88 (79-100)	
Affiliation	18:5	6:1	16:1	24: 4	15:0	12:2	91:13

All tagging of fish was carried out in the spillway, just below the dam, to minimize the risk of losing tagged fish during their movement from the river mouth up to the fish way (see Lundqvist et al, 2008). All tagging were done by experienced staff from SLU and the hatchery in Norrfors.

Migrating adult of Atlantic salmon which had ascended the spill way during high discharge were trapped with hoop-nets after that the discharge was turned off and guided in remaining water downstream the spill way to a holding tank (6x3x1 meter) c. 50 m upstream the fish way entrance (Figure 3). Fish were gently lifted up from the tank using a hoop-net and placed into a live-box cradle equipped with overhead cover and filled with ambient water. The water was supplemented regularly. At tagging all fish were examined concerning their health status, origin (wild/hatchery), sex (male/female) and length (total length in centimeter). Wild fish (no adipose fin cut) in a good health status and in good body condition were tagged with pulsed gastric radio transmitter 151 MHz model F1830, Advanced Telemetry System (ATS) and a passive integrated transponder (PIT-tag). Four different rates of BPM (Bit Per Minute) were used for the radio tags. 45 transmitters, with

30 and 55 BPM respectively, were used at the five first tagging occasions. Eleven 40 BPM and one 80 BPM were used in the last tagging session. The frequency varied between 151.214-151.755. During the insertion of gastric transmitters the eyes of the fish were covered by hand. No anesthetics were used. As described by Rivinoja et al (2006), each transmitter was provided with a rubber ring of vulcanization tape with a diameter of 16–20 mm and a width of 7–10 mm (depending on fish size) to reduce the risk of regurgitation. Insertion and placement of transmitters was made using a PEX-tube fitting the transmitter (Ø-inner 10 mm, Ø-outer 13.5 mm). A gentle pull in the antenna assured that the transmitter was placed just below the cardio. Antennas that reached all the way past the snout were carefully curved to the side of the mouth. This method of tagging is unlikely to affect the swimming performance of adult salmon (Rivinoja et al. 2006). After the insertion, genetic tissue sample from the anal fin was taken simultaneously as a PIT-tag (FDX 12 mm) was inserted via a revolving injector. The insertion of PIT-tags, neutrally buoyant in water, was made vertical c. 2 cm deep in the fat close to the dorsal fin. Finally the PIT-tag code was scanned and the number noted. Fish were carefully lifted up from the live box and put down in the water just downstream the tagging location. Total handling time for tagged fish was c. 3 min.

Tracking of tagged fish

Seven stationary data-loggers, of two different types were placed from the area just below the fish way and upstream to river Vindelälven (Figure 3). Each logger was individually set to pick up and store reliable data for its specific location. Knowledge achieved in earlier studies (FD P. Rivinoja, SLU, pers. comm. 2012) and range tests with true transmitters were used to set the gain. The area close to the dam was covered by five loggers (logger A1, A2, AU3, AU4 and A5, all LOTEK SRX_400) to evaluate the fish way and to monitor the fish migration behavior in detail. Logger A1 at Laxhoppet c. 500 m downstream of the fish way entrance covered the area downstream to Kungsmofallen (c. 1000 meter). Logger A2 close to the fish way covered the main river pool stretching from the fish way entrance to Laxhoppet. Logger AU3 (antenna underwater) was made of stripped coaxial cable and set at low gain to register presence of fish in the entrance pool. Logger AU4 (antenna underwater) was installed to detect fish present in the exit zone. Logger A5 covered the area outside the ladder exit. Logger A6 and A7 (ATS-4100) covered the upper part of the study area, evaluating the approach and entry into the river Vindelälven.

Additional manual tracking was conducted 2-5 times weekly, from car or by foot (ATS-receiver RS 2100 and Swedish 'Televilt' receiver Model RX 8910). Focus was on the bypass channel but was also carried out in the immediate vicinity of the ladder and between the ladder exit and river Vindelälven. In October, after the ladder was closed, one tracking from boat was conducted covering the stretch from the river mouth to the lower parts of the bypass channel to search for tag-drops and dead fish.

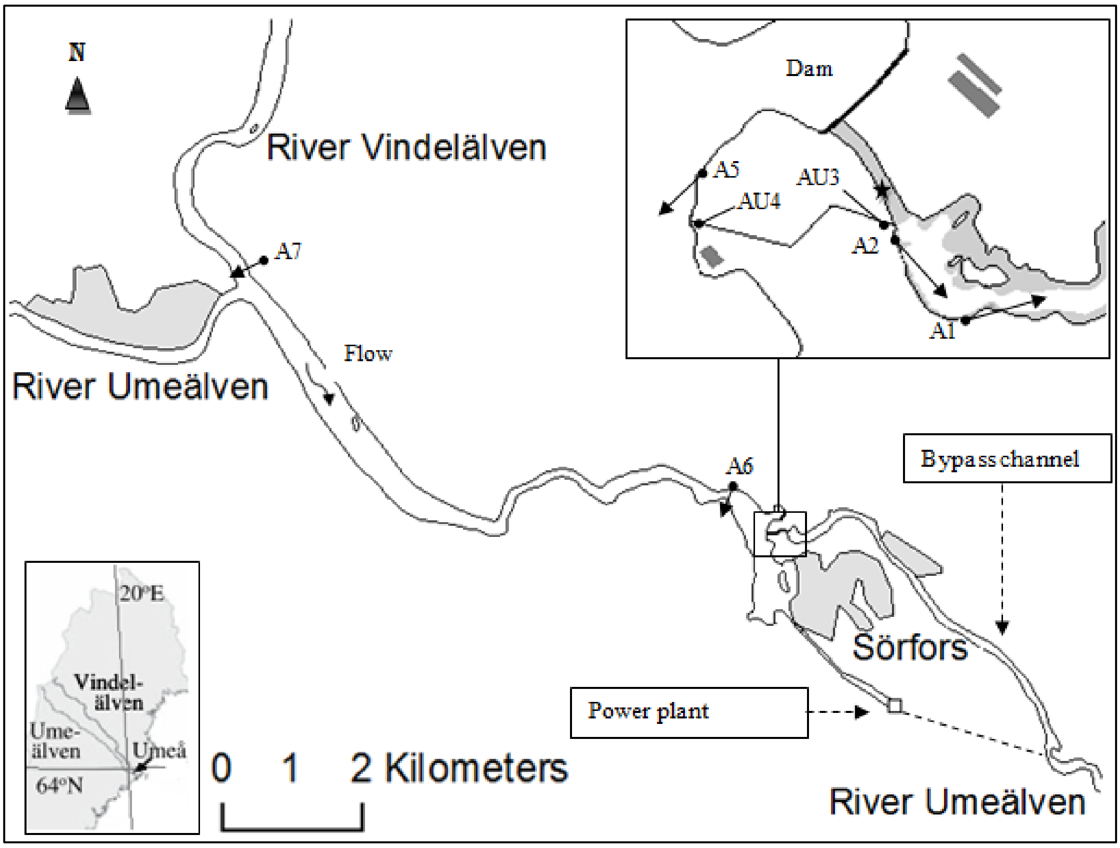

Figure 3 Map showing study area, the dam area (right box), the location of the seven stationary loggers (AX = Yagi 4 and 9 elements antennas; AUX = underwater antennas), the YAGI antennas primary catchment direction (•→), the tagging site (★) and the study areas position in Sweden (left box).

