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Raven Grandy-Rashap

Examensarbete i ämnet biologi
Department of Wildlife, Fish, and Environmental studies
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Raven Grandy-Rashap

Supervisor:	Hans Lundqvist, Dept. of Wildlife, Fish, and Environmental Studies
Assistant Supervisor:	Gustav Hellström, Dept. of Wildlife, Fish, and Environmental Studies
Examiner:	Kjell Leonardsson, Dept. of Wildlife, Fish, and Environmental Studies

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Abstract

The life cycle of the anadromous Atlantic salmon *(Salmo salar)* can span large geographic, political, and socio-economic boundaries. Management strategies and regulations that only concentrate on small spatial scales often overlook larger basin-wide problems, especially relating to post-spawn seaward migration. In this master thesis one entire migration cycle of wild adult Atlantic salmon in the unregulated northern Swedish river Vindelälven was monitored by radio-telemetry tracking during upstream spawning migration and downstream seaward migration back to the Baltic Sea. The effect of ladder passage variables (*time to pass, total time in the ladder, passage day over the ladder*) at a fish ladder downstream in the river Umeälven, as well as fish size, were evaluated to determine if differences in upstream migration distance in the river Vindelälven could be observed. Ladder passage variables did not affect migration distance, but size exhibited a negative relationship to migration distance. Additional aspects of spawning migration and spawning sites were also described. Microhabitat variables of depth, substrate and velocity were measured at spawning locations to compare fish size with habitat usage. No correlation with depth and substrate size compared to fish size could be found, but larger fish were found at significantly higher velocity spawning locations with an average velocity of 0.45 m/sec. Salmon kelts were monitored after spawning with evaluations of over-winter and downstream migration. Six tagged salmon migrated downstream soon after spawning and 30 tagged salmon over-wintered in the river. Salmon that migrated further upstream to spawn were significantly more likely to over-winter than leave directly after spawning. 22 corresponding spawning and over-wintering kelts were located, with over-winter locations on average 16.9 km below spawning areas. No correlation was observed between upstream migration distance and the distance travelled between spawning and over-winter sites. No salmon over-wintered above their spawning sites, and over-wintering locations were in deep, slow moving ice-covered sections of the river. Seaward migrating kelts were monitored in the spring with evaluations on the effects of river discharge and temperature on initiation of migration, with additional descriptions of timing, speed and the efficacy of the fish ladder as a bypass around the Stornorrfors power station. Seaward migration appeared to coincide with an increase in both river discharge and temperature with a majority of downstream migration occurring in late May with an average downstream migration speed of 2.5 km/hr. No kelts descended the fish ladder. Genetic analysis discovered that nine percent of tagged salmon that passed the fish ladder were strayers of river Luleälven stock. These fish were monitored to ascertain any differences in size and upstream spawning migration from native river Vindelälven stock. No differences were found between the two stocks.

Sammanfattning

Livscykeln hos den anadroma Atlantlaxen i Östersjön spänner över stora geografiska, politiska och socioekonomiska gränser. Förvaltningsstrategier och regelverk som koncentrerar sig på små rumsliga skalor förbiser ofta problematiken med arter som havsvandrar över stora vattenområden som Östersjön och därmed passerar många länders kust- och havsområden. Detta examensarbete visar en hel vandringscykel hos vild lekvandrande lax i den oreglerade Vindelälven, ett biflöde till Umeälven. Laxvandringen övervakades via spårning av radiomärkt fisk när de lekvandrade uppströms, övervintrade i älven och sedan vandrade nedströms mot havet. Jag analyserade effekten av tid för passage, total uppehållstid samt timingen genom en kustnära fisktrappa (Norrfors, Umeälven) hos radiomärkt lax av olika storlekar och kön för att utreda om detta kunde avgöra hur långt fisken vandrade innan lek i Vindelälven. Tid för passage i fisktrappan i älvens nedre del påverkade inte migrationsavstånd, men fiskens storlek visade sig ha en negativ relation till migrationsavstånd så att småvuxen lax vandrade längre distans i älven innan de positionerade sig för lek. Habitat studier vid valda lekområden beskrivs på mikrohabitatnivå (djup, substrat och vattenhastighet) för fisk av olika storlek. Jag fann ingen korrelation mellan djup och substratstorlek avseende fiskens storlek förutom att större lax hade valt lekområden med betydligt högre vattenhastighet. Vattnets medelhastighet på lekplatsen mättes till 0,45 m / sek. Föräldrafisk av lax övervakades efter leken på om de direkt vandrade nedströms eller om de övervintrade i älven och vandrade nedströms kommande vår-försommar. Sex märkta laxar vandrade nedströms relativt omgående efter leken medan 30 märkta laxar övervintrade i älven. Lax som vandrat längre uppströms för att leka var mer benägna att övervintra än de fiskar som lekte längre nedströms. I denna studie registrerades positioner för 22 lek- och övervintringsplatser. Utlekt lax, sk Kelt, övervintrade i genomsnitt 16.9 km nedströms sitt lekområde. Ingen korrelation mellan distans i laxens uppströmsvandring och den sträcka fisken simmade från lekplatsen till sitt övervintringsområde kunde observeras. Ingen kelt övervintrade uppströms sitt lekområde. Generellt återfanns laxens övervintringsplatser i djupa och långsamt strömmande samt istäckta delar av älven. Under våren följdes timingen hos nedströmsvandrande kelt i relation till ökning i vattenföring och temperatur. Nedströmsvandringen hos kelt observerades till slutet av maj med en genomsnittlig vandrings hastighet av 2,5 km / tim fram till området där denna fiskvandringsstudie började. En genetisk analys visade att nio procent av den märkta laxen som passerade fisktrappan och deltog i denna studie härstammade från en odlad laxstam (Luleälven stock). Dessa fiskar uppträdde på likartat sätt som älvens naturliga vilda laxar.

Introduction

Species that partake in migration expose themselves to a wide range of risky variables. Anadromous salmonids throughout the world experience difficulties in their migratory cycles for many reasons. Anthropogenic factors such as dams, pollution, overfishing, climate change, timber harvest and log floating compromise their anadromous life cycles (Karlsson and Karlström, 1994; Romakkaniemi *et al.*, 2003; Scruton *et al.*, 2008). Wild Atlantic salmon (*Salmo salar*) populations have been depleted by mixed stock fishing in the coastal and open-sea fishery, diseases and compensatory hatchery releases (ICES, 2012; Romakkaniemi *et al.*, 2003; Lundqvist *et al.*, 2008). In the Baltic Sea, the situation has long been especially precarious. Only 12 of the historic 44 naturally reproducing wild Atlantic salmon stocks in the northern Bothnian Sea remain (Karlsson and Karlström, 1994).

The river Vindelälven in northern Sweden is no exception, with all the aforementioned factors contributing to steep declines in wild Atlantic salmon. The undammed, 8^{th} order river Vindelälven is the main tributary of the larger mountain river Umeälven. Salmon have problems passing the lower section of the flow-regulated river Umeälven (Lundqvist *et al.*, 2008; Rivinoja *et al.*, 2001), which contains Sweden's largest hydroelectric power station (Stornorrfors) and a 350m fish ladder (Norrfors). Stornorrfors is located 32 km upstream from the coast. Salmon must successfully ascend this fish ladder to access spawning grounds upstream in the river Vindelälven. In addition to the power station, timber harvest, channelization and homogenization of riverine habitats for timber floating and compensatory releases of hatchery stock have had a deleterious effect on the wild salmon population during the last century in the river Vindelälven (Palm, 2007; Nilsson *et al.*, 2005).

A review of the scientific literature will reveal many migration studies on Atlantic salmon (Gerlier and Roche, 1998; Heggberget *et al.*, 1988; Lindberg, 2011; Lundqvist *et al.*, 2008; Rivinoja, 2005). Many studies focus on one particular life history event, with the vast majority addressing aspects of upstream migration and spawning. Often the best information concerning Atlantic salmon is a detailed account of the number of fish passing a fixed point. Post-spawn kelt over-wintering and seaward migration has been largely neglected, even though it is an important life history phase (Halttunen, 2011; Östergren and Rivinoja, 2008). The purpose of this study is to monitor a complete cycle of one particular upstream migration, spawning, kelt over-wintering and downstream migration. To my knowledge no studies in the northern Baltic region have monitored one complete up and downstream migration cycle of Atlantic salmon. Telemetry has proven effective in studies monitoring movements of salmonids in riverine systems (Gerlier and Roche, 1998; Karlsson and Karlström, 1994). Manual and archival data receivers were used in the rivers Ume- and Vindelälven throughout this study to monitor salmon movements and identify spawning and over-wintering areas. Below I address the questions investigated in this thesis, and each paragraph represents one topic.

In the year 2010, renovations on a new fish ladder at Norrfors were completed on the river Umeälven. The new fish ladder and its passage efficiencies are currently under evaluation with monitoring of all passage of salmonids. Fish passage variables from the Norrfors fish ladder pose interesting migration questions further upstream in the river Vindelälven.

There are limited microhabitat evaluations on salmon spawning habitat with regard to depth, substrate and velocity in rivers larger than 5th order (Louhi *et al.*, 2008; Erkinaro, 1997). Depth, substrate and velocity are common microhabitat variables measured to evaluate spawning habitat (Rosenfeld, 2003; Louhi *et al.*, 2008; Mäki-Petäys *et al.*, 2002). Further evaluations are needed on microhabitat spawning areas and the factors that make an area desirable for Atlantic salmon spawning in large rivers such as the 8th order river Vindelälven.

Anadromous Atlantic salmon have the capacity to survive after spawning and can potentially continue to spawn multiple years, which is called iteroparity. Fish that survive spawning are called kelts (Jonsson and Jonsson, 2011). These kelts will either leave the river system on their seaward migration directly after spawning, or over-winter in the river and migrate downstream the following spring (Scruton *et al.*, 2007; Halttunen, 2011).

Iteroparity has received some study in the Baltic region (Östergren and Rivinoja, 2008; Lindberg, 2011), but limited attention in the river Vindelälven with regard to Atlantic salmon kelt downstream migration and passage at Stornorrfors hydropower station. Current evaluations are underway concerning a guidance structure at the upstream entrance of the fish ladder in the reservoir. This guidance structure is designed to direct kelts to descend the fish ladder, as opposed the hydropower station.

A prominent reproductive characteristic of the salmonid fishes is their ability to home to their natal spawning location (Scheer, 1939; Quinn, 1993; Milner and Bailey, 1989). But many species of salmon exhibit a behavior called straying, which is the upstream spawning migration of mature individuals to a stream other than the one where they originated (Quinn, 1993; Milner and Bailey, 1989). Genetic analysis of all radio-tagged wild (adipose fin intact) salmon for this study showed that 13% of tagged fish were of river Luleälven genetic stock (Nilsson, 2013). This is a very large percentage, and unprecedented in this system.

The objectives of my study consisted of monitoring radio-tagged salmon throughout one complete cycle of upstream and downstream migration in the river Vindelälven. The following questions were addressed: 1) Did passage variables at the Norrfors fish ladder on the river Umeälven, as well as fish size, effect upstream migration distance in the river Vindelälven? I will also describe migration behavior and locations. 2) Was fish size a predictor of spawning habitat selection in relation to depth, substrate and velocity? 3) Did kelts migrate seaward directly after spawning, or did they over-winter in the river Vindelälven, and if so, where did they over-winter, and was there a correlation between upstream migration distance and the distance travelled between spawning and over-winter sites? 4) Were river discharge and river temperature important variables in triggering the seaward migration of kelts? I will also describe downstream migration timing, speed and the efficacy of the guidance structure to direct kelts to the fish ladder as a bypass around the Stornorrfors power station. 5) Did strayers of Luleälven stock origin differ from native Ume/Vindelälven fish with regard to upstream migration distance and size?

Materials and methods

Study Site

The unregulated river Vindelälven follows a snow-dominated flow regime and originates in the Scandinavian mountains close to the border of Norway and flows in a south easterly direction approximately 400 km before it empties into the larger flow-regulated river Umeälven. The catchment area of the river Vindelälven is approximately 12,625 km^2. The confluence of the river Vindelälven and river Umeälven is approximately 10 km above the Norrfors fish ladder. The Umeälven drains into the northern Bothnian Sea 32 km downstream of Norrfors at 63^o50´N, 20^o 05´E. Between the Norrfors fish ladder and the town of Sorsele (342 meters above sea level (masl)), the river rises 267 meters over a distance of 292 km. The study area encompasses from above the Norrfors fish ladder on the river Umeälven, up to the start of the river Vindelälven, to approximately 350 km upstream near the town of Sorsele (figure1).

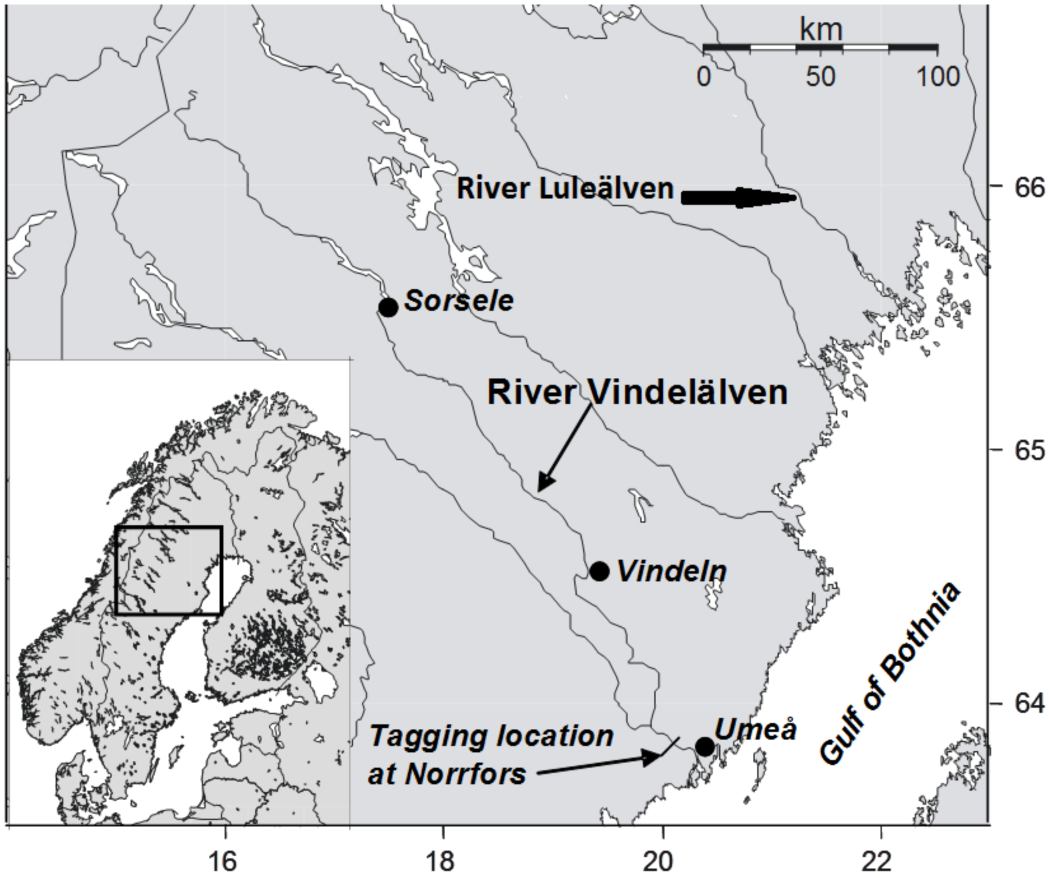

Figure 1. Map of study area. (modified from Lundqvist *et al.* (Manuscript)).

