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Effect of tunnel wash water on survival, growth and migration of Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) in river Årungselva

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Preface

This master thesis was written for the Department of Ecology and Natural Resource Management (INA) at the Norwegian University of Life Sciences (NMBU). This thesis is funded by the Norwegian Public Roads Administration (NPRA) and is part of a research and development program named “NORWAT” which is directed by the environmental section of NPRA. The goal of “NORWAT” is to gain knowledge about the pollution effect of the aquatic environment in order to plan, build and maintain roads without causing unacceptable harm to the aquatic environment.

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Abstract

Tunnel wash water is frequently released to the river Årungselva through a sedimentation pond. This tunnel wash water may cause harm to the fish through intrinsic and extrinsic toxic effects. A reduction in growth have previously been observed for 0+ brown trout at downstream locations of the sedimentation pond, where fish located below outlet point of the sedimentation pond had a 21 % lower length than fish located above the sedimentation pond. As no reduction in growth were observed prior to the establishment of the sedimentation pond, the author suggested that the reduced growth could be due to the toxic effect from the tunnel wash water. Since migration and density was not accounted for, it remains enigmatic whether the observed difference was solely due to the suggested toxic effect.

The aim of this study was to estimate differences in survival, growth and migration of Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) caught above and below the outlet point of the Vassum sedimentation pond in Årungselva.

The study was conducted using capture-mark-recapture methodology in combination with Passive Integrated Transponders (PIT) telemetry with two antennas. This set-up allowed for estimation of survival, individual growth and migration.

In total, 520 individuals were caught by electric fishing. Out of these, 253 individuals were PIT-tagged from which 75 were resighted at least once during the November 2014-October 2015 study period. The results show a lower size-adjusted survival in both species for individuals caught below the outlet point compared to those caught above the outlet point. Further, a lower length-at age among 0+ parr of brown trout and 1+ parr of Atlantic salmon, as well as lower length at first-winter for Atlantic salmon parr, were observed for below-individuals compared to above-individuals.

The reduced survival and growth rate observed in this study occur despite the fact that fish density is lower at below-sites of the outlet point of the sedimentation pond. Water chemistry variables generally did not vary between above and below sites, apart from chloride, sulphate and uranium that all attained higher below-values. However, other physiochemical variables that vary between above and below outlet point sites may influence growth and survival. In conclusion, fish at below-sites of the outlet point may experience a higher exposure to pollution due to the release of tunnel wash water based on these results.

Introduction

Run-off water from roads, tunnels and other impervious surfaces constitute a major contamination source for surface waters throughout the world, which severely affect fish populations (e.g. Feist et al 2011). Highway runoff and tunnel wash water contains several contaminants that can potentially be harmful to the aquatic environment. Because of several contaminants found in the wash water of highway and tunnel, it is most likely that the toxicity effect may have many biological effects caused by additional and/or synergistically interactions. Although, studies have shown wash water runoff from roads and tunnels to be highly polluted, the topic have received little public attention (Meland 2010). However, there have been many scientific studies about the toxic effect of highway runoff during recent years (Bækken 1994; Grapentine et al. 2008; Karlsson et al. 2010; Kayhanian et al. 2008; Maltby et al. 1995; Sriyaraj & Shutes 2001; Waara & Farm 2008), but most of these studies have not taken into account the toxicological responses on biological levels beyond the individual.

Fish are used as bioindicator for pollution monitoring as they are easy to measure in terms of abundance, diversity and behavior**.** In toxicological studies, fish have been the most frequently studied group of animal for many decades. This has contributed to a vast knowledge of toxicological effects on the environment, and toxic effect on physiological, biochemically and behavioral processes that are involved with contamination. (Markert et al. 2003).

Fish are unique in toxicological studies in the sense they take up xenobiotic trough both diet and from the water. These toxicological effects can often reveal sudden changes on a physiological and behavioral basis such as lowered swimming performance, equilibrium disturbances, avoidance/attraction behavior, changes in predator-prey relationship, etc. On a population basis, the effect of these changes can drastically reduce the number of individual in a short time period. On the other side, fish are able to recover very quickly from catastrophically events, and compared with lower aquatic organisms, they appear to be less sensitive to pollution. (Markert et al. 2003).

In general, fish are more applicable as bioindicator for evaluation of regional pollution effect rather than evaluation of localized pollution effect, owing to their higher mobility compared to other aquatic organisms (Attril & Depledge 1997; Gadzala-Kopciuch et al. 2004). This is an important consideration as organism that lives a more sedentary life reflect to a lesser degree the pollution effect in the local environment. Therefore, researchers must overweigh the utility of using a mobile or a sedentary species based on whether the pollution effect should be addressed on a regional or local scale (Attril & Depledge 1997).