During the study four regurgitations of the transmitter could be confirmed and both the fish that had passed and had not passed the fish way were represented. Three fish during the study were found dead, two in the bypass channel and one c. 23 km downstream of the bypass channel. Found and confirmed dead fish was left out from the calculation of passage efficiency since I can´t exclude the possibility that the cause of death is linked to the tagging procedure.

The fish ladder was covered with fourteen PIT-tag antennas (BIOMARK Inc., USA) from the ladder entrance to the exit zone (Figure 2). Antennas were installed in groups of four with the exception of the two uppermost installed in front of the two VAKI-counters. Each group of PIT antennas was installed in two adjacent pools enabling detection of tagged fish swimming both up- and downstream. Each pair of two PIT antennae (PITA1 to PITA6, respectively) consisted of an antenna covering the passage orifice at the bottom and one above the weir to detect fish in the overflow. It was observed that fish passing a PIT-antenna was not always registered. This is partly explained by a blockage of two antennas due to the presence of dropped PIT-tags close to the antennas for a longer period and that PITA7 was only operational from late august and onwards. Four fish that passed the fish way did so with no PIT-registration at all. However, the failure did not severely affect the results in this study but resulted in a smaller sample size in some of the analyses.

Data processing and analyses

The real-time information extracted from the telemetry loggers and the different PIT-readers were processed and analyzed in excel. Individual radio- and PIT-data was sorted on date and time. Registrations which were deemed incorrect were deleted. Incorrect registrations could be either registration derived from the surrounding environment (e.g. a passing train) or registration of same individual at more than one logger simultaneously (i.e. double registrations). Registration derived from the surrounding environment was recognized by improper BPMs or that the registration didn´t fit to adjacent registrations. When double registration occurred the cleaning was based on signal strength; the individual were considered to belong to the logger which showed registrations of highest signal strength. I made an exception from this if a fish had moved from the entrance pool into the ladder. It was then assumed to be in the ladder until subsequent registrations on the logger at the entrance pool or in the exit zone showed that it left the ladder. Fish were considered to have entered the ladder when it entered the ladders´ first pool, i.e. registration on PITA1 or registrations on the underwater antenna (logger AU4) less than 200 in strength with subsequent registration on any PIT-antenna. Exit of the ladder was assumed to coincide with last registration on the logger in the exit zone. After deleting incorrect registrations all first and last registrations in each logger position segment were given a unique code. Coded registrations were considered as the “movement” from one logger to another. These coded registrations were then used to link movements of fish and achieved environmental data based on date and time.

The calculation of the fish ways efficiency followed previous studies definition of passage efficiency: [number of fish that exited the fish way]/[number of fish that was detected in the fish way entrance] (Bunt et al. 1999; Aarestrup et al. 2003; Bunt et al. 2011). An essential part of my study was related to the behavior of the ascent through the fish way. To display the behavior, I used duration of time in different zones along the fish way and the time until a specific event occurred as response variables. These response variables (days and hours) were individually calculated for each tagged salmon based on the coded registrations explained earlier. In the following I define these response variables:

Time to first visit in the entrance pool: the time between tagging until the first registration in the entrance pool.
Time to first visit in the ladder: the time between tagging until the first registration in the ladder.
Total time in the entrance pool: the sum of the length of all visits in the entrance pool during the study.
Effective time in the entrance pool: the sum of the length of all visits in the entrance pool between tagging until the first registration in the ladder.
Total time in the ladder: the sum of the length of all visits in the ladder and the exit zone during the study.
Effective time in the ladder: the length of time spent in the ladder and the exit zone during the final ascent, i.e. from ladder entrance until the last registration in the exit zone.
Exit time: the time between the last registration on one of the uppermost PIT-antennas (PITA7) until the last registration on the logger in the exit zone.
Time to pass: the time between tagging until the last registration in the exit zone.
Time to river Vindelälven: the time between the last registration in ladder exit zone until the first registration in river Vindelälven (i.e. antenna A7)

One important finding in this study was observed when the genetics from the telemetry tagged fish was analyzed. My tagged fish obviously had two different origins although all sampled fish had their adipose fin intact. Hence, they were all classified as wild salmon but had a genetic origin to the Luleälven stock (13 %) and the rest as native Ume/Vindelälven stock (87 %). Even if no statistically significant behavioral differences between strayers and native salmon could be seen, I have treated this minor group of fish as obvious strayers and excluded them from the result except for the last part when I compare the two groups' migration behavior. I did so since previous studies conducted in the Norrfors bypass channel (Rivinoja et al. 2001; Lundqvist et al. 2008) includes only native salmon and I wanted to get a reference group as similar as possible compared to these studies. Since the distributional assumptions were uncertain for the strayers due to low sample size I bootstrap each sample with 1000 replications.

Results

Passage efficiency and time to pass

My study showed that 77 radio-tagged salmon visited the entrance pool, and 60 of these did successfully pass the fish way. This reveals a passage efficiency of 78%. For salmon that entered the entrance pool but did not pass the fish way there were three scenarios observed. Eleven fish moved downstream through the bypass channel and was never observed in the vicinity of the fish way again. Five salmon stayed in the most surrounding area below the fish way until the end of the study. The last salmon regurgitated the radio tag shortly after being tagged, thus no data is available to determine the fate of the salmon more precisely. However, registrations on PIT-antennas showed that it visited the fish ladder once but reversed downstream. It took between 2.6 and 84.9 (min-max) days post-tagging for the fish to pass the fish way (mean 30 days). A relative long delay time before passage of the fish way was seen for fish tagged first in the study than did individuals tagged later in the study (Figure 4).

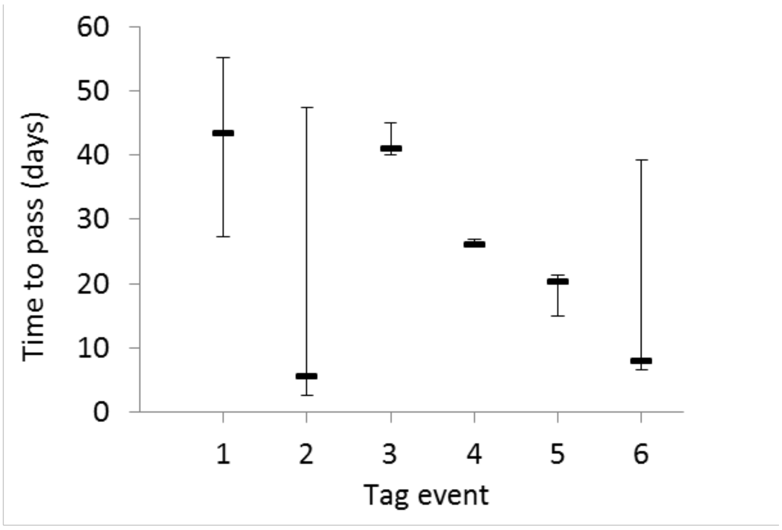

Figure 4 Median time (thick black bar) and the 95 % CI (error bars) from tagging to the passage of the fish way for salmon tagged at the six different tagging events during the study (N=8, N=4, N=12, N=20, N=11, N=3).

The entering, ascent and exiting of the fish way for successful passers

The number of visits into the entrance pool varied between 1 and 41 (mean 11.3 visits). Seven individuals made only one visit to the entrance pool before they ascended the ladder. It appeared that the salmon exhibited a diel rhythmicity in the traffic in and out from the entrance pool (Figure 5). Traffic into the entrance pool was more common in early morning and at noon, while passage out peaked in the evening. Revisits occurred mostly within a day (median 19.2 hours) but the range was large with a minimum of a few seconds to a maximum of 29.4 days.