In the river Umeälven, salmon must ascend the eight km long old river channel acting as a bypass to reach the 350 meter long, "Half-Ice Harbor" model fish ladder (see NMFS 2011) built at Norrfors. They must ascend the ladder to reach their natal spawning grounds in the river Vindelälven. The fish ladder was finished in 2010, and along with restoration efforts in the old river channel, has shown marked improvement in fish passage efficiencies (ICES, 2012; Karlsson, 2013). The Stornorrfors power station contains four Francis turbines and has the highest production capacity in Sweden with 2256,073 GWh/year and a maximum capacity of approximately 1000 m^3/sec. Legislation requires minimum spills to the bypass channel of 10 m^3/sec from May 20th to June 15th and 15–50 m^3/sec from June 15th to October 1st.

The top of the ladder has been newly constructed with the intention of accommodating the downstream migration of smolts and kelts and in turn monitor their passage through the ladder. A fish guidance structure was installed at the top of the ladder in the spring of 2012, and retrofitted in 2013. The purpose of this structure was to "guide" smolts and kelts to use the fish ladder for downstream migration, as opposed to going through the turbines at the Stornorrfors hydropower facility, thus averting likely mortality or injury.

River temperature in the river Umeälven was monitored from a temperature logger near the Norrfors fish ladder throughout the study period (Forssen, 2013). A temperature logger in the river Vindelälven was installed approximately 189 km upstream of the tagging site near the town of Björksele (64^{o}59.02´N, 18^{o} 30.88´E) to record temperature for the downstream migration of kelts in the spring of 2013. The temperature upstream in the spawning area in the river Vindelälven is approximately 1-2 degrees colder than down by the fish ladder in the river Umeälven. Discharge of the river Vindelälven was obtained from SMHI Vattenweb (http://vattenweb.smhi.se) from the monitoring station below Sorsele approximately 280 km upstream of the tagging site.

Tagging of Fish

There were 104 salmon tagged at the spillway at the Norrfors fish ladder in the river Umeälven. They were tagged on six different occasions in 2012 between July 6th and August 21st. 63 females and 40 males were tagged with both PIT-tags and gastric radio tags, while one female did not receive a PIT-tag. Fish lengths ranged from 39-116 cm L_T (total length) with a mean size of 89.7 cm. Tagging was carried out by experienced personnel from SLU (Swedish University of Agricultural Sciences) and the Norrfors fish hatchery. The adult upstream migrating salmon were trapped in remaining pools below the spillway after the water was turned off, and then subsequently caught with hoop nets. The insertion of the radio and PIT tags was done in a covered live box filled with river water that was refreshed often. Fish chosen for tagging were evaluated as per condition, origin (wild/hatchery), sex and L_T (cm). Only wild salmon (adipose fin intact) in good condition were chosen for tagging. The pulsed gastric radio transmitters used were Advanced Telemetry System (ATS) 151 MHz model F1830. Each radio tag had a unique radio frequency and pulse rate which made it possible to recognize individual fish. The radio tags used consisted of four different Bit Per Minute rates (BPM). 30 and 55 BPM transmitters were used for the first five tagging occasions, and there were 45 transmitters of each, which accounted for 90 transmitters. On the last tagging occasion, thirteen 40 BPM tags and one 80 BPM tag was used. Battery life for the 30, 40, and 55 BPM transmitters was 500, 365 and 280 days, respectively. The 80 BPM transmitter had an unknown battery life because it had been used previously. The frequencies of the transmitters were between 151.214-151.755 MHz. While inserting the gastric transmitters, the eyes of the salmon were covered by hand or a wet cloth, as this reduces stress (Rivinoja *et al.*, 2006). No anesthesia was used during the handling of the salmon. To prevent regurgitation, as described by Rivinoja *et al.* (2006), each transmitter was fitted with a rubber ring of vulcanization tape differing between 16-20mm with a width between 7-10mm (dependent on fish size). The insertion and placement of the transmitters were performed using a PEX tube that fitted the transmitter (Ø-inner 10 mm, Ø-outer 13.5 mm). The antennas that extended past the snout of the fish were bent to the side of the mouth. According to Rivinoja *et al.* (2006), this method of tagging is unlikely to affect swimming performance of the adult salmon. An anal fin clip was taken for genetic analysis simultaneously while a PIT tag was inserted via a revolving injector. The injections of the PIT tags (FDX 12mm), which are neutrally buoyant in water, were made approximately 2cm deep in the subcutaneous fat close to the dorsal fin. The PIT tags were then scanned and the numbers were noted. Fish were then released downstream of the tagging location, with a total handling time of approximately 3 minutes. Of those 104 tagged salmon, Karlsson (2013) observed that 66 successfully ascended the fish ladder. Those 66 salmon were then free to ascend the remaining 10 km up the river Umeälven to the confluence with the river Vindelälven and subsequently up to spawning grounds in the river Vindelälven.

Tracking of Fish

Fish were tracked using two different techniques during the upstream migration; stationary archival receivers and mobile manual receivers. For the upstream migration 3 archival receivers were utilized; two in the river Umeälven above the Norrfors fish ladder (*Björkudden* 63^{o}52.46´N, 20^{o} 00.48´E and *Betongkurvan* 63^{o}53.03´N, 20^{o} 00.28´E); and one in the river Vindelälven (*Spöland* 63^{o}55.20´N, 19^{o} 51.18´E). All archival receivers were LOTEK SRX_400 type and were connected to 6 element yagis. Each archival receiver was individually configured to detect and store applicable data for its specific location. Range tests were conducted and gains were set on the loggers as per knowledge from experienced personnel (PhD. P. Rivinoja, SLU, pers. comm. 2012; Mr. R. Karlsson, pers. comm. 2012). Manual tracking was conducted by car and by foot with an ATS receiver model RS 2100 and a Swedish 'Televilt' handheld receiver model RX 8910. An 18 element yagi antennae was mounted to the roof rack of the vehicle, and a six element handheld yagi was used on foot. Fish locations were marked on a Garmin GPSmap 60CSX. Manual tracking was conducted approximately two times per week in September and early October, and more frequently during spawning time in late October. Spawning in the river Vindelälven typically occurs in mid to late October and early November (Lundqvist *et al.*, 2008; Rivinoja *et al.*, 2006; Rivinoja *et al.*, 2001). Timing and movement patterns of the salmon, as well as physical habitat descriptions were also used to discern spawning locations in lieu of having pulsed activity sensor transmitters. Accuracy of tracking of approximately 10 m^2 was achieved for the detailed spawning evaluations. The other spawning locations not included in the detailed spawning evaluations were tracked to approximately 100 m^2.

Description of ladder variables

Ladder passage variables of salmon at the Norrfors fish ladder from the thesis work by Karlsson (2013), were evaluated with regard to migration distance upstream in the river Vindelälven. Karlsson´s (2013) study dovetailed with this study, as the same salmon were used in both studies. Ladder variables were evaluated in relation to distance travelled upstream to spawning areas from the tagging site at Norrfors.

Norrfors fish ladder variables and definitions included:

Time to pass: Time to pass (days) is the time between tagging until the salmon successfully ascended the fish ladder.

Total time in the ladder: Total time in the ladder (hours) is the sum of the length of all visits in the ladder.

Passage day over the ladder: Passage day over the ladder is the day after start of migration at which salmon successfully passed the ladder. Start of migration was determined by when the first wild salmon was counted on the VAKI-counter system in the ladder. The VAKI-counter is located at the upper end of the fish ladder, where fish can be counted, sexed and origin (wild/hatchery) can be ascertained. This date of start of migration was determined to be June 25th (PhD. K. Leonardsson, SLU, pers. comm. 2013). This date was converted to day of the year and then subtracted from passage day of the year of radio-tagged fish. Tagging date at the Norrfors fish ladder was not an accurate response variable for migration behavior upstream because it was not known how long of a time the fish were in the system prior to being tagged. Hence passage day over ladder in relation to start of migration was used in the analysis.

Analysis

These ladder parameters, as well as fish length (cm) compared to the distance traveled upstream were all evaluated using a multiple regression linear model, assuming normal distribution of the response variable. All ladder parameters and length were treated as continuous explanatory variables.

Spawning Site Evaluation

Spawning locations were identified between Oct. 22th and Nov. 1st, which was determined to be spawning time from the fishes’ movements and behavior, as well as consultation of similar studies in the river Vindelälven (Lindberg, 2011; Rivinoja *et al.*, 2006; Lundqvist *et al.*, Manuscript). Manual radio-telemetry tracking with an accuracy of 5m^2 was the goal to pinpoint exact microhabitat spawning locations. Spawning locations were accessed with the use of a rubber whitewater raft that was maneuvered just above the spawning location. Due to the early onset of winter in 2012, data collection in late October/early November proved extremely difficult. Limiting factors included: snow on secondary roads along the river, safe access to put-in and take-out areas for the raft, safety concerns with navigating substantial rapids, the sheer size of the river Vindelälven (8th order), ice cover on the river that had to be avoided, and equipment failure due to cold ambient temperatures. River depth and darkness also did not allow for visual verification of spawning sites. Therefore, a manual tracking accuracy of 10m^2 at best was achieved, with only a limited number of sites being accessible on the upper river due to more winter conditions with altitude gain. Eight sites were then successfully surveyed for velocity, depth, and substrate.

Velocity and depth were measured with an Acoustic Doppler Current Profiler (ADCP), Teledyne RDI StreamPro. The ADCP employs hydro acoustics to measure current, speed and direction. The raft was used to access the spawning location, which was maneuvered just upstream of the location and the ADCP was deployed behind the raft and measurements were recorded. The ADCP measured water velocities throughout the water column in 10 cm cells. Velocity was measured in m/sec 30cm from the river bottom. This depth used in the velocity measurements was chosen upon recommendations to measure velocity at approximately the position at which spawning salmon would be located (Beland *et al.*, 1982; Moir *et al.*, 2002).

Substrate was measured from the raft using an IR (infrared) camera attached to a pole and lowered to the bottom of the river in the spawning location. A ruler was attached to the end of the pole below the camera for scale. The IR camera was linked to a video camcorder so footage could be reviewed and substrate measured visually. Substrates were divided in frequency distributions of the sampling area and arranged according to a modified Wentworth scale (1, < 32mm; 2, 32,1 – 64 mm; 3, 64,1 – 128; 4, 128,1 – 256 mm; 5, 256,1 – 512 mm; 6, 256,1 – 1024 mm; 7, bedrock) (Wentworth, 1922).

Due to technical software problems associated with the ADCP for the spawning area survey, sites deeper than two meters could not be measured for velocity. Therefore, velocities deeper than two meters were estimated assuming a power-function relationship between depth and velocity (velocity = $a*depth^b$, where a and b are constants derived from the data).

Spawning site analysis

Size-dependent selection was tested in relation to micro-habitat variables. The data were evaluated based on mean values with linear regressions on depth, substrate size and velocity. For Modified Wentworth scale calculations fish were divided between small (78-83cm) and large (88-109cm) for the appropriate t-tests.

Kelt Behavior

Over-wintering

Atlantic salmon that survive after spawning are called kelts (Jonsson and Jonsson, 2011; Quinn, 2005). The seaward migration of kelts occur in two periods (Halttunen, 2011). They can either leave the river system directly, or spend the winter under deep, ice-covered slow-moving pools while expending very little energy (Östergren, 2006; Jonsson and Jonsson, 2011). Kelt survival differs largely between rivers, from 0.5 to 80 % (Bardonnet and Baglinière, 2000). It was not possible to ascertain spawning/over-wintering mortality during this study because the transmitters used were not equipped with activity sensors, and a number of transmitters lacked sufficient battery life to last into the spring. Over-winter sites were located with manual tracking throughout the winter and spring of 2012-13. One airplane tracking session on April 2nd was also conducted, as access was limited with car tracking by winter conditions on secondary roads. On the flight a four element yagi was attached to the strut of the airplane wing and was used with an ATS receiver.

Downstream migration

For the downstream migration of kelts, both stationary archival receivers and manual tracking were utilized. Four archival receivers were used; two on the river Vindelälven (*Björksele* 64°59.02´N, 18° 30.88´E and *Spöland*), and two on the river Umeälven (*Björkudden* and *Intake* 63°51.32´N, 20° 01.56´E). Registrations between stationary archival receivers by kelts during the downstream migration were used to calculate swimming speed between loggers. Temperature and discharge were also recorded with regard to kelt departure time.

Fish that descended the river Vindelälven and entered the river Umeälven then entered the reservoir behind the Norrfors dam with the guidance structure at the upstream entrance to the fish ladder. The guidance arm was newly designed and re-installed in the spring of 2013 to theoretically guide smolt and kelt downstream migrants to use the fish ladder. If the smolts and kelts did not descend the fish ladder they were then destined to pass through the hydropower turbines at the power plant. The kelts in turn were subjected to a mortality rate thought to be near 100% from turbine blade-strike (Lundqvist *et al.*, Manuscript), although I am not aware of any definitive studies of kelt mortality for Atlantic salmon at the Stornorrfors power station.

Downstream migration analysis

Swimming speeds were calculated as the distance travelled (km) between archival loggers divided by time between detections. Because of a lack radio-tag battery life in the spring, it was necessary to reference Pit-tag data from the Norrfors fish ladder (PhD. K. Leonardsson, SLU, pers. comm. 2013) to determine if any of the salmon were registered descending the ladder.