Fish is an important resource for human, both commercially and recreationally, and because some fish species is directly linked to human welfare, any undesirable effect on fish population or community will be recognized. For instance, Atlantic salmon (*Salmo salar*) that migrates up the river is considered to be an ultimate indicator of clean water (Attril & Depledge 1997).

In general, few fish studies have compared toxicological effect on both lower (cellular level and individual level) and higher (population and community) biological levels. In many cases it is difficult to extrapolate toxic result on an individual basis to higher biological organization such as population and community level when taken into account the complex population and community dynamics, difference in time and concentration of exposure, and multiple other stressor (natural and anthropogenic stressors) acting on the fish (Spromberg &Birge 2005). Although there have been many studies on an individual level, these have been considered less ecological relevant than studies on population level (see review in Weis et al. (2001).

There is also a lack of studies concentrating on pollution effect in the natural environment, and only a few *in situ* studies that have been undertaken in recent years. For example, Coghlan & Ringler (2005) studied the effect of pollution on growth and survival of populations of Atlantic salmon (*Salmo salar*) in two rivers with different pollution gradients. A comparable study of within-stream variation in pollution effect on growth has also been conducted on brown trout (*Salmo trutta*) (Brotheridge 1998) and redbreast sunfish (*Lepomis auritus*) (Adams et al. 1992). In addition, *in situ* studies have also looked at pollution effect on survival and growth of embryonic development in brown trout (*Salmo salar*) (Luckenbach et al. 2001; Luckenbach et al. 2003). Such *in situ* studies of growth and survival effects in the field are few as most pollution-induced growth and survival effects have been limited to laboratory experiments.

There are many weaknesses in assessment of pollution effect in a laboratory setting. For instance, not all physical factors (pH, salinity, water hardness etc.) can be accounted for, and the variation in these factors that is occurring in the field is difficult to simulate in a laboratory experiment. These physical factors, and the variation of these physical factors, plays an important role when determining the toxic effect of pollution, physiological state, and the metabolic rate of the organism (Heugens 2001). Laboratory experiment does neither take into account the interaction between species and conspecifics in the environment, predator-prey relationship and density-dependent interactions that works in confluence with the pollution. The knowledge of these factors are essential for understanding the total impact of toxicity on population or community level (Preston 2002; Hansen et al. 2002).

Another weakness in many of these laboratory studies is that they do not take into account the long-term effect of pollution, and they often only examine one pollution stressor. In an *in situ* setting, individuals are being exposed to realistic level of pollution and during longer period. It is difficult to simulate this type of situation and conditions in a laboratory experiment as there are often many polluters that acts either synergistically, additionally or antagonistically (Marentette 2012; Preston 2002). Therefore, questions have been raised whether laboratory test should be abandon since its ecological relevance is not adequate to give a realistic result of how xenobiotics affect fish in a natural setting. Additionally, these laboratory experiments are more “intervening” than *in situ* studies, as fish in laboratory experiment are exposed to sublethal and lethal doses of xenobiotics (Dell’Omo 2002).

However, assessing information about changes in population and community structure in an *in situ* setting is not sensitive enough to detect pollution effect at an early pollution phase. When changes in population structure first have occurred, the pollution effect will already have done harm, as the effect of pollution on a higher biological level is the expression of the long-term effect of pollution on a lower level (Attril & Depledge 1997). From a toxicological viewpoint, the effect of pollution is expected to be observed first at a subcellular and cellular level before the effect will be transparent on an individual level. It is also expected to see individual changes in physiological and behavioral response before there are any evidence of pollution effect on a population and community level (Weis et al. 2001). It is important to remember that chances taking place on this level not necessarily constitute direct irreversible damage, but may be an expression of sublethal effects potentially leading to reduced growth, impairment of immune system and decreased reproductive capacity (Lawrence & Hemingway 2003). Another important notice is that physiological and biochemical responses to xenobiotics does not necessarily transcends to changes at higher biological level as there are many regulatory mechanisms that may counteract the pollution effects. Thus, fish from a contaminated and an uncontaminated site may be similar in body condition and size, even though fish from the contaminated site may suffer from physiological impairments (Heugens 2001; Marentette et al. 2012).

Another difficulty with *in situ* studies is to find out whether the population or the community will respond directly to the effect of contamination, or as a respond to an indirect effect through changes in density dependent and density independent processes. The pollution effect on these two processes are rather difficult to distinguish from each other when finding the total response of the pollution effect, and it is difficult to find out whether they will increase or decrease the toxicity of a given pollutant (Liess & Beketov 2011; Preston 2002). In many instances, these indirect effects of pollution can have a more negative effect on a population rather than the direct physiological, physical or behavioral effect of pollution (Dell'Omo 2002; Preston 2002). For example, toxicological effects on density dependent process have the potential of changing the competition among species or conspecifics directly, or indirectly through changes in the amount of available prey species. Toxicological effect has also potential of changing density independent processes within river, but it is difficult to find out whether it is the environmental condition that will make the organism more sensitive to the toxicant effect, or whether it is the toxicant effect that will make the organism more sensitive to physical stress from the environment. Thus, attempting to link pollutant effect to density dependent and density-independent processes through several trophic level becomes difficult, as these interactions are rather complex in the aquatic system (Dell'Omo 2002; Heugens et al. 2001).