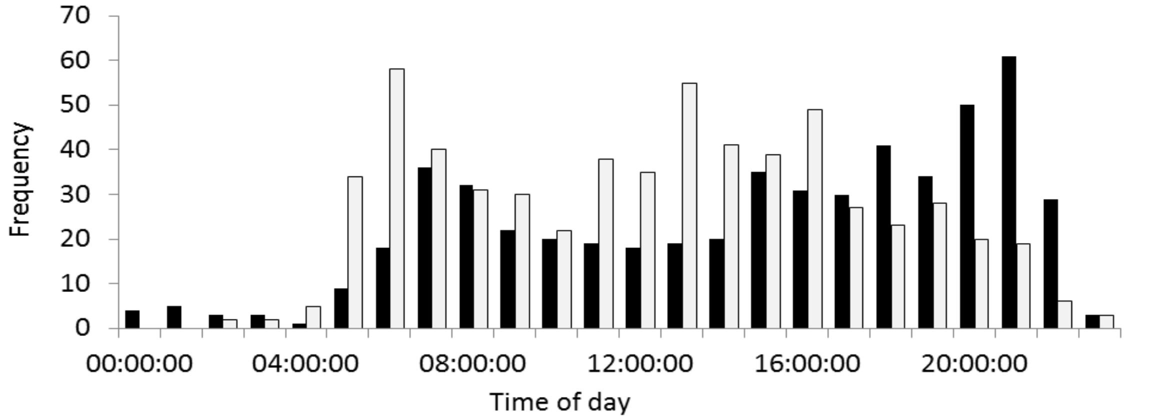

Figure 5 The distribution of the movements into the entrance pool (grey bars) and movements out from the entrance pool (black bars) performed by wild Vindelälven salmon (N=58) in relation to the time of day.

Traffic in and out from the entrance pool occurred to about the same extension regardless of discharge in the spill way or not (Figure 6). Time to first visit in the entrance pool varied between 4.8 hours and 35.1 days (mean 7.5 days). Movements downstream of the bypass channel were observed for those with the longest delay time before visit in the entrance pool. However, no salmon moved more than c. 1000 m downstream the fish way entrance (i.e. out of logger A2 detection zone). No relationship between time to first visit in the entrance pool versus sex, size or final fate (pass or non-pass) was found (P>0.05, d.f. 77, ANOVA).

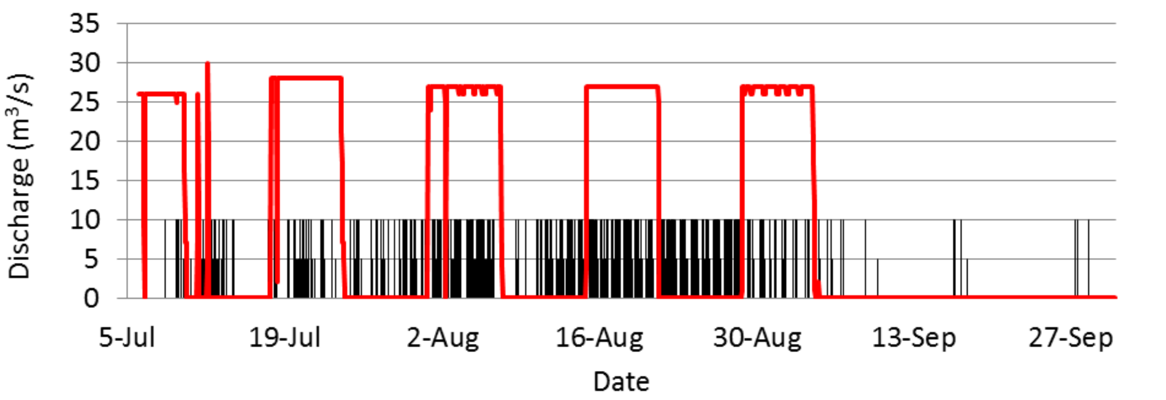

Figure 6 Discharge in the spill way during the study period (red line).Vertical bars show movements into the entrance pool (long bars, N=607) and movements out from the entrance pool (short bars, N=543) performed by radio-tagged salmon (N=58).

The fish spent, in general, a large amount of time in the entrance pool. Of the total time the fish spent from tagging until arrival in river Vindelälven (i.e. observed at logger A7), there was on average 8% of the time spent in the entrance pool. The individual total time fish were holding in the entrance pool varied between 1.3 hours to 13.4 days (min-max), with a mean of 2.4 days. The effective time spent in the entrance pool was somewhat shorter with a mean of 2.0 days.

Movement of salmon from the entrance pool into the ladder took place mostly place during daytime and especially in the afternoon. 70% (62 of 89) of all movements in occurred between 13:00:00 and 19:00:00. The salmon visited the ladder between 1 and 11 times before the final ascending and the mean time until the first ladder visit was 24.6 days. Most common was only 1 visit (mean 1.5 visits). Fish movements up to PITA6 were seen in non-final ladder visits but they never past PITA7. Revisits occurred within 11 minutes and 43.9 days (median 4.7 days). The length of time spent in the ladder during the final ascent of the fish way (i.e effective ladder time) varied between 2.3-167.5 hours (min-max) with an average of 17.7 hours. I observed clear but not significant relation between effective ladder time and fish size (Figure 7a) and between effective ladder time and time of day for ladder entry (Figure 7b). No correlation with water temperature was seen for the effective ladder time (R2=0.003) neither was there any significant difference in effective ladder time between males and females (P>0.05, d.f. 58, ANOVA).

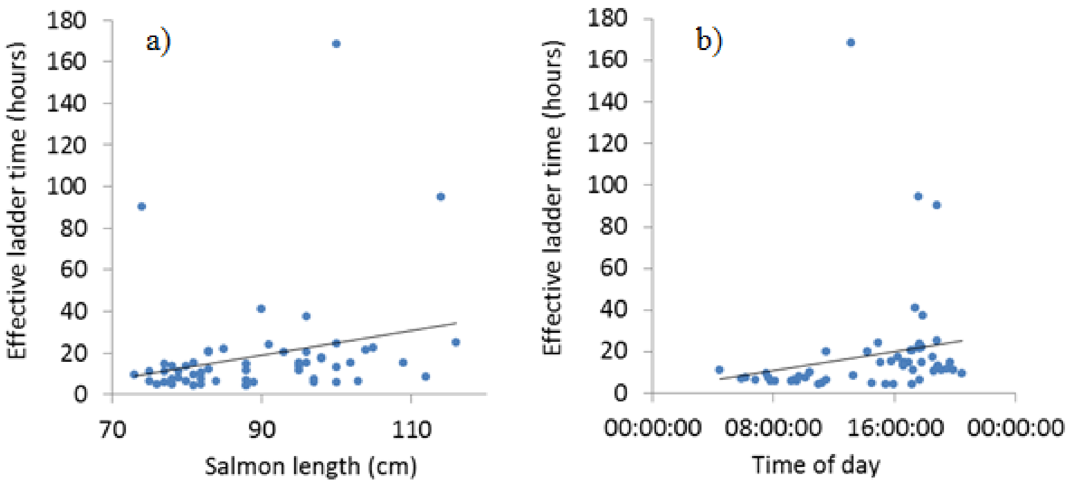

Figure 7a-b Effective ladder time plotted against (a) salmon length (N=58) and (b) the time of day for the final movement from the entrance pool into the ladder (N=58).