Strayers

A prominent reproductive characteristic of the salmonid fishes is their ability to home to their natal spawning location (Scheer, 1939; Quinn, 1993; Milner and Bailey, 1989). But many species of salmon exhibit a behavior called straying, which is the upstream spawning migration of mature individuals to a stream other than the one where they originated (Quinn, 1993; Milner and Bailey, 1989). There are fundamental gaps in the understanding of straying behavior, and a lack of comprehensive studies on straying in wild populations of salmonids (Jonsson *et al.*, 2003; Quinn, 1993). According to Quinn (2005), one to five percent of Pacific salmonids stray to other rivers. Through genetic analysis of all radio-tagged wild (adipose fin intact) salmon, it was determined that 13% were of river Luleälven genetic origin (Nilsson, 2013). The river Luleälven has no wild salmon, and stocks are based exclusively on releases of reared fish (PhD. H. Lundqvist, SLU, pers. comm. 2013) Out of the 66 salmon that passed the Norrfors fish ladder, I located 55 in the river Vindelälven, with five (9%) of those successful passers being strayers. This phenomenon of a large number of strayers to this system is unique to 2012 (PhD. H. Lundqvist, SLU, pers.

comm. 2013; PhD. J. Nilsson, SLU, pers. comm. 2013). I will evaluate differences in size and upstream spawning migration distance strayers exhibited compared to native fish in the river Vindelälven.

Strayer analysis

Salmon with genetic stock origin of river Luleälven (strayers) and Ume/Vindelälven (natives) were compared in relation to their spawning migration distance. Due to the low sample size of strayers, I have bootstrapped both strayers and native fish with 1000 replications and used median values to determine significance. Fish size (cm) between the two groups was also analyzed for significance. Whatever the outcome of significant differences of strayer verses native salmon, I have chosen to group them together for all calculations and evaluations, with the exception of the aforementioned instances.

Data Processing

Tracking data from archival and manual receivers were processed in excel. Radio-tag registrations were sorted and filtered on signal strength (>90), BPM (bits per minute) and adjacent registrations. Registrations were considered legitimate if they satisfied the filtering process and coincided with other archival receivers and manual tracking. Environmental disturbances, etc., that caused false registrations were recognized by improper BPMs and if they did not coincide with adjacent receivers and manual tracking. Statistical analyses were performed in excel, JMP 10 and R.

Results

Upstream Migration

Did passage variables at the Norrfors fish ladder on the river Umeälven, as well as fish size, effect upstream migration distance in the river Vindelälven?

Variables from the Norrfors fish ladder did not have any significant effect on migration distance to spawning grounds further upstream in the river Vindelälven (Table 1).

Table 1. The effect of passage variables from the Norrfors fish ladder on the river Umeälven tested in relation to distance travelled upstream to spawning grounds in the river Vindelälven.

Passage variables from Norrfors fish ladder	***Definitions***	**Significant difference?**
Time to pass (days)	Time between tagging until the salmon successfully ascended the ladder.	NO
Total time in ladder (hrs)	Sum of length of all visits in the ladder.	NO
Passage day over ladder	Days after "start of migration", where start of migration was determined from when the first fish was counted on the VAKI system in the ladder.	NO

Fish length was found to be negatively correlated with migration distance (P < 0.05, t - 2.159, D.f. 5,29, Linear regression) (Figure 2).

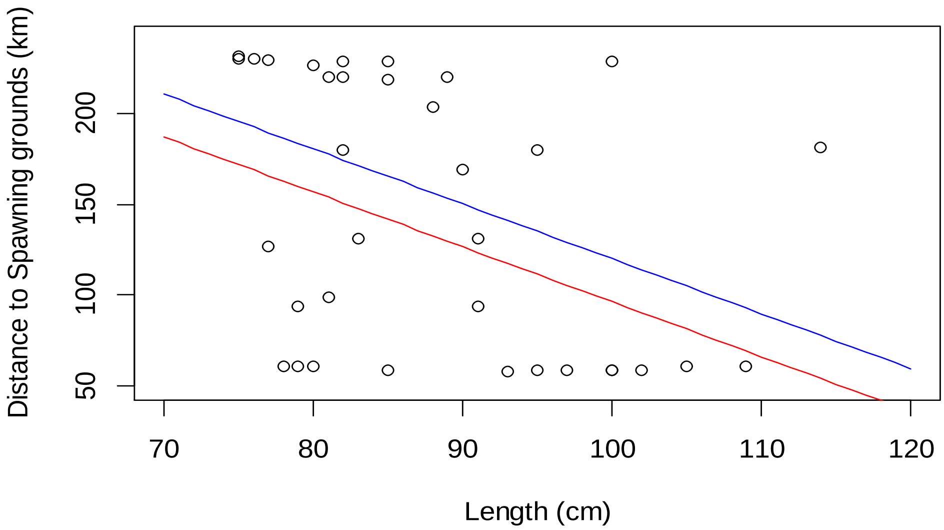

Figure 2. Fish length was found to be negatively correlated with migration distance up the river Vindelälven. Smaller salmon migrated significantly further up the river than did larger fish. Blue and red trend lines denote male and female salmon.

Additional descriptions of spawning migration

There were two distinct phases of spawning migration observed. The first phase after successful ladder passage was an active upstream movement to spawning grounds. The time it took the salmon to reach their respective spawning grounds could not be calculated with certainty because it was not known what exact day they actually arrived at the spawning site. The onset of the second phase of upstream migration was characterized by little or no activity in close proximity to spawning areas with movements <500m between tracking occasions.

One tagged salmon (native ♂ 82cm) exhibited a very large searching pattern prior to onset of spawning. This fish was first located on October 2nd at a well-known spawning location just below the rapid Linaforsen (180 km above tagging site). 19 days later on October 21st it was then located 81 km downstream in the vicinity of Ekorrsele bridge (101 km above tagging site). Three days later on October 24th it was back up just below its original position at Linaforsen (179 km above tagging site) for spawning. This searching behavior was the only instance observed on such a large scale. Subsequently this fish over-wintered two km downstream of its spawning area (177 km above tagging site).

35 tagged salmon were located at their respective spawning areas (Figure 3).

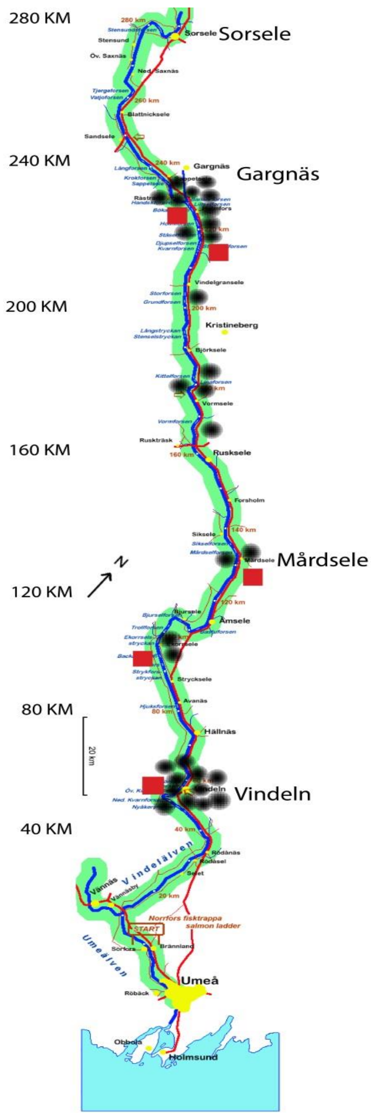

Figure 3. Spawning locations of 35 male and female salmon. Black dots denote native stock from the river Vindelälven and red squares denote strayers from river Luleälven stock.

Exact spawning locations (<5m^2) were impossible to attain due to inaccessibility because of the sheer size of the river Vindelälven, rapids, water depth and darkness. Therefore, spawning was inferred from timing and relative inactivity at probable spawning locations. The lowest documented spawning location of a tagged salmon in the river Vindelälven was just below Degerforsen rapid (58 km above tagging site) and the highest documented spawning location was just below the Krokforsen rapid (231 km above tagging site). Manual telemetry tracking identified two distinct areas of concentrated spawning. The first area of concentrated spawning (12 fish for 34%) was located 58-61 km upstream of the tagging location adjacent to the town of Vindeln. The second area (11 fish for 31%) identified was further upstream 210-231 km above the tagging location in the Gargnäs/Råstrand vicinity. These two combined areas totaling 24 river km accounted for the majority (65%) of spawning locations in the river Vindelälven. Female spawning locations will be compared to a similar study later in the discussions section. Six (31%) out of 19 females spawned in the upper reaches of the river Vindelälven from 210-246 km above the tagging site at Norrfors. Eight (42%) out of 19 females in my study spawned in the lower river 58-61 km above Norrfors in the vicinity of the town of Vindeln.

Spawning Site Evaluation

Was fish size a predictor of spawning habitat selection in relation to depth, substrate and velocity?

No correlation was observed between fish size and modified Wentworth substrate usage at spawning locations (p> 0.05). The most utilized modified Wentworth substrate size in spawning areas were 64.1-128mm and 128.1-256mm, with 28.4 and 25%, respectively (Figure 4).

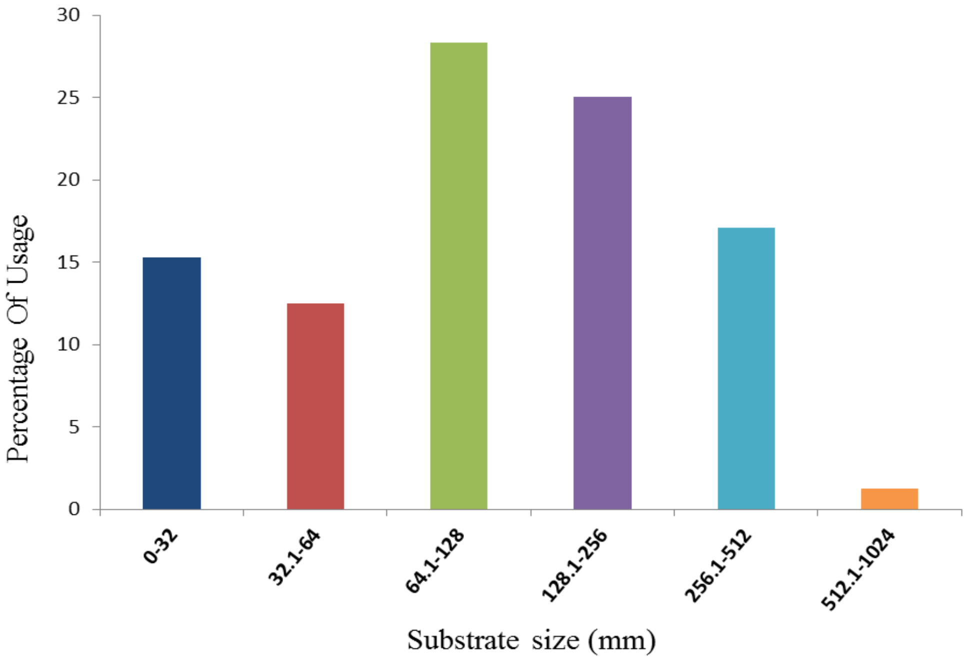

Figure 4. Modified Wentworth scale of substrate sizes with totaled values of all fish.

There was no correlation found between fish length and depth at which those fish were located at time of spawning. A positive correlation was discovered where larger salmon (cm) were positioned at significantly higher velocity (m/sec) areas than smaller salmon (F-value 8.83, D.f. 1, P <0.05 Linear regression) (Figure 5).

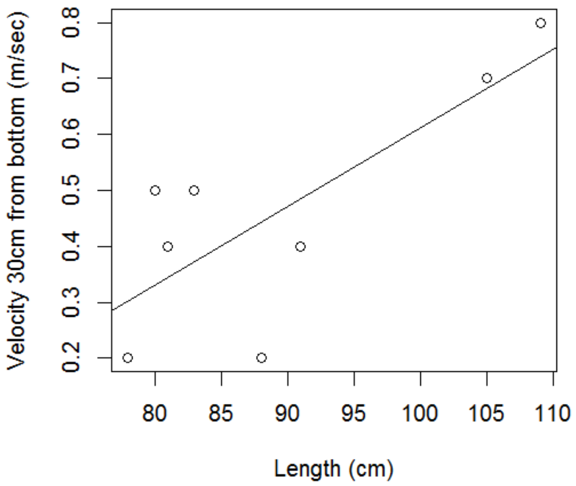

Figure 5. Length plotted against velocity (m/sec) 30cm from the river bottom showed that larger salmon at spawning areas were found at significantly higher velocities.

The two largest (109 and 105cm L_T) fish were observed in the locations with the highest recorded velocities, with 0.78 and 0.65 m/sec, respectively. The average velocity at spawning locations utilized was 0.46 m/sec.

The spawning sites that were measured for depth, substrate and velocity are illustrated in figure 6.

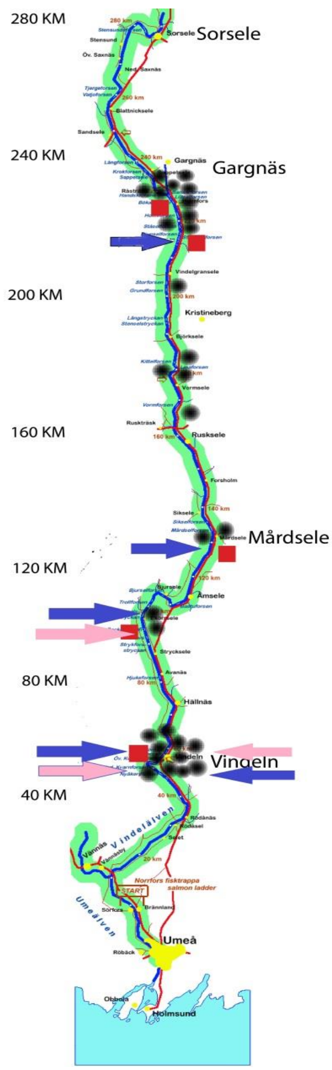

Figure 6. Locations of velocity, depth and substrate measurements at eight spawning locations. Male fish denoted in blue arrows, female fish denoted in pink arrows.

Kelt Over-wintering

Did kelts migrate seaward directly after spawning, or did they over-winter in the river Vindelälven, and if so, where did they over-winter, and was there a correlation between upstream migration distance and the distance travelled between spawning and over-wintering sites?

Six tagged salmon were detected leaving the river Vindelälven directly after spawning. These salmon were detected by stationary archival receivers leaving the river Vindelälven after spawning and foregoing over-wintering in the river (figure 7). All these out-migrants were of native Ume/Vindelälven genetic stock. They consisted of five females and one male with lengths between 78-100 cm.