A clear delay was observed in front of the last PIT-antenna and the VAKI-system (Figure 8). After passage of last PIT-antenna (PITA7), travel exit time ranged between 16 minutes and 16.8 hours (median 36 minutes). Two fish had exit times longer than 10 hours. Both passed PITA7 in the evening, stayed in the ladder exit area during the night and continued the following day. All other fish passed PITA7 and left the ladder exit area the very same day. Average time from the ladder exit to river Vindelälven (i.e. logger A7) was 6.8 hours (N=48). A large percentage of the passages coincided with a sharp drop in temperature and luminosity in late August (Figure 9).

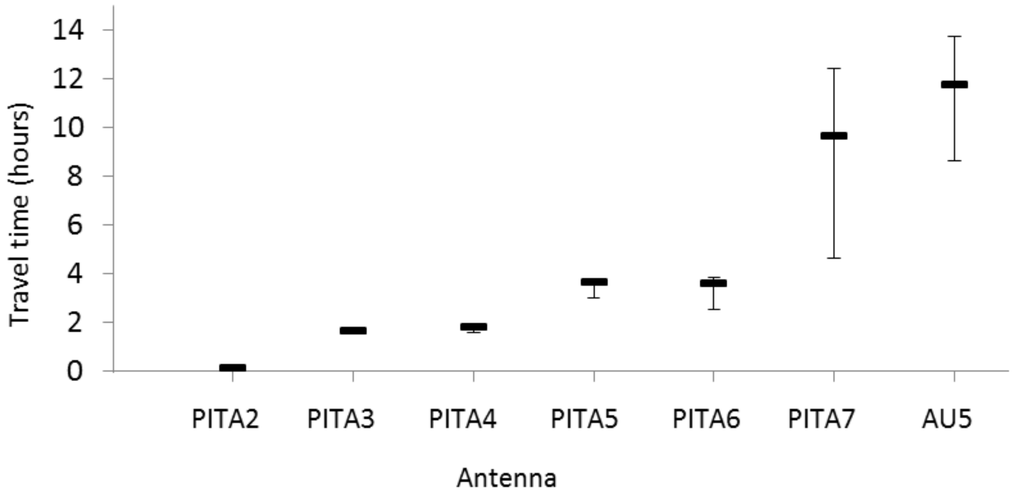

Figure 8 Median travel time (thick black bar) and the 95 % CI (error bars) from ladder entry to the first registration on PITA2 (N=44), PITA3 (N=34), PITA4 (N=47), PITA5 (N=32), PITA6 (N=34); PITA7 (N=19) and AU5 (N=58) in the final ascending of the ladder.

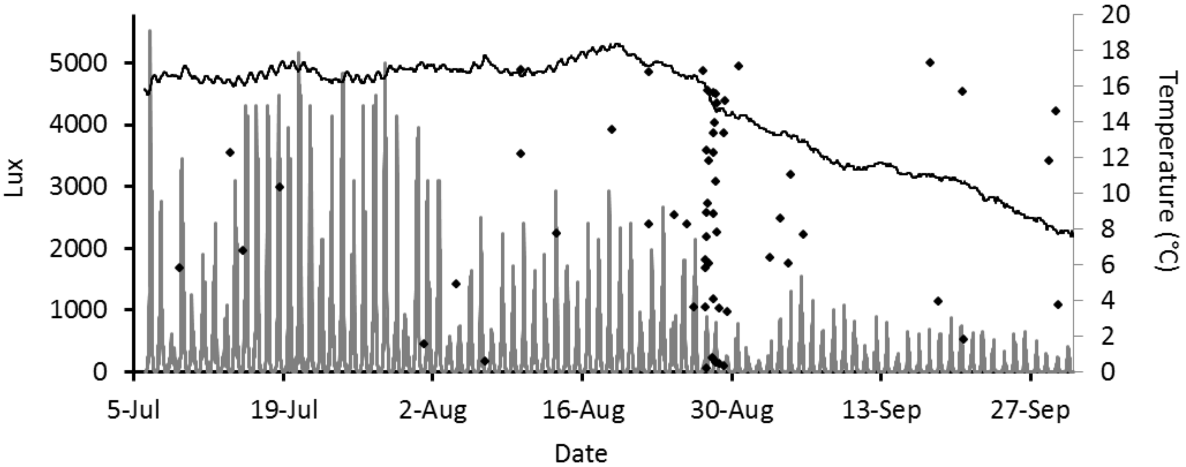

Figure 9 Water luminosity (lux) (grey line) and water temperature (black line) measured in the fish ladder during the study period. Each dot symbolizes the time (date on x-axel) for a passage of the fish way of a radio-tagged salmon (N=58).

Behavioral differences between strayers and native salmon?

I saw no significant difference in the median time for any time response variable between fish originating from river Ume/Vindelälven or strayers (Table 2). However, a searching behavior was observed for a strayer (664/30) which wasn't observed for any native fish. It left the ladder on August 27th, got registered immediately outside the ladder exit, "disappeared" for two days before it got registered on the logger c. 1000 m upstream the ladder exit. This fish therefore exhibited a yoyo pattern between river Vindelälven and the area close to fish way (i.e. logger A6) until September 10th when it "disappeared" again with the last registration on the logger outside the ladder exit (logger A5).

Table 2 Comparison between native fish originating from river Ume/Vindelälven stock and strayers originating from the Luleälven stock. The value for each response variable is displayed with median value and the 95 % CI for each median value (i.e. percentile 2.5 and 97.5). The 95% CI show that no significant difference can be seen between the two groups for any of the response variables.

	Ume/Vindelälven				Strayers				
Response variabel	2.5 perc.	Median	97.5 perc.	N	2.5 perc.	Median	97.5 perc.	N	Significant differnce
Time to first visit in the entrance pool	3,2	4,2	8,3	58	1,9	3,2	4,7	6	No
Total time in the entrance pool	41,0	59,2	73,2	58	16,6	37,4	62,1	6	No
Effective time in the entrance pool	21,3	35,9	50,0	58	16,6	37,4	62,1	6	No
Total time in the ladder	11,0	14,1	17,3	58	4,2	12,0	15,7	6	No
Time to first visit in the ladder	19,4	25,3	26,0	53	6,4	21,3	33,3	6	No
Effective time in the ladder	8,9	11,4	14,7	58	4,2	12,0	15,7	6	No
Time to pass	25,6	26,2	30,5	58	6,9	21,7	33,7	6	No
Time to river Vindelälven	5,4	6,0	7,3	48	4,0	5,7	72,6	5	No

Discussion

Passage efficiency and time to pass

My most important finding was that 60 of the 77 radio-tagged salmon, recorded in the entrance pool at Norrfors fish way did succeed in their ascending of the fish ladder. This reveals a passage efficiency of 78% for the fish way during the spawning migration of 2012. In comparison to many other fish ways it has a high efficiency. Bunt et al. (2011) reviewed 101 different evaluations of fish ways and reported an average passage efficiency of 48 %. However, my result signifies an average loss of c. 22% potential spawners, and to consider a fish way to be sufficient it is suggested that 90-100% of the adult upstream migrants should be able to pass the bypass in a safe and rapid manner (Lucas and Baras 2001; Ferguson et al. 2002).