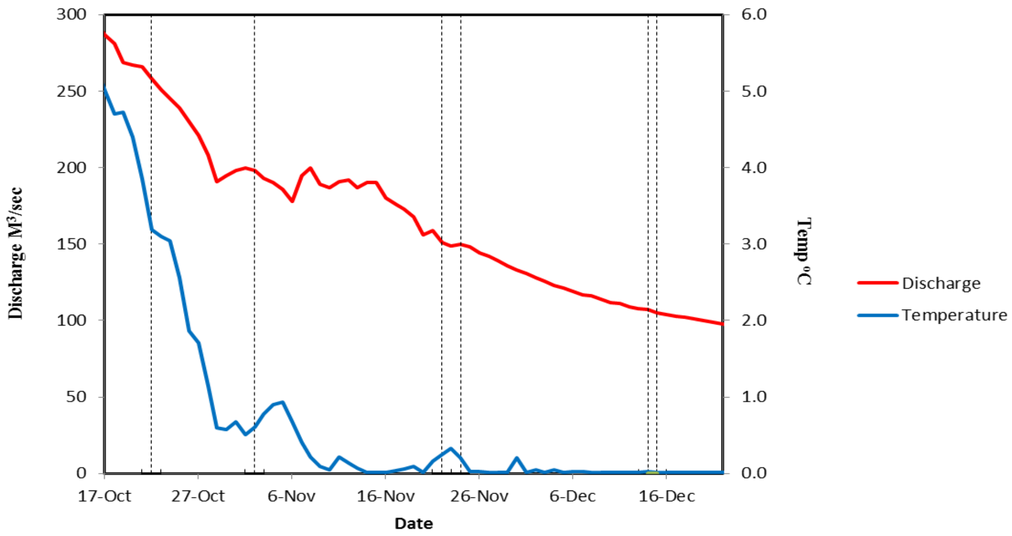

Figure 7. Temperature at Norrfors (river Umeälven) and discharge at Granåker (lower river Vindelälven) with vertical hash lines denoting date at which tagged salmon passed the stationary archival receiver at Björkudden. These salmon migrated downstream soon after spawning and did not over-winter in the river Vindelälven. This receiver is located directly upstream of the Norrfors fish ladder in the reservoir at Norrfors and salmon must pass this receiver during their descent.

These salmon that did not over-winter and left directly all spawned in the lower part of the river Vindelälven. The highest salmon (♀ 91cm) location recorded for these six tagged salmon was at Mårdseleforsen (131 km above Norrfors). Salmon that migrated further upstream to spawn were significantly more likely to over-winter than leave directly after spawning (F-value 8.58, Df 1,33, $P < 0.05$ anova) (Figure 8).

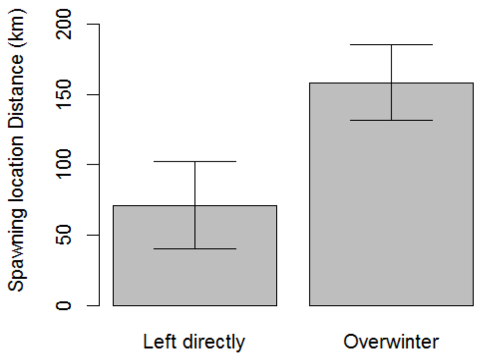

Figure 8. Salmon that migrated further upstream to spawn were significantly more likely to over-winter than leave directly after spawning.

There was no correlation found between upstream spawning migration distance and the distance travelled between spawning and over-wintering sites (Linear regression, $p > 0.05$).

Additional kelt over-wintering observations

The average distance travelled from spawning locations downstream to over-wintering locations was 16.9 km (SD ±22.4) with a minimum migration distance of 0 km and maximum of 81 km downstream. No salmon over-wintering locations were detected upstream of spawning areas. Both spawning and over-wintering locations were identified for 22 tagged salmon (figure 9).

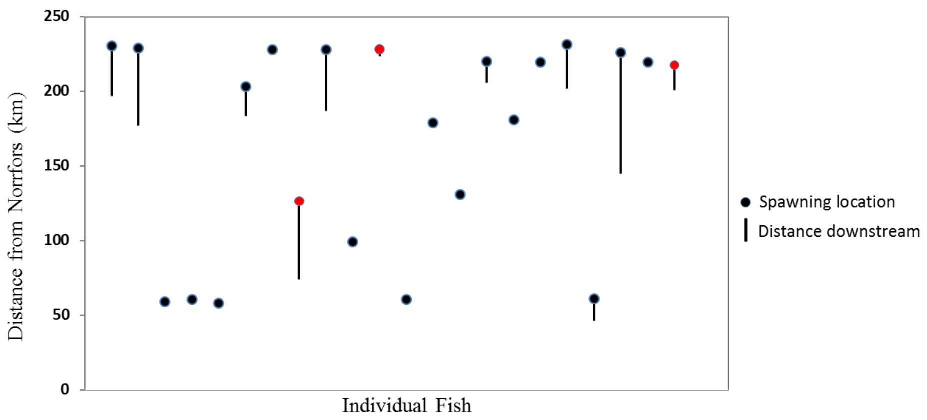

Figure 9. Spawning locations of 22 kelts with distance travelled downstream to over-winter locations. Vertical lines below dots denote distance travelled downstream to over-winter locations. In instances where no vertical line is present, over-wintering location is in the same approximate location. Red dots denote strayers.

30 over-wintering salmon were located in the late winter/early spring of 2013 from manual tracking by car and one airplane tracking occasion (figure 10).

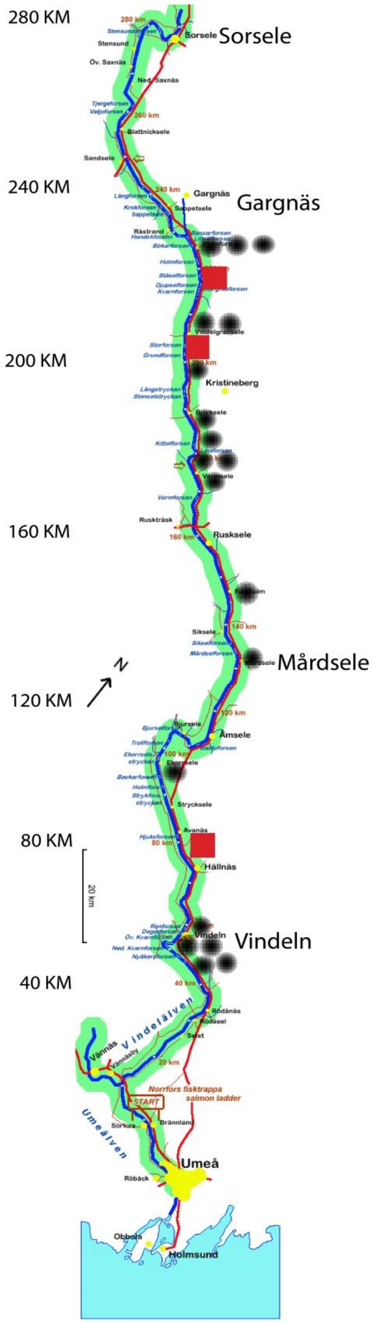

Figure 10. Over-wintering locations for 30 salmon. Black dots denote native river Vindelälven fish and red squares denote strayers of river Luleälven stock.

Over-wintering locations were typically slow moving, deep (>2m) areas with ice cover from December to March with river temperatures typically less than 1.0^{o}C. These areas were well suited for salmon to hold on the river bottom and expend very little energy. Manual radio tracking showed very limited kelt activity throughout the winter months. It was not possible to ascertain mortality of post-spawn kelts because the radio transmitters did not have activity sensors and many transmitters lacked sufficient batteries to last into the spring.

Kelt Downstream Migration

Did river discharge and river temperature trigger the seaward migration of kelts?

Seaward migration appeared to be initiated with an increase in both river temperature and discharge. River temperature rising above 8-10 C and river discharge rising above 150m^3/sec appeared to initiate seaward migration in the upper river. The five tagged salmon that did over-winter in the river Vindelälven and had transmitters with viable battery powerwere detected passing the Björksele archival receiver in the spring downstream migration (figure 11).

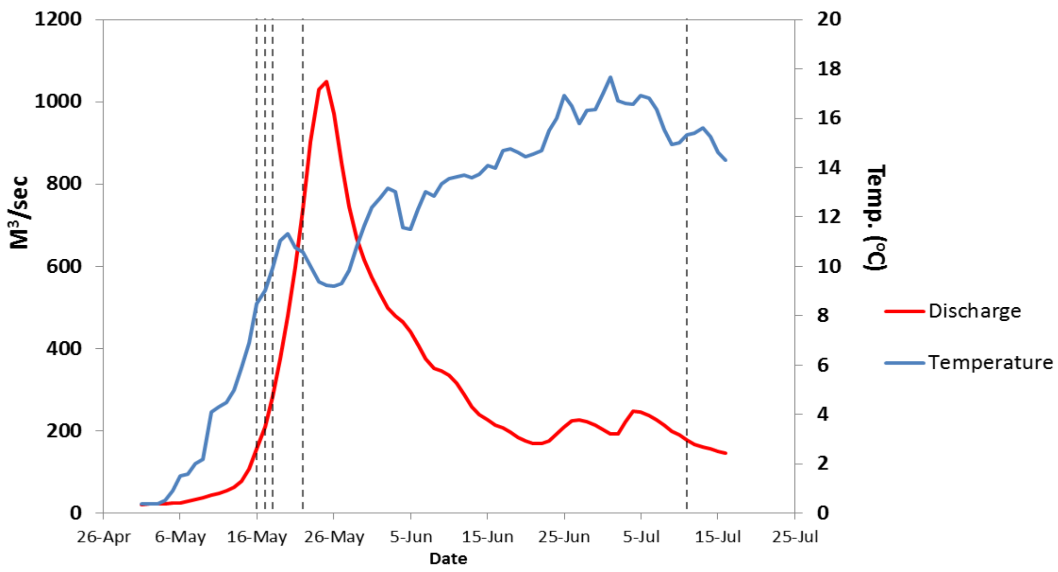

Figure 11. Temperature (at Björksele) and discharge (at Sorsele) with vertical hash lines denoting date at which tagged salmon passed the stationary archival receiver at Björksele. This receiver is located approximately 189km above the tagging site at Norrfors on the river Vindelälven. These salmon migrated downstream after over-wintering in the river.

Detection dates at the Björksele archival receiver ranged between May 16th to July 11th, with four out of five of those detections occurring between May 16th and May 22nd. The fifth tagged salmon's descent was considerably later in the season (July 11th) and was considered an outlier. These five salmon that were detected at the Björksele receiver were also detected subsequently at archival receivers further downstream. The dates that these fish (excluding the outlier) reached the downstream loggers ranged from May 20th to May 25th. River temperature at the Norrfors fish ladder at the time of kelt arrival (excluding the outlier) was between 11.9-13.5 C, averaging 12.5 C. Discharge at the SMHI gauge station on the river Vindelälven at time of kelt arrival (excluding the outlier) was between 401-903 m^3/sec, averaging 630 m^3/sec.

Additional kelt migration observations

Downstream migration speed between archival receivers was between 1.5-3.4 km/hour, averaging 2.5 km/hour. Another tagged salmon (♀ 105cm) that spawned close to the town of Vindeln (61km above tagging site) was detected at the Björkudden receiver on May 20th, but migration speed could not be calculated. All variables of spring downstream migration are summarized in table 2.

Table 2. Downstream migration summary for kelts in the spring of 2013. Fish 453/30 was not detected at Björksele receiver, therefore some fields are absent. Fish 253/30 (*) was not included in calculations due to its downstream migration occurring much later in the season than the other seaward migrants.

Fish	Origin	Sex	Length (cm)	Passed Björksele logger	Discharge (m3/sec.) at Sorsele	Temp.(C) at Björksele at pass time	Downstream logger and date passed	Temp.(C) at ladder at time passing dwnstrm logger	Hours between loggers	Distance (km) between loggers	Dwnstrm speed between loggers (km/hr)	
223/30	Native	♀	75	5/16/13 19:57	157	8.6	Björkudden 5/20/13 09:54	11.9	85.9	188.7	2.2	
703/40	Strayer	♂	85	5/17/13 20:15	210	9	Björkudden 5/20/13 10:51	11.9	62.6	188.7	3.0	
532/30	Native	♀	81	5/18/13 8:30	285	8.6	Intake 5/23/13 19:09	13.5	130.7	191.8	1.5	
473/30	Native	♀	77	5/22/13 19:27	740	10.6	Intake 5/25/13 03:23	13.4	55.9	191.8	3.4	
453/30	Native	♀	105	-	-	-	Björkudden 5/20/13 03:39	11.9	-	-	-	
253/30 *	Native	♀	77	7/11/13 0:48	179	14.1	Spöland 7/16/13 23:13	16.4	142.4	178.1	1.3	
					348.0	9.2		12.5	83.8	190.3	2.5	Mean
					157.0	8.6		11.9	55.9	188.7	1.5	Min
					740.0	10.6		13.5	130.7	191.8	3.4	Max
					266.6	1.0		0.8	33.8	1.8	0.9	St. Dev

* This fish was not included in calculations because it was an obvious outlier.

No Pit-tag detections of kelts were recorded in the Norrfors fish ladder during their downstream migration at the Stornorfors hydropower station. The fish guidance structure at the upstream entrance to the fish ladder did not appear to divert the seaward migrating kelts to use the fish ladder as a bypass. All the kelts likely continued downstream towards the hydroelectric power station at Stornorrfors, although tracking evaluations were not performed in detail below the fish ladder entrance.

Strayers

Did strayers of Luleälven stock origin differ from native Ume/Vindelälven fish with regard to upstream spawning migration distance and size?

Out of the 55 salmon that were located in the river Vindelalven, five (9%) were strayers of genetic stock of the river Luleälven. When comparing bootstrapped median values for native and strayer salmon in relation to distance migrated upstream to spawning locations, no significant difference was seen between the two groups (Table 3).

Table 3. Bootstrapped median values with 1000 replications of native Ume/Vindelälven and strayer Luleälven salmon stock. Overlapping confidence intervals show no significant differences in the two groups.

Variable	Natives				strayers				
	2.5 % CI	median	97.5 % CI	N	2.5 % CI	median	97.5 % CI	N	sig. Diff.
Spawning distance from Norrfors (km)	61.1	150.2	203.5	30	58.8	126.6	228.2	5	**N**

Fish size was also not significantly different between native river Vindelälven fish and strayers of river Luleälven stock.

Additional strayer observations

No instances of excessive searching behavior were observed by these strayers in the river Vindelälven that would suggest confusion or “being lost”. The upstream migration patterns of strayers appeared to follow the same patterns as that of native salmon. Strayers’ spawning locations were distributed throughout the river in the same general spawning locations as did native river Vindelälven fish (Figure 12).

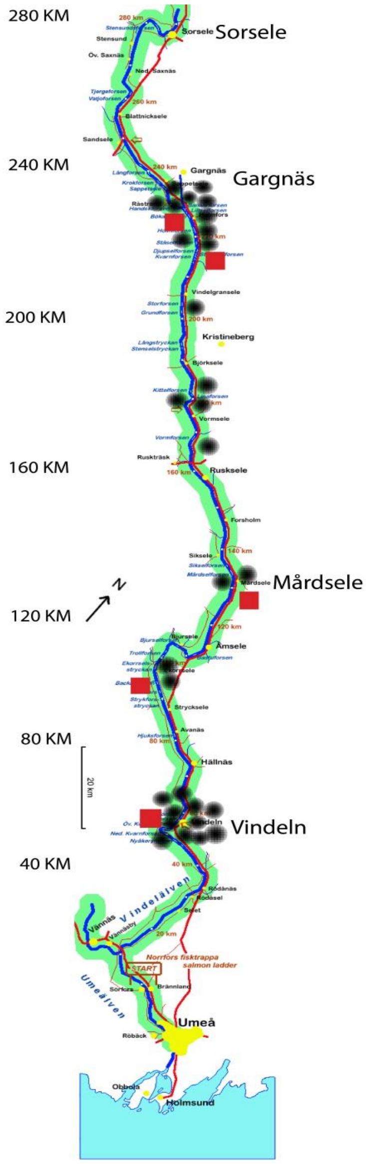

Figure 12. Spawning locations of all tagged salmon in the river Vindelälven. Strayers of river Luleälven stock denoted with red squares and native river Vindelälven salmon denoted with black dots.

Out of the eight spawning salmon whose locations were surveyed for depth, substrate and velocity, one fish was a strayer (♀ 91cm). This spawning location was in the vicinity of Bäckarforsen (93.7 km above tagging site). Anecdotally there was no difference in depth, substrate or velocity between this strayers' site compared to the sites of native salmon.

With regard to over-wintering/downstream migration, none of the six salmon that left the river Vindelälven directly after spawning were strayers. Three over-wintering locations of strayers were identified (figure 10), and those strayers' over-wintering locations did not appear to deviate from those of native fish. After spawning, the three strayers descended down the river Vindelälven 53, 17 and 5 km to their over-winter sites (figure 9). These movements appear consistent with the movements of the other 19 native salmon. Out of the five kelts that were monitored during their downstream migration in the spring, one was a strayer (♂ 85cm). That strayer's downstream migration behavior appeared to be consistent with that of the majority of the other outmigrating kelts. The strayer was detected at the Björksele receiver on May 17th and the Björkudden receiver on May 20th with a downstream migration speed of 3.01 km/hr.

Discussion

Upstream Migration

Results from the linear model exhibited that passage variables at the Norrfors fish ladder (*time to pass, total time in the ladder, passage day over the ladder*) did not significantly affect upstream migration distance in the river Vindelälven. These results need to be considered in context with ladder passage problems and tagging procedure. According to the Norrfors fish ladder passage study by Karlsson (2013), a mean delay time of 30 days post-tagging was observed, which could have many consequences in migration upriver in the river Vindelälven. Delays at power stations can cause considerable problems farther upstream during spawning migrations (Scruton *et al.*, 2008; Thorstad *et al.*, 2008). Catching, tagging and handling of salmon after they enter the river have been found to cause delays migrating upstream and aversion to the place of tagging (Thorstad *et al.*, 2005; Gerlier and Roche, 1998). Tagging of salmon for this study took place at the dam tailrace, which is very close to the entrance to the fish ladder. Future studies of this nature are recommended to tag salmon at the Umeälven estuary, as has been done with success in past studies (Lundqvist *et al.*, 2008; Rivinoja *et al.*, 2001).

In the three year study by Lundqvist *et al.* (Manuscript), tagging date was significantly correlated with spawning migration distance for two out of three years, but it must be noted that "tagging date" and the variable I used of "*passage day over the ladder"* are different, so direct comparisons are not valid. In the study by Lundqvist *et al.* (Manuscript), tagging took place at the top of the fish ladder after the salmon successfully ascended, and were subsequently released in the reservoir where they were free to continue their migration up to the river Vindelälven. In my study, salmon were tagged at the spillway next to downstream entrance to the ladder. The study by Lundqvist *et al.* (Manuscript), female salmon spawning locations were identified, and I have compared female spawning locations from my study with those of Lundqvist *et al*. (Manuscript) (Figure 13).

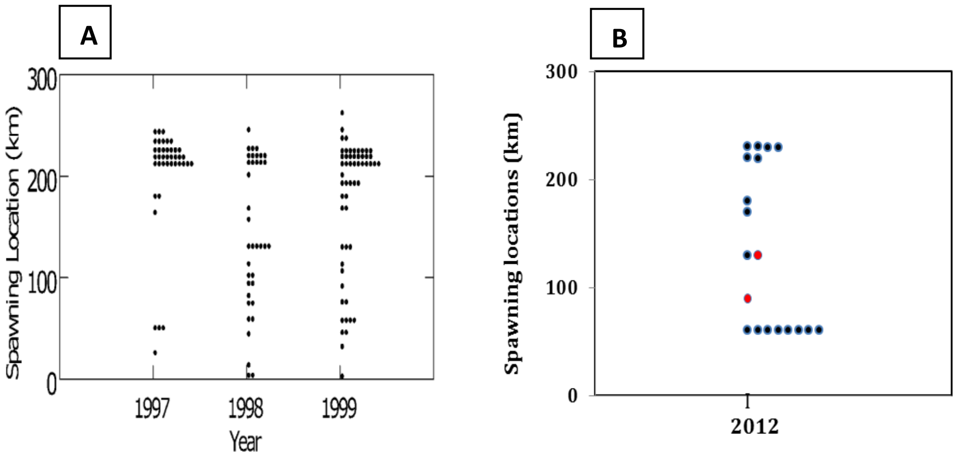

Figure 13. Graph A (adopted from Lundqvist, *et al* (Manuscript)), illustrates female spawning location distances in the river Vindelälven above the tagging site at Norrfors for 1997, 1998 and 1999 with discharges of 45 m^3/s, 137 m^3/s and 57 m^3/s, respectively. Graph B illustrates female spawning locations for 2012 with discharge of 89 M^3/sec. Discharges for all years shown were taken on October 28^{th,} which was estimated as peak spawning time. Average river discharge on October 28th for the last 50 years is 91 m^3/s. Black dots in graph B denote native salmon of river Vindelälven stock, and red dots denote strayers of river Luleälven stock.

Six (31%) out of 19 females in my study spawned in the upper reaches of the river Vindelälven from 210-246 km above the tagging site at Norrfors. This is in comparison with Lundqvist's (Manuscript) findings from 1997-99 of 79,38 and 52 % respectively, of locations being in this same approximate area. Eight (42%) out of 19 females in my study spawned in the Degerforsen/Renforsen section 58-61 km upstream from the tagging site at Norrfors. The distribution of spawning locations was similar to the three year study by Lundqvist *et al.* (Manuscript) on female salmon on the river Vindelälven, with one notable exception. My survey of spawning distribution compared to Lundqvist *et al* (Manuscript) show spawning locations distributed relatively the same, with the exception of a large number of fish (eight out of 19 females for 42%) spawning between 58-61 km above tagging site in the vicinity of Vindeln (figure 5). The study by Lundqvist *et al.* (Manuscript) shows only minimal (1-3 salmon) spawning for all years taking place in the area around Vindeln. River discharge at time of spawning did not appear to be a factor, with large variations in discharge for Lundqvist *et al*. (Manuscript) of 45 m^3/sec., 137 m^3/sec. and 57 m^3/sec., and discharge in my study of 89 m^3/sec. The reason for the vast differences in spawning locations is unknown, but differences in the aforementioned tagging and release procedures must be considered. Consideration on why certain areas are not utilized for spawning would be interesting for future studies.

Fish size (cm) did show a negative correlation with regard to spawning distance. Smaller salmon migrated farther up the river during their spawning migration than did larger salmon. The study by Baglinière *et al*. (1991) did not find size to be a determining factor in spawning distance, but the study by Lundqvist *et al*. (Manuscript) did find that smaller salmon migrated at significantly faster speeds than larger salmon, although speed could not be effectively calculated for my study.

The two distinct phases of migration I observed were consistent with similar Atlantic salmon studies and literature (Lundqvist *et al.*, Manuscript; Heggberget *et al.*, 1988; Jonsson and Jonsson, 2011). The first phase consisted of an active upstream movement to spawning grounds followed by little or no activity in close proximity to spawning areas. One tagged salmon exhibited a wide searching pattern travelling a maximum of 81km before settling on a spawning area.

Future studies would benefit from employing more archival receivers throughout the river Vindelalven, and using coded radio-tags that scan all channels simultaneously. This would decrease the labor-intensive task of manual tracking throughout the large drainage of the river Vindelälven.

Spawning Site Evaluations

Velocity was positively correlated with fish size for the eight locations sampled. Larger salmon are able to maintain positions in higher velocities area, as physical endurance is proportional to body size (Beland *et al.*, 1982). The velocities I measured fit with other studies (Beland *et al.*, 1982; Moir *et al.*, 2002). Higher velocity areas may also be more satisfactory to keep eggs aerated in the redds, which also speaks to increased success of larger female spawners (Quinn, 2005).

There was no correlation between depth and modified Wentworth substrate size usage compared to fish size. Studies on depth and substrate in large river (Rosenfeld, 2003; Louhi *et al.*, 2008), show similar findings of larger substrate and deeper water at spawning locations in large rivers with bigger fish. Caution must be used when discussing these results. Tracking of salmon to their spawning areas often lacked the necessary accuracy needed for microhabitat spawning evaluations. Due to the lack of specialized transmitters, as well as personnel and safety concerns it was not possible to always obtain pinpoint accuracy at spawning locations. For the purpose of this part of the study it would have been ideal to use transmitters with activity sensors that would have been able to discern digging of redds that is typical of spawning behavior. The reason activity transmitters were not used is because fish used in this study were initially only tagged for the purpose of evaluating movements around and pertaining to ladder passage efficiencies at Norrfors. The best possible spawning locations were identified given this constraint.

Procedural problems with data collection in this part of the study could also have affected these data. The ADCP can be severely influenced by water bubbles and disturbance (Beland *et al.*, 1982; Lindberg, 2011), and given that many salmon spawning locations were just below rapids, water bubbles were a considerable problem. During the survey, many errors were recorded because of bubbles and surface turbulence, as well as small pieces of ice suspended in the water column. This led to many bad readings and limited areas to sample. The ADCP also did not record velocity measurements below 2 meters. This was unfortunately a software update problem. In turn, it was necessary to extrapolate the velocities to the river bottom. The ADCP equipment and IR camera used for the depth, substrate and velocity measurements also had trouble functioning in the cold conditions, as well as difficulty maintaining battery power while in the field. Late October-early November 2012 was unseasonably cold. Many rivers sections in the main spawning areas far upstream were already iced over at the time of survey. This made for limited access with a raft and dangerous conditions. In order to access previously identified spawning areas, it was necessary to float between river access points and maneuver the raft into position. Throughout the Vindelälven, many whitewater rapids are present, and accessing spawning areas necessitated navigating some rapids. This added to procedural complexity while planning survey areas. Viable access spots along the river to load/unload the raft into the river were also very limited due to snow and ice. New areas were scouted farther downstream, but at the cost of being less desirable and done with some haste.

There are limited microhabitat studies on rivers larger than 5th order (Louhi *et al.*, 2008). The 8th order river Vindelälven with its assorted rapids in winter conditions is a challenging location to conduct in-depth field studies. Hopefully this aspect of my study, and the problems that were encountered, will help serve as a baseline for future studies.

Kelt Over-wintering

Atlantic salmon kelts in the river Vindelälven migrated seaward in two general time periods, with the first being soon after spawning in November-December, and the second being in May-July after over-wintering. Six salmon kelts migrated soon after spawning in November and December, and 30 kelts over-wintered and left in the spring. Kelts in smaller rivers (0.5-3$m^3 s^{-1}$) typically leave directly after spawning, while the majority of fish in larger rivers (300 $m^3 s^{-1}$) such as the river Vindelälven over-winter in the river and leave the subsequent spring (Jonsson and Jonsson, 2011). Five out of the six out-migrants were female. My results are in contrast to studies showing that males (Niemelä *et al.*, 2000; Jonsson *et al.*, 1990), and more specifically males in poor body condition (Halttunen, 2011) are more likely to out-migrate before females.

My study found that upstream spawning distance was positively correlated with the likelihood of over-wintering. I did not find any studies that investigated this same correlation. The unbalanced sample sizes of this analysis must be taken into consideration, as only six salmon were detected leaving the river directly and 30 salmon over-wintered. These results also need to be taken into context with passage variables at the fish ladder in Norrfors, which could have affected the outcome of over-wintering. For future studies, it would be interesting to see if this same correlation exists with larger, more balanced sample sizes, as well as tagging fish at the estuary.

There was no correlation between spawning migration distance and the distance travelled between spawning and over-wintering sites. I found no other studies that investigated this relationship. All salmon moved downstream to over-winter areas, with some only moving approximately 100 meters below their spawning location, which was similar to the results from Cunjak *et al.* (1998). In the two year study on anadromous sea trout in the river Vindelälven by Östergren and Rivinoja (2008), kelts moved both up and downstream of spawning locations to over-winter sites. The average distance salmon travelled downstream to over-winter areas in my study was 16.9 km. The average distance sea trout travelled between spawning and over-winter sites in the study by Östergren and Rivinoja (2008) was 2.7 and 6.1 km for two years in the river Vindelälven, and 48.8 in the river Piteälven.

The 30 over-wintering locations I identified were typical of Atlantic salmon (Scruton *et al.*, 2002; Jonsson and Jonsson, 2011). These areas were in deep, slow moving areas with ice cover throughout the winter, where the kelts' movements were very limited.

Kelt Downstream Migration

It appeared that both river temperature and discharge were important in initiation of seaward migration in kelts in the river Vindelälven. Temperature and discharge are said to be important cues for salmon to initiate downstream migration (Jonsson and Jonsson, 2011; Halttunen, 2011). Conversely, the study on sea trout by Östergren and Rivinoja (2008), found that only water temperature initiated downstream migration on the river Vindelälven.