It took on average 30 days for the tagged salmons to pass the fish way. Prolonged migration time due to hydropower facilities, similar to what is observed in this study, is not unusual and has been reported in previous studies (Gowans et al. 1999; Chanseau and Lariner 2000; Karrpinen et al. 2002). The most prominent factor revealed in scientific studies causing delays seems to be unsatisfactory attraction rate for the fish way due to a stronger water source like a tailrace or spill way. This, however, should not be a problem according to the flow regime within the bypass channel at Norrfors. The ladder flow and related auxiliary as the only water source during a large proportion of the operation time of the bypass channel should mitigate any attraction problems. Furthermore, the fact that the mean time to the first visit in the entrance pool was measured to 7.5 days attests to this. It is more likely that the salmon for some other reason entered a quiescent period in their migration. This kind of periods, with delays of several weeks and even months has been reported in previous studies (Webb, 1990, Gowans et al. 1999; Økland et al. 2001). It has even been suggested that obstacles like hydro powers may be the trigger which leads to a quiescent period (Gowans et al. 1999).

The observed pattern with longer delay time for fish tagged early in the season is consistent with results observed in other studies (Gowans et al. 1999; Laine et al. 2002). It has been discussed that an increase in motivation to migrate as spawning time approaches is the underlying factor (Thorstad et al. 2008). In contrast, similar correlation with longer delay time for fish tagged early in the season was not found for Atlantic salmon in river Tuloma studied by Karppinen et al. (2002).

The entering, ascent and exiting of the fish way for successful passers

Very few of the visits in the entrance pool resulted in a ladder visit and the effective time spent in the entrance pool was large (mean 2.0 days). Laine et al. (1995) suggested that the fish need to become acquainted with the fish way entrance, flows and perhaps even the lowest pools of the fish ladder before they will continue their upstream migration. This may explain some of the delay between entry in the entrance pool and until entry of the ladder but there is little evidence to suggest that initial experience of the lower pools is required prior to final entry and ascent. Furthermore, it does not explain the extension of the delay observed at Norrfors (compare Gowan et al. 1999; Bjornn et al. 2000). According to Gowans et al. (1999) and the National Marine Fisheries Service (2011), there are two possible explanations to why fish hesitate in the entrance pool and do not proceed to ascent the ladder: 1) Fish get discouraged by a poor relationship between water flow from the ladder and the auxiliary water through the entrance pool, or 2) non-uniform water velocities within the entrance pool discourage or distract the fish (Gowans et al. 1999; NMFS 2011). To determine whether the velocities are uniform or not I suggest that measurements are conducted before the migration run 2013. An Acoustic Doppler Velocimeter would perhaps be a suitable option for the implementation of the measurements. An adjustment of the entrance pool to minimize the total and the effective time in the entrance pool is desirable for two reasons. First to decrease the migration delay but also to maintain the salmon's condition. Non-uniform velocities may cause adult fish to jump, causing associated injuries (NMFS 2011). Also, the accumulation of fish in a confined space may increase the risk of disease outbreak; for instance furunculosis, especially at low water discharges and when the water temperatures are high (Mills 1989; Johnsen and Jensen 1994). A possible measurement to resolve non-uniform water velocities, if this is the case, and achieve more uniform flow conditions is to install baffles (i.e. physical structures placed in the flow path designed to dissipate energy or to re-direct flow) (NMFS 2011).

The presence of fish in the entrance pool was related to time of day. In general, movements into the entrance pool occurred early in the day while movements out occurred mostly in the afternoon. Similar results were presented by Lundqvist et al. (2008) for the old fish ladder. Also Smith et al. (1997) and Chanseau and Larinier (2000) reported a diel behavior pattern with fish presence at the vicinity of the fish way, starting mainly at dawn and ending at dusk. In contrast, Webb et al. (1990) reported that salmons approaching towards the fish way entrance did not take place at a particular time of day.

Fish entered the entrance pool to about the same extension independent of discharge from the spill way. A result consistent with Webb (1990) but still unexpected since it is generally known that a fish ways attraction rate decreases with increased discharge in a nearby tailrace or spill way. Furthermore it was unexpected since considerable amount of fish was seen in the spill way during the tagging. Perhaps the fish way entrances do not lose any substantial attraction rate since the relative flow between the fish way and the spill way is approximately equal. However, the results do not preclude a yoyo-behavior between the entrance pool and the spill way, similar to what is reported in several other studies (Gowan et al. 1999; Chanseau and Larinier 2000; Karppinen et al. 2002). It may be that fish move between the entrance pool and the spill way instead of the entrance pool and the main river pool during discharge in the spill way. To assess the movement patterns between the entrance pool and the spill way would include a different setup of radio loggers that would be necessary compared to what I used. My suggestion would be to use three underwater antenna, installed in the entrance pool, outside the entrance pool and at the inception of spill way. This approach can also be tested by having a shorter period of time without discharge in the spill way so fish in the entrance pool not are stimulated to leave the lowest part of the ladder and start to explore the spillway.

Ladder flows were normally held constant at c. 1.2 m^3/s, yet the effective ladder time among individuals in the ladder showed a large disparity, varying from 2.3 to 167.3 hours with a mean of 17.7 hours. Compared to the old fish ladder this is an improvement. Lundqvist et al (2008) reported a mean of 35 and a range of 3-133 hours duration in the old ladder. The observed pattern with fish ceasing the ascent of the ladder at dawn and continue the following morning is in agreement with Gowan et al. (1999). I observed three salmon with considerably longer total and effective time in the ladder. The explanation to why they stayed for more than one night is unknown, however, the same phenomena has earlier been (Gowan et al. 1999).

According to Lundqvist et al. (2008) travel time through the old fish ladder not related to fish size. In my study I could not observe a size-dependent effect on the time fish spent on passing the ladder although there was a clear tendency for this, it looks like larger fish tend to have longer effective time in the ladder compared to smaller fish. Any significant difference between male and females was not observed for the effective time in the ladder. In contrast Lundqvist et al. (2008) showed that the average duration for male salmon was significantly shorter than for females in the old ladder. Besides Lundqvist et al. (2008) I have found no other studies that suggested a sex-related differences in migration patterns in regulated rivers. No relationship was found between effective ladder time and water temperature in the present study. This is in agreement with McKinnell et al. (1994) who found no effect of ambient river temperatures on the upstream migration for salmon in river Umeälven. Also result based on data from fish counters in weirs has showed limited effect of water temperature on the pattern of fish way passage (Trépanier et al. 1996). On the contrary, Gowan et al. (1999) observed that the rate at which salmon ascended the ladder was related directly to water temperature. A large proportion of the radio-tagged fish were seen to ascended and pass the fish way almost simultaneously in late August. The contemporary decline in water temperature and luminosity was perhaps the trigger. However, other environmental factors such as air temperature, turbidity, atmospheric pressure, cloud cover, variations in concentrations dissolved ions, and odor are also possible factors affecting the time of upstream migration (Thorstad et al. 2008; Bendall et al. 2012) and can not be excluded. Furthermore, it is likely that one or several factors may be covariates to others Thorstad et al. (2008). Another aspect that should be mentioned is the possibility for a peer pressure which might have increased the number of fish that ascent at the particular moment. However, any scientific evidence for this has not been found.