The temperature threshold that appeared to trigger downstream migration past the Björksele receiver in the upper river was between 8-10 C. These temperatures are well within the range of 6-18.5 C for downstream migration of kelts found by Scruton *et al.* (2007) in Newfoundland, Canada, between May 28th to June 18th. Discharge rising above approximately 150 m^3/sec., and more importantly a spike in discharge, appeared to also initiate downstream migration. But for certain I cannot hypothesize that these variables of temperature and discharge, on their own, would not initiate downstream migration. Anecdotally, when consulting figure 11 in the results section, it appears both variables are important for downstream migration.

The majority of detections of downstream migrating kelts occurred between May 16th and May 22nd at the Björksele logger in the upper river. It took on average 83.8 hours for those fish to reach the receiver at Björkudden by the Norrfors ladder with an average downstream migration speed of 2.5 km/hour.

No kelts were detected in the fish ladder at Norrfors during seaward migration. It is likely that all the seaward migrating kelts were not diverted by the fish guidance structure to use the fish ladder as a bypass around the Stornorrfors hydropower station. Safe passage through the Francis turbines at Stornorrfors is assumed to be unlikely (Lundqvist *et al.*, 2008), although I am not aware of definitive studies on kelt mortality for Atlantic salmon at the Stornorrfors hydropower station. Östergren and Rivinoja (2008) found that mortality of sea trout attempting to pass the turbines at Storrnorrfors was 69%. Those sea trout were smaller (L_T =50–86 cm) than the salmon (L_T = 39-116 cm) used for this study, and fish length has a positive correlation with blade strike mortality in hydropower stations with Francis turbines (Ferguson *et al.*, 2008). Up and downstream movements of anadromous sea trout have been observed between the intake to the power station and the reservoir at the upstream entrance to the fish ladder (Östergren and Rivinoja, 2008), and it is likely that Atlantic salmon would move similarly. The intake entrance to the power station has a trash collecting rack with iron bars with gaps 9 cm apart (Forssen, 2013). This 9 cm gap does not allow larger-sized fish to pass, and in turn many larger salmonids cannot enter the turbines. Many large kelts would then aggregate around the intake entrance to the turbines. This could pose a compounding problem with predation of smolts by hungry kelts, that because of their larger size, cannot pass the trash rack (PhD H. Lundqvist, SLU, pers. comm. 2013). This problem could be exacerbated with regard to predation on seaward migrating smolts if the trend of increasing numbers of returning adult salmon (8,058 in 2012 and approximately 15,000 in 2013) continues (PhD H. Lundqvist, SLU, pers. comm. 2013). The timing of kelt arrival at the Stornorrfors area in 2013 coincided with the peak smolt migration as monitored at Spöland (PhD. K. Leonardsson, SLU, pers. comm. 2014).

There are numerous studies on fish mortality in hydroelectric power facilities (Coutant and Whitney, 2000; Ferguson *et al.*, 2008; Östergren and Rivinoja, 2008), and as many measures being employed to mitigate the harmful effects hydropower facilities have anadromous salmonids. Detailed kelt passage studies are currently underway at the Stornorrfors hydropower station evaluating passage and mortality, hopefully these studies will produce results that will aid in kelt passage at Stornorrfors.

Strayers

I found no differences in my analyses between the native river Vindelälven stock and the strayers of Luleälven stock. Strayers did not migrate further upstream than native salmon, nor did they differ in size. Karlsson (2013), also observed no significant difference between the two groups in his study of ladder efficiency at the Norforrs fish ladder. The river Luleälven strayers were most likely offspring of released salmon smolts from the Luleälven fish hatchery (anal fin intact) (PhD J. Nilsson, SLU, pers. comm. 2013), which accounts for the second largest compensatory release of salmon smolts in Sweden, with over 500,000 released yearly (ICES, 2012). There is equivocal evidence that standard hatchery practices increase straying behavior (Quinn, 1993), but there are so few comprehensive studies on strayers in wild populations that comparisons are not valid.

The large number of strayers in the Ume/Vindelälven system in 2012 begs the question of what are the implications for the Ume/Vindelälven system? According to Quinn (1993), it is important to steer away from broad generalizations concerning straying, as there are many diverse and unique populations of salmonids with vastly different proportions and occurrences of straying behavior. Straying is thought to be important for salmonid populations because it leads to the colonization of new habitats as well as aids in avoiding unfavorable local conditions (Milner and Bailey, 1989; Leider, 1989). Conversely, straying is thought to pose a threat to discreet native populations and decrease fitness , as well as disrupt local gene pools with unique adaptations (Allendorf *et al.*, 2001; Jonsson *et al.*, 2003).

What could be the reasons for this large proportion of strayers in the Ume/vindelälven? The close proximity between the river Luleälven and Ume/Vindelälven could increase straying between the two systems, as found in the study by Jonsson *et al.* (2003). Did strayers "forget" the smell of their natal river because they were older and spent a longer time ranging out and foraging in the open ocean, as seen in the studies by Jonsson *et al.* (2003) and Quinn (1993) but conversely, not by Hard and Hoard (1999)? Tagging data does not appear to support the hypothesis that strays are older, as the size ranges of strays compared to natives is similar.

There is no doubt that salmon stray, only the consequences can be disputed. Interestingly, genetic analysis of tagged salmon in the river Umeälven the next year (2013) showed clear results of no strayers within the sample (PhD J. Nilsson, SLU, pers. comm. 2013). Further study on this subject in the Ume/Vindelälven system could answer some of these convoluted questions concerning strayers.

Conclusion

This thesis highlighted the many variables affecting the migratory life cycle of Atlantic salmon in the Ume/Vindelälven. Passage variables at the fish ladder at Norforrs in the river Umeälven did not affect upstream migration distance in the Vindelälven, but smaller salmon were found to migrate further up the river. No correlation between depth and substrate was found compared to fish size, but larger fish spawned in higher velocity areas. Two time periods were identified for kelt downstream migration, one soon after spawning in early winter, and the other in the spring after the kelts over-wintered. Salmon that migrated further upstream to spawn were more likely to overwinter as opposed to leave directly after spawning. No correlation was observed between upstream migration distance and distance travelled between spawning and over-winter sites. All kelts over-wintered below their spawning sites, and over-wintering locations were in deep, slow moving ice-covered sections of the river. Rising river discharge and temperature both appeared to initiate downstream migration of kelts in late May with an average downstream migration speed of 2.5 km/hr. The fish guidance structure at Norrfors did not appear to influence kelts to use the fish ladder as a bypass around the Stornorrfors power station. Finally, no differences were observed between strayers and native salmon during upstream migration.

In this study of Atlantic salmon, I attempted to attain a snapshot of one complete spawning, over-wintering and downstream migration in the Ume/Vindelälven system. These evaluations were very broad in scope, and in terms of a master thesis, were quite ambitious. But my hope is that future studies will be able to build on some of these results and finetune the experimental procedure. For future management strategies, regulatory bodies and research to be effective, it may be necessary to expand into a more holistic approach concerning Atlantic salmon management and conservation, especially concerning the very important life stages of post-spawning and downstream migration of kelts.

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Appendix 1. Tracking data

Date&Time tagged	Freq/BPM	Sex	Length	location	GPS	tracking date	tracking method	Genetic origin	misc.
8/2/2012	**,215/55**	2	85	~ 1km above Renforsen	64,21902/19,70312	9/2/2012	car and handheld	STRAYER	
8/2/2012	**,234/55**	1	91	Nyåkersforsen (from gate on rd.)	64,17203/19,70947	9/2/2012	car and handheld	STRAYER	
7/6/2012	**,244/30**	2	78	Krokforsen, above sappetsele	65,28159/17,87578	9/2/2012	car and handheld	native	
8/2/2012	**,245/55**	1	76	Lillselforsen	65,25204/18,08939	9/2/2012	car and handheld	native	
7/6/2012	**,253/30**	1	77	Lillselforsen	65,25204/18,08939	9/2/2012	car and handheld	native	
8/2/2012	**,254/55**	2	102	Renforsen	64,20746/19,70243	9/2/2012	car and handheld	native	
8/2/2012	**,274/55**	1	79	~ 1km above Renforsen	64,21902/19,70312	9/2/2012	car and handheld	native	
8/2/2012	**,285/55**	2	109	Above Renforsen	64,21902/19,70312	9/2/2012	car and handheld	native	
8/2/2012	**,294/55**	1	93	below renforsen by bridge	64,20201/19,70037	9/2/2012	car and handheld	native	
8/2/2012	**,344/55**	1	98	Ekorrsele bridge	64,43920/19,22212	9/2/2012	car and handheld	native	
8/2/2012	**,375/55**	2	100	Lillselforsen	65,25204/18,08939	9/2/2012	car and handheld	native	
8/2/2012	**,393/55**	1	82	Above storgräsforsen (below junc. w/ rd 370)	65,19380/18,22474	9/2/2012	car and handheld	native	
8/2/2012	**,423/55**	2	81	Ekorrsele bridge	64,43920/19,22212	9/2/2012	car and handheld	native	
8/2/2012	**,444/55**	2	85	Lillselforsen	65,25204/18,08939	9/2/2012	car and handheld	STRAYER	
7/11/2012	**,453/30**	1	105	Above Renforsen	64,21902/19,70312	9/2/2012	car and handheld	native	
7/18/2012	**,474/55**	1	96	~3km above Mårdseleforsen	64,68876/19,20032	9/2/2012	car and handheld	native	
8/7/2012	**,534/55**	1	74	~1km below Mårdsele	64,64494/19,28455	9/2/2012	car and handheld	native	
8/7/2012	**,544/55**	2	78	Hemseleforsen "lake" @ below big bend	64,17196/19,66179	9/2/2012	car and handheld	native	
8/7/2012	**,563/55**	2	75	Lillselforsen	65,25204/18,08939	9/2/2012	car and handheld	native	
7/18/2012	**,571/30**	2	116	below Vindeln @ Hemseleforsen cabins	64,17543/19,68829	9/2/2012	car and handheld	native	
8/7/2012	**,584/55**	1	80	Above Renforsen	64,21902/19,70312	9/2/2012	car and handheld	native	
8/7/2012	**,594/55**	2	84	Långforsen	64,03051/19,90680	9/2/2012	car and handheld	native	
7/18/2012	**,603/30**	1	100	Renforsen	64,20746/19,70243	9/2/2012	car and handheld	native	
7/18/2012	**,623/30**	1	95	Hemseleforsen "lake" @ big bend	64,17493/19,66316	9/2/2012	car and handheld	native	
8/7/2012	**,624/55**	2	80	holmforsen below junc. with rd. 370	65,23996/18,13703	9/2/2012	car and handheld	native	
8/7/2012	**,635/55**	1	77	Vormforsen (above Rucksele)	64,86856/18,72001	9/2/2012	car and handheld	native	
8/7/2012	**,653/55**	1	97	above Långforsen @ footbridge	64,04604/19,91697	9/2/2012	car and handheld	native	
8/21/2012	**,673/40**	2	95	Mårdseleforsen	64,67926/19,24014	9/2/2012	car and handheld	native	
8/21/2012	**,703/40**	2	85	Mårdseleforsen	64,67926/19,24014	9/2/2012	car and handheld	STRAYER	
8/2/2012	**,215/55**	2	85	below Renforsen	64,20687/19,70225	9/18/2012	car and handheld	STRAYER	
7/6/2012	**,223/30**	1	75	Lillselforsen	65,25204/18,08939	9/18/2012	car and handheld	native	
7/6/2012	**,244/30**	2	78	just below sappetsele Br.	65,25498/17,98134	9/18/2012	car and handheld	native	
8/2/2012	**,245/55**	1	76	Lillselforsen	65,25204/18,08939	9/18/2012	car and handheld	native	
7/6/2012	**,253/30**	1	77	Above Holmforsen	65,23996/18,13703	9/18/2012	car and handheld	native	
8/2/2012	**,254/55**	2	102	Renforsen	64,20746/19,70243	9/18/2012	car and handheld	native	
8/2/2012	**,274/55**	1	79	Above Renforsen	64,21902/19,70312	9/18/2012	car and handheld	native	
8/2/2012	**,285/55**	2	109	Above Renforsen	64,21902/19,70312	9/18/2012	car and handheld	native	
8/2/2012	**,294/55**	1	93	Renforsen	64,20746/19,70243	9/18/2012	car and handheld	native	
8/2/2012	**,303/55**	2	88	Above Storforsen	65,07950/18,33531	9/18/2012	car and handheld	native	
7/6/2012	**,334/30**	1	73	below lillseleforsen (s. side rd) sappetavan sign	65,27935/17,77944	9/18/2012	car and handheld	native	
8/2/2012	**,344/55**	1	98	below town Grandfors at Grandforsen rapid	65,04858/18,40023	9/18/2012	car and handheld	native	
8/2/2012	**,375/55**	2	100	Lillselforsen	65,25204/18,08939	9/18/2012	car and handheld	native	
8/2/2012	**,383/55**	1	96	Renforsen	64,20746/19,70243	9/18/2012	car and handheld	native	
8/2/2012	**,393/55**	1	82	Laxselet	65,26100/18,05282	9/18/2012	car and handheld	native	
8/2/2012	**,405/55**	2	112	Kvarnforsen	65,17587/18,23845	9/18/2012	car and handheld	native	
8/2/2012	**,423/55**	2	81	Ekorrsele bridge	64,43920/19,22212	9/18/2012	car and handheld	native	
7/11/2012	**,453/30**	1	105	Above Renforsen	64,21902/19,70312	9/18/2012	car and handheld	native	
7/11/2012	**,473/30**	1	77	Lillseleforsen (s.side rd) by lumber mill	65,28374/17,76352	9/18/2012	car and handheld	native	
7/6/2012	**,493/55**	2	83	Below Mårdseleforsen	64,67118/19,25233	9/18/2012	car and handheld	native	
8/2/2012	**,504/55**	1	89	Kvarnforsen	65,17587/18,23845	9/18/2012	car and handheld	native	
7/11/2012	**,503/30**	1	88	"old ferry xing" below Krokforsen, above Sappetsele	65,27521/17,84633	9/18/2012	car and handheld	native	
7/18/2012	**,532/30**	1	81	Above Kvarnforsen	65,20359/18,21516	9/18/2012	car and handheld	native	
8/7/2012	**,544/55**	2	78	Renforsen	64,17196/19,66179	9/18/2012	car and handheld	native	
7/18/2012	**,553/30**	2	88	Lillseleforsen (s.side rd) by lumber mill	65,28374/17,76352	9/18/2012	car and handheld	native	
8/7/2012	**,563/55**	2	75	Lillselforsen	65,25204/18,08939	9/18/2012	car and handheld	native	
7/18/2012	**,571/30**	2	116	below Vindeln @ Hemseleforsen cabins	64,17543/19,68829	9/18/2012	car and handheld	native	
8/7/2012	**,584/55**	1	80	Above Renforsen	64,21902/19,70312	9/18/2012	car and handheld	native	
8/7/2012	**,594/55**	2	84	below lillseleforsen (s. side rd)	65,27935/17,77944	9/18/2012	car and handheld	native	
7/18/2012	**,603/30**	1	100	Renforsen	64,20746/19,70243	9/18/2012	car and handheld	native	
7/18/2012	**,623/30**	1	95	Hemseleforsen "lake" @ big bend	64,17493/19,66316	9/18/2012	car and handheld	native	
8/7/2012	**,624/55**	2	80	Above Holmforsen	65,23996/18,13703	9/18/2012	car and handheld	native	
7/18/2012	**,644/30**	2	82	Above Renforsen	64,21902/19,70312	9/18/2012	car and handheld	native	
8/7/2012	**,653/55**	1	97	Hemseleforsen "lake" @ big bend	64,17196/19,66179	9/18/2012	car and handheld	native	

9/27/2012	**,214/30**	1	90	Renforsen	64,20746/19,70243	10/2/2012	car and handheld	native	No registers thru ladder or loggers!
8/2/2012	**,215/55**	2	85	Just above Renforsen	64,21902/19,70312	10/2/2012	car and handheld	STRAYER	
7/6/2012	**,223/30**	1	75	Beukaforsen rapid	65,24778/18,10322	10/2/2012	car and handheld	native	
8/2/2012	**,234/55**	1	91	~2km above Renforsen	64,21902/19,70312	10/2/2012	car and handheld	STRAYER	
7/6/2012	**,244/30**	2	78	Just below Br. Below Sappetsele	65,25500/17,98134	10/2/2012	car and handheld	native	
8/2/2012	**,245/55**	1	76	Beukaforsen parking area	65,25204/18,08939	10/2/2012	car and handheld	native	
7/6/2012	**,253/30**	1	77	Holmforsen rapid	65,22875/18,16991	10/2/2012	car and handheld	native	
8/2/2012	**,254/55**	2	102	Renforsen	64,20746/19,70243	10/2/2012	car and handheld	native	
7/6/2012	**,263/30**	2	78	Below Sappetsele Br. (side rd before Br. N.side HW)	65,25312/18,01775	10/2/2012	car and handheld	native	
8/2/2012	**,274/55**	1	79	Renforsen	64,20746/19,70243	10/2/2012	car and handheld	native	
8/2/2012	**,285/55**	2	109	Above Renforsen	64,21902/19,70312	10/2/2012	car and handheld	native	
8/2/2012	**,294/55**	1	93	Renforsen	64,20746/19,70243	10/2/2012	car and handheld	native	
8/2/2012	**,303/55**	2	88	Just below Mattjokkbäcken (above Vindelgransele)	65,17085/18,24426	10/2/2012	car and handheld	native	
7/6/2012	**,314/55**	1	91	Renforsen	64,20746/19,70243	10/2/2012	car and handheld	native	
7/6/2012	**,334/30**	1	73	Torviksele (s. side rd) AKA Lillseleforsen	65,27935/17,89841	10/2/2012	car and handheld	native	
8/2/2012	**,335/55**	2	83	Below Br. At Lillforsen (lower river)	64,05331/19,92767	10/2/2012	car and handheld	native	
8/2/2012	**,344/55**	1	98	below storforsen rapid, AKA Grundforsen	65,07132/18,35436	10/2/2012	car and handheld	native	
8/2/2012	**,375/55**	2	100	Laxselet	65,25782/18,05199	10/2/2012	car and handheld	native	
7/6/2012	**,382/30**	1	77	Below Mårdsele	64,64854/19,27797	10/2/2012	car and handheld	STRAYER	No registers thru ladder or loggers!
8/2/2012	**,393/55**	1	82	Laxselet	65,25782/18,05199	10/2/2012	car and handheld	native	
8/2/2012	**,405/55**	2	112	Just below Mattjokkbäcken (above Vindelgransele)	65,17085/18,24426	10/2/2012	car and handheld	native	
8/2/2012	**,414/55**	1	81	Above Vindelgransele	65,15379/18,25593	10/2/2012	car and handheld	native	
8/2/2012	**,423/55**	2	81	Ekorrsele bridge	64,43920/19,22212	10/2/2012	car and handheld	native	
8/2/2012	**,444/55**	2	85	Beukaforsen	65,25204/18,08939	10/2/2012	car and handheld	STRAYER	
7/11/2012	**,453/30**	1	105	Above Renforsen	64,21902/19,70312	10/2/2012	car and handheld	native	
8/2/2012	**,464/55**	2	82	Linaforsen (below Björksele)	64,93851/18,62453	10/2/2012	car and handheld	native	
7/6/2012	**,493/55**	2	83	Mårdseleforsen	64,68175/19,23909	10/2/2012	car and handheld	native	
8/2/2012	**,504/55**	1	89	Ståselforsen (below junc. With rd. 370)	65,20954/18,20254	10/2/2012	car and handheld	native	
7/11/2012	**,503/30**	1	88	below Långforsen, above Orrkulla	65,28987/17,81466	10/2/2012	car and handheld	native	
7/18/2012	**,524/30**	2	114	Vormforsen	64,87186/18,72642	10/2/2012	car and handheld	native	
8/7/2012	**,525/55**	1	95	1km below storforsen	65,06440/18,37288	10/2/2012	car and handheld	native	
7/18/2012	**,532/30**	1	81	below Holmforsen, below rd. junc. 370	65,21458/18,19459	10/2/2012	car and handheld	native	
7/18/2012	**,553/30**	2	88	Lillseleforsen (s.side rd) by lumber mill	65,28374/17,76352	10/2/2012	car and handheld	native	
8/7/2012	**,563/55**	2	75	Krokforsen @ krokforskoja	65,28177/17,88230	10/2/2012	car and handheld	native	
7/18/2012	**,571/30**	2	116	below Vindeln @ Hemseleforsen cabins	64,17543/19,68829	10/2/2012	car and handheld	native	
8/7/2012	**,584/55**	1	80	Above Renforsen ~2km	64,21902/19,70312	10/2/2012	car and handheld	native	
8/7/2012	**,594/55**	2	84	below lillseleforsen (s. side rd)	65,27935/17,77944	10/2/2012	car and handheld	native	
7/18/2012	**,603/30**	1	100	Renforsen	64,20746/19,70243	10/2/2012	car and handheld	native	
7/18/2012	**,613/30**	1	97	below Ekkorsele @ Bäckarforsen	64,41395/19,28350	10/2/2012	car and handheld	native	
7/18/2012	**,623/30**	1	95	Hemseleforsen "lake" @ big bend	64,17493/19,66316	10/2/2012	car and handheld	native	
8/7/2012	**,624/55**	2	80	below Holmforsen, below rd. junc. 370	65,21458/18,19459	10/2/2012	car and handheld	native	
8/21/2012	**,634/40**	1	100	Degerforsen, just below Renforsen	64,20573/19,69928	10/2/2012	car and handheld	native	
8/7/2012	**,635/55**	1	77	Vormforsen	64,87186/18,72642	10/2/2012	car and handheld	native	
7/18/2012	**,644/30**	2	82	below Holmforsen, below rd. junc. 370	65,20393/18,21619	10/2/2012	car and handheld	native	
8/7/2012	**,645/55**	1	104	below br. Above Vännaforsen (lower river)	64,04812/19,92508	10/2/2012	car and handheld	native	
8/7/2012	**,653/55**	1	97	Hemseleforsen "lake" @ big bend	64,17493/19,66316	10/2/2012	car and handheld	native	
8/21/2012	**,703/40**	2	85	Just below Mattjokkbäcken (above Vindelgransele)	65,17085/18,24426	10/2/2012	car and handheld	STRAYER	
9/27/2012	**,214/30**	1	90	below vormforsen	64,86584/18,71803	10/13/2012	car and handheld	native	
8/2/2012	**,215/55**	2	85	Degerforsen	64,20573/19,69928	10/13/2012	car and handheld	STRAYER	
7/6/2012	**,223/30**	1	75	Laxselet	65,25782/18,05199	10/13/2012	car and handheld	native	
8/2/2012	**,245/55**	1	76	Laxselet	65,25782/18,05199	10/13/2012	car and handheld	native	
7/6/2012	**,253/30**	1	77	lillselforsen P. lot	65,27882/17,88731	10/13/2012	car and handheld	native	
8/2/2012	**,254/55**	2	102	Renforsen	64,20711/19,96687	10/13/2012	car and handheld	native	
8/2/2012	**,274/55**	1	79	just above Renforsen	64,21902/19,70312	10/13/2012	car and handheld	native	
8/2/2012	**,285/55**	2	109	Above Renforsen	64,21902/19,70312	10/13/2012	car and handheld	native	
8/2/2012	**,294/55**	1	93	Renforsen	64,20746/19,70243	10/13/2012	car and handheld	native	
8/2/2012	**,303/55**	2	88	storforsen	65,06440/18,37288	10/13/2012	car and handheld	native	
7/6/2012	**,314/55**	1	91	just below mardseleforsen	64,67061/19,25224	10/13/2012	car and handheld	native	
8/2/2012	**,375/55**	2	100	Laxselet	65,25782/18,05199	10/13/2012	car and handheld	native	
7/6/2012	**,382/30**	1	77	Below Mårdsele	64,64854/19,27797	10/13/2012	car and handheld	STRAYER	
8/2/2012	**,393/55**	1	82	Laxselet	65,26100/18,05282	10/13/2012	car and handheld	native	
8/2/2012	**,423/55**	2	81	Ekorrsele bridge	64,43920/19,22212	10/13/2012	car and handheld	native	
8/2/2012	**,444/55**	2	85	Beukaforsen	65,25204/18,08939	10/13/2012	car and handheld	STRAYER	
7/11/2012	**,453/30**	1	105	Above Renforsen	64,21902/19,70312	10/13/2012	car and handheld	native	
7/6/2012	**,493/55**	2	83	below Mårdseleforsen	64,67061/19,25224	10/13/2012	car and handheld	native	
7/18/2012	**,524/30**	2	114	linaforsen	64,93851/18,62453	10/13/2012	car and handheld	native	
8/7/2012	**,544/55**	2	78	1km above renforsen (rapid with lawn chair)	64,22159/19,70698	10/13/2012	car and handheld	native	
8/7/2012	**,563/55**	2	75	~300 m. below Krokforsen	65,28177/17,88230	10/13/2012	car and handheld	native	Manual track w/in 25m. Gain 2,5. Good ADCP location
8/7/2012	**,584/55**	1	80	Above Renforsen ~2km	64,21902/19,70312	10/13/2012	car and handheld	native	
7/18/2012	**,603/30**	1	100	middle renforsen rapid	64,21159/19,70695	10/13/2012	car and handheld	native	
7/18/2012	**,623/30**	1	95	Degerforsen	64,20573/19,69928	10/13/2012	car and handheld	native	
8/21/2012	**,634/40**	1	100	Degerforsen	64,20573/19,69928	10/13/2012	car and handheld	native	
7/18/2012	**,644/30**	2	82	below Holmforsen, below rd. junc. 370	65,19921/18,22070	10/13/2012	car and handheld	native	
8/7/2012	**,653/55**	1	97	Degerforsen	64,20573/19,69928	10/13/2012	car and handheld	native	
8/21/2012	**,703/40**	2	85	Just below Mattjokkbäcken (above Vindelgransele)	65,17085/18,24426	10/13/2012	car and handheld	STRAYER	