A delay was seen in front of PITA7 and the VAKI-counter. A possible explanation is that fish hesitate because of wariness for the fence and the tunnel aiming to lead the fish through the VAKI-system. Measurements to make this section more fish-friendly should therefore be taken. Well past the VAKI-counter the possibility to leave the ladder and continue the upstream migration seems very good. Median exit time was 36 minutes and radio data indicated that all radio-tagged salmons, except for one strayer, rapidly found the river current and proceeded their migration upstream towards river Vindelälven.

The use of the spillway as the tagging location has very likely caused inadequacies in my study. This must be kept in mind throughout the discussion. The estimated value for several of the response variables is the minimum possible value. The actual data is unknown since we do not know what kind of activity the fish had performed prior to tagging. Furthermore, it is very likely that the choice of tagging location may have affected the behavior and migration pattern of tagged fish. It is well known that catching, handling and tagging, after river entry, may alter the upstream migration pattern for Atlantic salmon causing stress-related delays and/or downstream movements after release (Gerlier and Roche 1998; Jokikokko 2002; Thorstad et al. 2005b). It has also been suggested that salmon tagged in rivers move downstream to avoid areas that they perceive to have ‘‘unfavorable conditions’’ (Thorstad et al. 2005b). I therefore strongly recommend that future telemetry studies, aiming to study the migration behavior in the Norrfors bypass channel should catch, tag and release fish in coastal area prior the river entry. Analyses based on PIT-tag data comparing the ladder efficiency for fish tagged at the spill way in 2012 and returning wild adult fish, PIT-tagged as smolts, support the theory about a handlings effect for fish tagged in the present study (Lundqvist et al. 2012).

Behavioral differences between strayers and native salmon?

Interestingly my result revealed no significant difference between fish originating from river Ume/Vindelälven and strayers of fish originating from the Luleälven. Since genetics in many cases is related to local adaptation (Allendorf et al. 2001) this must be considered as surprising. The result entails that further studies of strayers higher up in the river system is of prime importance to clarify which potential effect these strayers may actually have on the native population. At the moment do preliminary results show that the strayers, tagged in the present study, migrated high up in the river Vindelälven and used same spawning grounds as native fish (Mr R. Grandy-Rashap, pers. comm. 2013). The extension of the genetic result in this study was somewhat unexpected since genetic analyses in previous studies indicated that all radio tagged salmons approaching the Stornorrfors hydro power belonged to the river Ume/Vindelälven population (Lundqvist et al. 2008). In contrast, Vasemägi et al. (2005) did show that a large proportion of fin-damaged upstream migrating salmon (adipose fin present) caught at the Norrfors fish way originated from three non-native hatchery releases. Among them the river Luleälven was included. There are two reasons it is not surprising that the river Luleälven is one of the major immigrant sources. First, there are over half a million releases of hatchery reared river Luleälven smolts per year (ICES 2012). Of all smolt releases in the Baltic Sea, only the Neva stock is released in greater quantity. Second, the Luleälven hatchery stock has been formed by mixing salmon from several different origins, including river Ume/Vindelälven (reviewed in Vasemägi et al. 2005).

Conclusion

My results prove once again that hydropower is associated with problems for Atlantic salmon on their spawning migration. Despite completed rebuilding and improvements of the fish way at Stornorfors hydropower it remains a significant migration obstacle for adult Atlantic salmon on their migration towards river Vindelälven. The fish ways' efficiency was estimated to 78 % and a prolonged delay was seen before entry into the ladder and in front of the VAKI-system. Mean time post-tagging until the first visit in the entrance pool was 7.5 days. Thereafter, followed in general a phase with several revisits in the entrance pool and the bypass channel. The final ascending of the fish ladder occurred after a mean of 30 days and during the ascent of the ladder a delay was seen in front of the VAKI-system. Furthermore, I revealed that there was no significant difference in the behavior between the strayers with different genetic background coming from Luleälven and fish originating from river Ume/Vindelälven.

Acknowledgements

I would like to thank my supervisor Hans Lundqvist for the support and guidance that he gave me during the study. Peter Rivinoja for the effort and the instructions whom he consisted with during the field work and during the data processing. Kjell Leoarndsson for his advisory skills and support with statistical analyzes. Åke Forssen for the rewarding discussions about salmon migration behavior at Norrfors. Raven Grandy-Rashp for companionship during the field work and support in report writing. Anders Alanärä my examinator and last but not least, my family and especially my girlfriend Anette Karinsdotter who has contributed with amounts of support and positive energy.

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Appendix 1. Data for the 104 radio- and PIT-tagged Atlantic salmon tagged at Norrfors spill way 2012.

<u>Fate explanation:</u>

PASS= Passage of the dam

PASS PL = Pass but no PIT registration (time in italic style is based only on radio data).

PASS RL= Pass but radio tag loss before ascending the ladder (time in bold italic style is based on only PIT data).

LEFT= Left the ladder area downstream

DEAD= Found dead

TAGLOSS= Regurgitated transmitter

POOLFISH= Fish caught in gillnet in most surrounding area downstream the ladder after ladder closure

RT/DEAD= Fate unknown. Either regurgitated transmitter or dead fish.

[1] Female=1; Male=2

[2] Individual river Vindelälvs stock affiliation probability.

TAG Date	Frequency/BPM	FATE	Sex[1]	Length	PIT	P-value[2]	Number of visits in the entrance pool	Time to first visit in the entrance pool	Total time in the entrance pool	Effective time in the entrance pool	Number visits in the ladder	Time to first visit in the ladder	Total time in the ladder	Effective ladder time	Time to leaving	Time to pass	Exit time	Time to river Vindelnälven
								(days)	(hours)	(hours)		(days)	(hours)	(hours)	(days)	(days)	(hours)	(hours)
06-jul	,214/30	PASS	1	90	0009B6837E	0.99	31	2.8	203.5	203.5	1	83.2	16.8	16.8		84.9	16.8	5.5
06-jul	,223/30	PASS	1	75	0009B682A7	1	25	2.9	165.3	2.3	11	3.0	27.2	11.2		28.7		
06-jul	,243/30	PASS	2	78	0009B68493	0.88	17	2.9	59.8	15.3	4	12.2	76.3	7.5		53.1	1.5	8.1
06-jul	,233/30	DEAD	1	99	0009B68297	0.01									24.8			
06-jul	,253/30	PASS PL	1	77	0009B68320	0.59	6	4.8	50.2	50.2	*1*	*34.3*	*10.8*	*10.8*		34.7		
06-jul	,263/30	PASS	2	78	0009B68412	0.99	19	3.1	76.4	17.3	2	34.3	7.6	4.7		55.1		6.0
06-jul	,273/30	LEFT	1	100	0009B68151	1									5.3			
06-jul	,284/30	LEFT	1	104	0009B68102	0.96									3.2			