8/2/2012	**,215/55**	2	85	Degerforsen	64,20573/19,69928	10/17/2012	car and handheld	STRAYER	
8/2/2012	**,234/55**	1	91	Bäckarforsen	64,40994/19,28415	10/17/2012	car and handheld	STRAYER	manual tracked w/in 35m. Gain 3. Good ADCP location
8/2/2012	**,254/55**	2	102	Renforsen	64,20711/19,96687	10/17/2012	car and handheld	native	
8/2/2012	**,285/55**	2	109	Above Renforsen	64,21902/19,70312	10/17/2012	car and handheld	native	manual track w/in 35m. Gain 3. Good ADCP location
8/2/2012	**,294/55**	1	93	between Renforsen and degerforsen	64,20711/19,96687	10/17/2012	car and handheld	native	
8/2/2012	**,303/55**	2	88	~300m below Storforsen	65,06440/18,37288	10/17/2012	car and handheld	native	manual tracked w/in 35m. Gain 3. Good ADCP location
7/6/2012	**,314/55**	1	91	below mardseleforsen, below f.b. ~200m	64,67889/19,24366	10/17/2012	car and handheld	native	manual track w/in 40m. Gain 3. Good ADCP location
8/2/2012	**,375/55**	2	100	Laxselet	65,25782/18,05199	10/17/2012	car and handheld	native	
8/2/2012	**,393/55**	1	82	Laxselet	65,26100/18,05282	10/17/2012	car and handheld	native	
8/2/2012	**,423/55**	2	81	Ekorrsele bridge	64,43920/19,22212	10/17/2012	car and handheld	native	manual track w/in 25m. Gain 2.5. Good ADCP location
8/2/2012	**,444/55**	2	85	Beukaforsen	65,25204/18,08939	10/17/2012	car and handheld	STRAYER	manual track w/in 35m. Gain 3. Good ADCP location
7/11/2012	**,453/30**	1	105	Above Renforsen	64,21954/19,70152	10/17/2012	car and handheld	native	manual track w/in 40m. Gain 3. Good ADCP location
7/6/2012	**,493/55**	2	83	below mardseleforsen, below f.b. ~250m	64,67872/19,24450	10/17/2012	car and handheld	native	manual track w/in 50m. Gain 3. Good ADCP location
8/7/2012	**,525/55**	1	95	~1km below linaforsen	64,93095/18,60268	10/17/2012	car and handheld	native	Manual tracked w/in 30m. Gain 3. Good ADCP location
8/7/2012	**,544/55**	2	78	1km above renforsen (rapid with lawn chair)	64.22315/19.70426	10/17/2012	car and handheld	native	manual track w/in 50m. Gain 3. Good ADCP location
8/7/2012	**,563/55**	2	75	Below Krokforsen ~300m	65,28177/17,88230	10/17/2012	car and handheld	native	manual track w/in 25m. Gain 2.5. Good ADCP location
8/7/2012	**,584/55**	1	80	Above Renforsen ~1km	64,22232/19,70354	10/17/2012	car and handheld	native	manual track w/in 50m. Gain 3. Good ADCP location
7/18/2012	**,603/30**	1	100	middle renforsen rapid	64,21159/19,70695	10/17/2012	car and handheld	native	
7/18/2012	**,623/30**	1	95	degerforsen	64,20380/19,69916	10/17/2012	car and handheld	native	
8/7/2012	**,653/55**	1	97	degerforsen	64,20380/19,69916	10/17/2012	car and handheld	native	
7/6/2012	**,223/30**	1	75	laxselet	65,25782/18,05199	10/21/2012	car and handheld	native	probably spawning
8/2/2012	**,234/55**	1	91	Bäckarforsen	64,40994/19,28415	10/21/2012	car and handheld	STRAYER	manual tracked w/in 35m. Gain 3. Good ADCP location
8/2/2012	**,245/55**	1	76	laxselet	65,25782/18,05199	10/21/2012	car and handheld	native	probably spawning
8/2/2012	**,254/55**	2	102	between Renforsen and Degerforsen	64,20735/19,70234	10/21/2012	car and handheld	native	probable spawning
8/2/2012	**,285/55**	2	109	Above Renforsen, pool above footbridge	64,21902/19,70312	10/21/2012	car and handheld	native	manual track w/in 35m. Gain 3. Good ADCP location
8/2/2012	**,294/55**	1	93	below lower br below vindeln	64,19897/19,70011	10/21/2012	car and handheld	native	moving down
8/2/2012	**,303/55**	2	88	~300m below storforsen	65,07394/18,34588	10/21/2012	car and handheld	native	Manual tracked w/in 30m. Gain 3. Good ADCP location
8/2/2012	**,362/55**	2	79	Bäckarforsen	64,42115/19,25896	10/21/2012	car and handheld	native	Manual tracked w/in 30m. Gain 3. Good ADCP location
8/2/2012	**,375/55**	2	100	Beukaforsen	65,25204/18,08939	10/21/2012	car and handheld	native	Manual tracked w/in 30m. Gain 3. Good ADCP location
8/2/2012	**,393/55**	1	82	Laxselet	65,26100/18,05282	10/21/2012	car and handheld	native	probable spawning
8/2/2012	**,423/55**	2	81	Ekkorrsele Br.	64,44555/19,21421	10/21/2012	car and handheld	native	manual track w/in 25m. Gain 2.5. Good ADCP location
8/2/2012	**,444/55**	2	85	Beukaforsen	65,25204/18,08939	10/21/2012	car and handheld	STRAYER	manual track w/in 35m. Gain 3. Good ADCP location
7/11/2012	**,453/30**	1	105	Above Renforsen	64,21954/19,70152	10/21/2012	car and handheld	native	manual track w/in 40m. Gain 3. Good ADCP location
8/2/2012	**,464/55**	2	82	above Ekkorrsele Br.	64,45218/19,21304	10/21/2012	car and handheld	native	moving down
8/2/2012	**,504/55**	1	89	below ståselforsen	65,20553/18,20889	10/21/2012	car and handheld	native	
8/7/2012	**,525/55**	1	95	~1km below linaforsen	64,93095/18,60268	10/21/2012	car and handheld	native	Manual tracked w/in 30m. Gain 3. Good ADCP location
7/18/2012	**,532/30**	1	81	just below Holmforsen	65,20395/18,21598	10/21/2012	car and handheld	native	probable spawning
8/7/2012	**,544/55**	2	78	1km above renforsen (rapid with lawn chair)	64,22159/19,70698	10/21/2012	car and handheld	native	manual track w/in 50m. Gain 3. Good ADCP location
8/7/2012	**,563/55**	2	75	Below sappetsele br.	65,25404/17,98599	10/21/2012	car and handheld	native	probably already spawned at Krokforsen, now down
8/7/2012	**,584/55**	1	80	~400m above Renforsen footbridge	64,22232/19,70354	10/21/2012	car and handheld	native	manual track w/in 50m. Gain 3. Good ADCP location
7/18/2012	**,603/30**	1	100	between Renforsen and Degerforsen	64,20717/19,69961	10/21/2012	car and handheld	native	probable spawning
7/18/2012	**,623/30**	1	95	below Degerforsen	64,20380/19,69916	10/21/2012	car and handheld	native	probable spawning
8/7/2012	**,624/55**	2	80	1.5 K below road junc. 370	65,24025/18,13037	10/21/2012	car and handheld	native	
7/18/2012	**,644/30**	2	82	just below Holmforsen	65,20395/18,21598	10/21/2012	car and handheld	native	probable spawning
8/21/2012	**,703/40**	2	85	Just above Åtjärnforsen	65,18618/18,23296	10/21/2012	car and handheld	STRAYER	
7/6/2012	**,223/30**	1	75	laxselet	65,25782/18,05199	10/24/2012	car and handheld	native	probable spawning, or done
8/2/2012	**,245/55**	1	76	laxselet	65,25782/18,05199	10/24/2012	car and handheld	native	probably spawning, or done
8/2/2012	**,303/55**	2	88	~300m below storforsen	65,07394/18,34588	10/24/2012	car and handheld	native	probable spawning, or done
8/2/2012	**,375/55**	2	100	Beukaforsen	65,25204/18,08939	10/24/2012	car and handheld	native	probable spawning, or done
8/2/2012	**,393/55**	1	82	Beukaforsen	65,25204/18,08939	10/24/2012	car and handheld	native	moving down
8/2/2012	**,444/55**	2	85	Beukaforsen	65,25204/18,08939	10/24/2012	car and handheld	native	ADCP measured today, but no substrate; too deep
8/2/2012	**,464/55**	2	82	just below linaforsen	64,93851/18,62453	10/24/2012	car and handheld	native	spawning
7/6/2012	**,493/55**	2	83	below mardseleforsen, below f.b. ~250m	64,67872/19,24450	10/24/2012	car and handheld	native	ADCP and Substrate measurements today
8/7/2012	**,563/55**	2	75	Below Krokforsen ~300m	65,28177/17,88230	10/25/2012	car and handheld	native	ADCP and substrate measurements today
8/2/2012	**,303/55**	2	88	~300m below storforsen	65,07435/18,34385	10/30/2012	car and handheld	native	ADCP and substrate measurements today
8/2/2012	**,423/55**	2	81	Ekkorrsele Br.	64,44427/19,21774	10/31/2012	car and handheld	native	ADCP and substrate measurements today
8/7/2012	**,525/55**	1	95	~1km below linaforsen	64,93109/18,60147	10/31/2012	car and handheld	native	substrate measurement today, ADCP malfuntion

8/2/2012	**,234/55**	1	91	Bäckarforsen	64,40994/19,28415	11/1/2012	car and handheld	STRAYER	ADCP and substrate measurements today
8/2/2012	**,285/55**	2	109	Above Renforsen, pool above footbridge	64,21902/19,70312	11/1/2012	car and handheld	native	ADCP and substrate measurements today
7/11/2012	**,453/30**	1	105	Above Renforsen	64,21954/19,70152	11/1/2012	car and handheld	native	ADCP and substrate measurements today
8/7/2012	**,544/55**	2	78	1km above renforsen (rapid with lawn chair)	64,22315/19,70426	11/1/2012	car and handheld	native	ADCP and substrate measurements today
8/7/2012	**,584/55**	1	80	~400m above Renforsen footbridge	64,22232/19,70354	11/1/2012	car and handheld	native	ADCP and substrate measurements today
8/2/2012	**,245/55**	1	76	~5km below grundfors	65,03058/18,42271	3/12/2013	car and handheld	native	kelts
8/2/2012	**,254/55**	2	102	just below Vindeln Br.	64,19934/19,69925	3/12/2013	car and handheld	native	kelts
8/2/2012	**,285/55**	2	109	Above Renforsen, pool above footbridge	64,21902/19,70312	3/12/2013	car and handheld	native	kelts
8/2/2012	**,344/55**	1	98	~2.5km below linaforsen	64,91956/18,62866	3/12/2013	car and handheld	native	kelts
8/2/2012	**,375/55**	2	100	Beukaforsen	65,24976/18,09859	3/12/2013	car and handheld	native	kelts
8/2/2012	**,423/55**	2	81	Ekkorrsele Br.	64,44555/19,21421	3/12/2013	car and handheld	native	kelts
8/2/2012	**,444/55**	2	85	just below Holmforsen	65,22714/18,17374	3/12/2013	car and handheld	STRAYER	kelts
7/11/2012	**,453/30**	1	105	Above Renforsen	64,21954/19,70152	3/12/2013	car and handheld	native	kelts
8/2/2012	**,464/55**	2	82	~2km below linaforsen	64,91956/18,62866	3/12/2013	car and handheld	native	kelts
7/6/2012	**,493/55**	2	83	below Mårdseleforsen ~1km	64,67061/19,25224	3/12/2013	car and handheld	native	kelts
8/7/2012	**,563/55**	2	75	Grundfors	65,06643/18,36921	3/12/2013	car and handheld	native	kelts
8/7/2012	**,594/55**	2	84	just above laxselet	65,25885/18,04478	3/12/2013	car and handheld	native	kelts
7/18/2012	**,644/30**	2	82	storgräsforsen	65,19376/18,22477	3/12/2013	car and handheld	native	kelts
7/6/2012	**,253/30**	1	77	Above Vormsele	64,91383/18,63865	4/2/2013	flight	native	kelts
8/2/2012	**,285/55**	2	109	SAL	64,21902/19,70312	4/2/2013	flight	native	kelts
8/2/2012	**,294/55**	1	93	Between Hemseleforsen and Vindeln	64,17594/19,69241	4/2/2013	flight	native	kelts
8/2/2012	**,354/55**	1	96	~ 2km above Ekkorrsele Br.	64,47193/19,20871	4/2/2013	flight	native	kelts
8/2/2012	**,375/55**	2	100	SAL	65,24976/18,09859	4/2/2013	flight	native	kelts
7/6/2012	**,382/30**	1	77	just above Hällnäs	64,31050/19,60101	4/2/2013	flight	STRAYER	kelts
8/2/2012	**,383/55**	1	96	Below mittiforsen, above Överrödå	64,14854/19,86193	4/2/2013	flight	native	kelts
8/2/2012	**,423/55**	2	81	SAL	64,44555/19,21421	4/2/2013	flight	native	kelts
8/2/2012	**,444/55**	2	85	SAL	65,22714/18,17374	4/2/2013	flight	STRAYER	kelts
8/2/2012	**,464/55**	2	82	SAL	64,92784/18,60517	4/2/2013	flight	native	kelts
7/18/2012	**,474/55**	1	96	below Strycksele	64,35716/19,44226	4/2/2013	flight	native	kelts
7/6/2012	**,493/55**	2	83	SAL	64,67061/19,25224	4/2/2013	flight	native	kelts
8/2/2012	**,504/55**	1	89	below Vindelgransele	65,09230/18,32047	4/2/2013	flight	native	kelts
8/7/2012	**,624/55**	2	80	Just below Forsholm	64,74232/19,10346	4/2/2013	flight	native	kelts
7/18/2012	**,644/30**	2	82	below holmfors ~4km	65,20820/18,20356	4/2/2013	flight	native	kelts
7/6/2012	**,253/30**	1	77	SAL Above Vormsele	64,91383/18,63865	4/24/2013	car and handheld	native	kelts
8/2/2012	**,254/55**	2	102	SAL just below Vindeln Br.	64,19934/19,69925	4/24/2013	car and handheld	native	kelts
8/2/2012	**,285/55**	2	109	SAL Above Renforsen, above footbridge	64,21902/19,70312	4/24/2013	car and handheld	native	kelts
8/2/2012	**,303/55**	2	88	Above Linaforsen	64,95137/18,59962	4/24/2013	car and handheld	native	kelts
8/2/2012	**,344/55**	1	98	SAL ~2.5km below linaforsen	64,91956/18,62866	4/24/2013	car and handheld	native	kelts
8/2/2012	**,375/55**	2	100	SAL Beukaforsen	65,24976/18,09859	4/24/2013	car and handheld	native	kelts
7/6/2012	**,382/30**	1	77	SAL just above Hällnäs	64,31050/19,60101	4/24/2013	car and handheld	STRAYER	kelts
8/2/2012	**,393/55**	1	82	Below Björksele	64,97415/18,56328	4/24/2013	car and handheld	native	kelts
8/2/2012	**,405/55**	2	112	SAL Just below Mattjokkbäcken	65,17085/18,24426	4/24/2013	car and handheld	native	kelts
8/2/2012	**,414/55**	1	81	SAL Above Vindelgransele	65,15379/18,25593	4/24/2013	car and handheld	native	kelts
8/2/2012	**,423/55**	2	81	SAL Ekkorrsele Br.	64,44555/19,21421	4/24/2013	car and handheld	native	kelts
8/2/2012	**,444/55**	2	85	SAL just below Holmforsen	65,22714/18,17374	4/24/2013	car and handheld	STRAYER	kelts
7/11/2012	**,453/30**	1	105	SAL Above Renforsen	64,21954/19,70152	4/24/2013	car and handheld	native	kelts
8/2/2012	**,464/55**	2	82	SAL ~2km below linaforsen	64,91956/18,62866	4/24/2013	car and handheld	native	kelts
7/6/2012	**,493/55**	2	83	SAL below Mårdseleforsen ~1km	64,67061/19,25224	4/24/2013	car and handheld	native	kelts
8/2/2012	**,504/55**	1	89	SAL below Vindelgransele	65,09230/18,32047	4/24/2013	car and handheld	native	kelts
7/18/2012	**,524/30**	2	114	Just below linaforsen	64,92773/18,60530	4/24/2013	car and handheld	native	kelts
7/18/2012	**,532/30**	1	81	SAL just below Holmforsen	65,20395/18,21598	4/24/2013	car and handheld	native	kelts
8/7/2012	**,563/55**	2	75	SAL Grundfors	65,06643/18,36921	4/24/2013	car and handheld	native	kelts
8/7/2012	**,584/55**	1	80	Below Hemseleforsen	64,16634/19,79554	4/24/2013	car and handheld	native	kelts
8/7/2012	**,624/55**	2	80	SAL Just below Forsholm	64,74232/19,10346	4/24/2013	car and handheld	native	kelts
8/7/2012	**,635/55**	1	77	Forsholm	64,77114/19,02840	4/24/2013	car and handheld	native	kelts
7/18/2012	**,644/30**	2	82	SAL storgräsforsen	65,19376/18,22477	4/24/2013	car and handheld	native	kelts
8/21/2012	**,703/40**	2	85	Just below Grundfors	65,05614/18,38526	4/24/2013	car and handheld	STRAYER	kelts

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2013:15 Effects of brown bear (*Ursus arctos*) odour on the patch choice and behaviour of different ungulate species.
Författare: Sonja Noell

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Författare: Eva Domingo Gómez

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Författare: Martin Johansson

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