06-jul	,293/30	PASS	1	88	0009B68117	0.96	13	25.7	20.1	5.7	2	30.1	14.9	6.8		52.0		
06-jul	,303/30	LEFT	1	94	0009B68274	0.26	6	2.4	32.7	32.6	1	5.0	28.4		8.0			
06-jul	,314/30	LEFT	1	97	0009B68149	0.03	6	2.9	15.7	15.5	1	5.3	11.0		13.0			
06-jul	,324/30	DEAD	1	95	0009B68105	0.99	4	1.8	6.2	2.6	2	1.9	15.0					
06-jul	,334/30	PASS	1	73	0009B6811D	1	9	3.8	65.9	65.9	1	25.3	9.5	9.5		25.7		4.3
06-jul	,343/30	LEFT	1	98	0009B68307	0.99									7.5			
06-jul	,353/30	LEFT	1	86	0009B683BB	0.99									4.8			
06-jul	,362/30	LEFT	2	80	0009B68224	1	4	2.9	7.1									
06-jul	,374/30	LEFT	1	91	0009B68271	1	1	3.7	11.2						7.3			
06-jul	,382/30	PASS	1	77	0009B68467	0.03	8	1.6	17.1	17.1	1	6.3	10.6	10.6		6.8		6.3
06-jul	,392/30	LEFT	2	106	0009B68161	0.02	4	1.8	12.1						5.2			
06-jul	,404/30	PASS	2	83	0009B68221	0.99	1	1.9	1.3	1.3	1	1.9	20.2	20.2		2.8		8.0
06-jul	,413/30	LEFT	1	95	0009B68190	0.99	7	1.9	12.6						5.0			
06-jul	,422/30	LEFT	1	97	0009B684B8	0.99									3.1			
06-jul	,443/30	LEFT	1	99	0009B68252	0.98									4.8			
11-jul	,453/30	PASS	1	105	0009B682FA	0.84	7	8.6	29.8	29.8	1	46.4	22.4	22.4		47.3		
11-jul	,463/30	LEFT	1	101	0009B684D1	0.96									6.2			
11-jul	,473/30	PASS	1	77	0009B681D8	0.99	1	3.1	3.3	3.3	1	3.3	14.5	14.5		3.9		7.7
11-jul	,483/30	LEFT	1	98	0009B681FC	0.29	6	3.0	13.5						5.2			
11-jul	,493/30	LEFT	1	92	0009B68415	0.99	7	2.2	20.2						7.0			
11-jul	,503/30	PASS	1	88	0009B682AF	0.93	1	6.8	1.5	1.5	1	6.8	8.5	8.5		7.3		8.2
11-jul	,513/30	PASS PL	2	103	0009B68327	1	16	2.2	4.8	4.8	*1*	*2.4*	*6.2*	*6.2*		2.6		7.1
18-jul	,524/30	PASS	2	114	0009B682DA	1	18	2.1	34.2	5.2	2	16.5	122.7	94.7		64.3		4.2
18-jul	,532/30	PASS	1	81	0009B684AB	0.99	5	31.2	21.4	21.4	1	40.4	14.9	14.9		41.0	1.6	4.6
18-jul	,542/30	PASS	1	98	0009B68346	0.97	16	14.2	44.6	44.6	1	38.4	17.6	17.6		39.2		3.8
18-jul	,553/30	PASS	2	88	0009B6842B	1	9	3.9	47.8	47.8	1	19.4	4.2	4.2		19.5		5.9
18-jul	,563/30	LEFT	2	92	0009B680FB	0.91	1	3.5	1.5						5.4			
18-jul	,571/30	PASS	2	116	0009B68461	1	17	8.4	69.5	65.7	2	34.4	33.2	25.0		41.5		15.9
18-jul	,583/30	LEFT	2	94	0009B68387	1	23	1.4	41.4						30.0			
18-jul	,592/30	PASS	1	88	0009B68306	0.64	41	2.8	87.9	87.9	1	40.3	14.8	14.8		41.0	1.7	8.2
18-jul	,603/30	PASS	1	100	0009B68216	0.95	9	1.5	103.1	103.1	1	40.3	13.3	13.3		40.9		
18-jul	,613/30	PASS	1	97	0009B68287	0.95	12	3.0	45.4	20.1	2	31.3	13.1	5.9		40.2		4.3
18-jul	,623/30	PASS	1	95	0009B68355	0.96	26	13.8	96.5	96.5	1	41.3	13.6	13.6		41.9		5.6
18-jul	,635/30	LEFT	1	100	0009B6836E	0.99	7	1.5	3.1	3.0	1	30.2	3.1		9.5			
18-jul	,644/30	PASS	2	82	0009B6848B	0.95	9	2.9	155.0	155.0	1	61.0	7.6	7.6		61.3	0.4	4.2

18-jul	,664/30	PASS	2	70	0009B683BF	0.45	15	3.2	74.8	74.8	1	40.3	4.2	4.2		40.5	0.4	72.6
18-jul	,474/55	PASS	1	96	0009B683A9	0.87	8	17.3	22.5	13.6	2	25.4	24.4	15.0		40.0		4.9
18-jul	,514/55	PASS	1	100	0009B682BD	0.78	16	13.9	70.3	70.3	1	41.2	167.5	167.5		48.2		
18-jul	,653/30	LEFT	1	90	0009B684AE	0.99	6	1.5	17.4						5.2			
02-aug	,324/55	POOLFISH	1	77	0009B68112	0.97												
02-aug	,314/55	PASS	1	91	0009B681B9	0.97	24	3.2	320.7	320.7	1	56.4	23.8	23.8		57.4	0.6	10.1
02-aug	,453/55	PASS RL	2	85	0009B681A2	0.99					***1***	***25.2***	***2.7***	***2.7***		*25.4*		
02-aug	,223/55	DEAD	1	99	0009B683EC	0.56	6	13.5	88.0	87.3	1	26.0	32.5					
02-aug	,362/55	PASS PL	2	79	0009B68364	0.99	7	8.2	58.9	58.9	*1*	*15.0*	*11.2*	*11.2*		26.0		5.6
02-aug	,254/55	PASS	2	102	0009B68481	1	6	3.1	61.4	61.4	2	25.4	14.9	14.9		26.0		
02-aug	,245/55	PASS	1	76	0009B684B0	0.99	11	3.2	35.6	35.6	1	16.3	4.5	4.5		16.5		6.3
02-aug	,294/55	PASS	1	93	0009B683DA	0.57	15	3.9	35.4	11.9	2	16.3	29.7	20.4		31.2		4.2
02-aug	,262/55	RL/DEAD	1	96	0009B68360	0.29	4	26.3	3.1									
02-aug	,274/55	PASS	1	79	0009B680F8	0.99	2	3.2	36.3	36.3	1	25.1	2.3	2.3		25.4		10.2
02-aug	,285/55	PASS	2	109	0009B68138	1	14	8.2	85.5	85.5	1	25.5	1.0	1.0		26.1	1.0	8.5
02-aug	,234/55	PASS	1	91	0009B6827B	0.22	7	3.1	49.4	49.4	1	25.4	13.4	13.4		25.9		5.7
02-aug	,335/55	PASS	2	83	0009B68215	1	8	25.1	27.1	27.1	1	31.4	20.7	20.7		32.2	0.5	4.4
02-aug	,303/55	PASS	2	88	0009B683E2	0.99	9	2.1	130.3	130.3	1	25.3	4.4	4.4		25.5		5.3
02-aug	,444/55	PASS	2	85	0009B6830A	0.22	9	3.3	33.7	33.7	1	17.3	4.1	4.1		17.4		4.0
02-aug	,405/55	PASS	2	112	0009B681FE	0.98	16	16.1	73.2	73.2	1	26.2	8.2	8.2		26.5	1.4	7.1
02-aug	,344/55	PASS	1	98	0009B682D5	0.86	18	10.3	59.6	59.1	2	26.3	17.3	17.3		27.0		5.4
02-aug	,375/55	PASS	2	100	0009B681F5	1	26	0.2	49.9	49.9	1	26.0	5.9	5.9		26.2	0.3	6.3
02-aug	,383/55	PASS	1	96	0009B68208	1	13	9.3	76.3	76.3	1	24.4	37.3	37.3		25.9	10.7	12.3
02-aug	,393/55	PASS	1	82	0009B6843F	1	6	3.2	41.0	41.0	1	23.2	4.8	4.8		23.4		5.4
02-aug	,493/55	PASS PL	2	83	0009B681BC	1	3	13.0	11.8	11.8	*1*	*25.4*	*11.9*	*11.9*		25.9		13.4
02-aug	,464/55	PASS	2	82	0009B68483	0.99	5	4.3	30.4	0.8	2	4.4	21.5	10.7		19.8		4.6
02-aug	,414/55	PASS	1	81	0009B68447	0.99	13	2.3	93.9	61.8	2	25.3	4.5	4.4		27.3	0.3	4.7
02-aug	,354/55	PASS	1	96	0009B6812B	0.51	7	25.2	28.6	28.6	1	46.2	20.1	20.1		47.0		8.2
02-aug	,215/55	PASS	2	85	0009B68128	0.23	15	2.2	41.1	41.1	1	26.3	16.0	16.0		27.0		4.5
02-aug	,504/55	PASS	1	89	0009B684C5	0.99	6	15.2	42.4	42.4	1	26.0	5.9	5.9		26.3		6.7
02-aug	,483/55	LEFT	1	75	0009B68183	1	1	35.1	12.6						56.7			
02-aug	,423/55	PASS	2	81	0009B68174	0.93	4	3.3	53.4	53.4	1	24.9	9.6	9.6		25.3	0.3	4.0
07-aug	,525/55	PASS	1	95	0009B6824A	0.99	5	10.5	21.3	21.3	1	14.5	11.6	11.6		15.0		9.5
07-aug	,624/55	PASS	2	80	0009B68424	1	2	1.3	8.0	8.0	1	2.4	32.1	13.7		2.9		4.6
07-aug	,635/55	PASS	1	77	0009B683FE	0.76	5	8.8	16.9	16.9	1	21.1	6.0	6.0		21.3		5.9

07-aug	,553/55	Poolfish	1	84	0009B68303	0.99	15	13.3	101.7									
07-aug	,604/55	Poolfish	1	98	0009B68422	1	23	4.9	83.6	13.1	4	5.4	40.5					
07-aug	,614/55	PASS	2	85	0009B68384	0.99	4	4.3	5.9	1.4	3	4.4	21.9	21.8		6.3		7.6
07-aug	,645/55	PASS	1	104	0009B6848C	0.95	16	11.1	44.0	44.0	1	19.4	21.4	21.4		20.3		4.1
07-aug	,563/55	PASS	2	75	0009B68226	1	5	14.2	20.5	20.5	1	17.1	6.4	6.4		17.3		7.2
07-aug	,572/55	TAGLOSS	1	80	0009B68413	1		*23.3*			1	*23.3*	*17.7*					
07-aug	,544/55	PASS	2	78	0009B68315	0.98	2	21.3	10.1	6.6	2	26.1	13.5	13.4		28.0		5.9
07-aug	,534/55	PASS PL	1	74	No PIT	1	2	14.5	21.2	21.2	*1*	*16.4*	*90.1*	*90.1*		20.2		8.1
07-aug	,584/55	PASS	1	80	0009B6816D	0.97	5	4.0	99.2	99.2	1	20.9	6.2	6.2		21.2	1.2	10.5
07-aug	,653/55	PASS	1	97	0009B6830B	0.92	17	8.4	77.6	77.6	1	29.1	7.4	7.4		29.4		7.5
07-aug	,664/55	RL/DEAD	2	85	0009B6834E	0.97	4	5.9	6.8									
07-aug	,594/55	PASS	2	84	0009B68228	0.98	13	3.2	49.5	7.9	4	6.0	60.4	6.1		20.4	0.4	4.9
21-aug	,724/40	Poolfish	2	79	0009B68427	0.97	19	6.9	80.3	7.8	3	7.4	15.5					
21-aug	,703/39	PASS	1	80	0009B6826C	0.03	1	6.1	16.1	16.1	1	6.4	15.3	15.3		7.0	1.4	
21-aug	,712/40	PASS RL	2	80	0009B682A3	0.94					***1***	***26.4***	***97.4***	***97.4***		*30.4*		
21-aug	,533/40	RL/DEAD	1	99	0009B680F6	0.99												
21-aug	,664/40	LEFT	1	85	0009B68351	0.79												
21-aug	,544/40	RL/DEAD	1	83	0009B682D7	0.33	8	7.2	34.0									
21-aug	,755/40	PASS	2	82	0009B68156	0.97	9	0.9	58.0	58.0	1	6.1	9.9	9.9		6.5	0.3	
21-aug	,704/40	Poolfish	2	85	0009B682C9	0.61	4	7.3	13.8									
21-aug	,692/40	LEFT	2	87	0009B6814D	0.94	7	2.3	26.8						27.1			
21-aug	,643/40	Poolfish	2	84	0009B6841C	0.99	25	1.9	76.8	28.6	4	7.1	155.2					
21-aug	,634/40	PASS	1	100	0009B68485	0.87	20	6.2	26.5	21.8	2	9.3	24.6	24.4		39.3	0.3	
21-aug	,664/39	RL/DEAD	1	93	0009B683DB	0.98	4	6.0	6.2									
21-aug	,673/40	PASS	2	95	0009B681B3	1	3	4.2	27.4	27.4	1	7.3	15.2	15.2		7.9	0.6	
21-aug	,395/80	LEFT	1	96	0009B68338	0.79	2	8.3	27.3	0.4	1	8.4	0.8		25.8			

SENASTE UTGIVNA NUMMER

2011:9	Klövviltets nyttjande av foderraps på viltåker och betespåverkan på angränsande skog. Författare: Maria Lidberg
2012:1	Attityder till återintroduktion av visent i Sverige. Författare: Axel Bergsten
2012:2	Viltanpassad röjning längs skogsbilvägar som en foderskapande åtgärd för älgen. Författare: Ida Forslund
2012:3	Spawning site selection of brown trout in habitat restored streams. Författare: Jonas Svensson
2012:4	The shift in forest and tree limits in Troms County – with a main focus on temperature and herbivores. Författare: Kristoffer Normark
2012:5	Clover (*Trifolium* spp) gamefields: Forage product ion, utilization by ungulates and browsing on adjacent forest. Författare: Karl Komstedt
2012:6	Habitat use and ranging behaviour of GPS tracked juvenile golden eagles *(Aquila chrysaetos).* Författare: Carolin Sandgren
2012:7	Spatial and temporal variation in the quality of summer foods for herbivores along a latitudinal gradient. Författare: Michaela Holá
2012:8	Hur livshistoriekaraktärer hos Europeisk abborre (*Perca fluviatilis* L.) påverkas av cykliska förändringar i populationsstrukturen. Författare: Christian Andersson
2012:9	Neighborhood effects as a plant defence against ungulate herbivory. Författare: Bregje Koster
2012:10	Comparison of bird communities in stands of introduced lodgepole pine and native Scots pine in Sweden. Författare: Arvid Alm
2013:1	Site fidelity of a migratory species towards its annual range. Författare: Peter Lojander
2013:2	Selection of habitat and resources during migration by a large mammal – A case study of moose in northern Sweden. Författare: Jens Lindberg
2013:3	Predicting spawning bed erosion and longevity: a case study in tributaries to river Vindelälven, northern Sweden. Författare: Viktor Tylstedt

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