In addition to the indirect effect that will either increase or decrease the pollutant effect, the pollution effect will vary on a seasonal basis through fluctuation in water temperature, water discharge and food availability etc. These seasonal variations in environmental factors will also change the condition of the fish that may change the pollutant effect. For instance, lower fat and general calorie of Atlantic salmon and brown trout (*Salmo trutta*) during winter makes them more vulnerable to adverse effect from the environment during this time of the year. Under such circumstances, pollution that are otherwise considered sublethal can suddenly become lethal (Berg & Bremset 1998). In spring-summer when there is an abundance of food, a higher food intake could increase the uptake of the chemical and/or it could increase the detoxifying process in the body of the fish. Higher temperature in spring-summer period will also have an effect on bioavailability of xenobiotics, as it affects the toxicokinetic of xenobiotic in several organs (Heugens 2001). In addition to temporal variation in toxic effect, reduction in suitable habitat condition due to spatial variation in pollution could lead to density dependent effect on growth and survival in unaffected areas (Svecevičius 1999).

Toxicological effect can impose great energetic costs, as fish often have to respond to the pollution by initiating compensatory processes that have a great metabolic expenditure (Barton 2002; Lawrence & Hemingway 2003). Allocation of energy to these processes comes at the expense of other processes that relates to somatic growth. Other toxic effects that can be linked to reduction in growth is reduction in food digestion (Berntssen et al. 1999), food availability

(Coghlan and Ringler, 2005), reduced food consumption (Lett et al. 1976), social interaction (Sloman et al. 2002), swimming performance and circadian rhythm (Campbell 2005) and altered behavior related to changes in the chemosensory system (Dell'Omo 2002). Additionally, there are certain polluters that can affect growth through raised metabolic cost associated with reduced oxygen carrying capacity of blood, and reduced oxygen uptake through physiological and/or structural damage on the gill (Little & Finger 1990; Waiwood & Beamish 1978). All of these sublethal effects on growth can translate into effect on survival if the energy reserves are depleted. However, if the fish lives in a benign environment with abundant of food and space available, the overall effect could become less severe as the fish would then have sufficient energy reserves to allow the energetic cost of compensatory processes (Beyers et al. 1999).

As pollution is involved in so many physiological and behavioral processes in the organism, it has a generalized effect on the energetic balance of the fish. Reduction in growth has been used as bioindicator for pollution stress by linking physiological and behavioral responses to the organism's energy budget. Growth rate comparison have also often been used to measure the energetic cost of pollution stressors (see review in Hansen et al. (2002) and Lawrence & Hemingway (2003)).

Growth rate and size are important factors that determines life history characteristic of individuals which influence, age and size at smolting and maturation, survival rate, longevity, egg size, fecundity, competitive ability and reproductive success (Jonsson & Jonsson 2011). Good growth rate and greater fish size have been linked to decreased risk of mortality to predation and improved foraging behavior, while reduced growth rate have been linked to parasitism and disease and increased mortality during period of stress (see review: Jenkins et al. (1999)). An early experience of reduced growth rate can reduce the survival rate and affect life history traits later in life, such as time of maturing and smolting. Particularly, the decrease in growth of parr during their first growing season can have a great negative effect on survival later during winter (see review: Jonsson & Jonsson 2011).

The river Årungselva in southeastern Norway (Figure 1) is subjected to major input from road runoff water as well as tunnel wash water from no less than three tunnels. Ecotoxicological studies have been conducted on fish in Årungselva. Meland (2010) used blood plasma, gill and liver sample to provide evidence of contamination and sublethal effect on brown trout in Årungselva. The fish was exposed to tunnel wash water in a water tank and was measured for various biomarkers such as metal accumulation in gills, hematological parameters and hepatic gene expression. The result revealed both a higher concentration of trace metals in gills and liver compared to control fish. Consequently, they had higher activity of the antioxidant defense system indicated by higher level of stress protein such as superoxide dismutase (SOD), catalase (CAT) and metallothionein (MT). Exposure to tunnel wash water also contributed to an accumulation of metals on the gills, which gave a short-term effect in blood plasma with a higher concentration of Cl^- and Na^+ and an increase in the level of glucose. Although concentration of the chemicals in the tunnel wash water was high in the experimental study of Meland (2010), there were no mortality observed during and after the experiment, and there was no difference in condition factor observed between control and exposed fish.

Dybwad (2015) studied the effect of tunnel wash water on brown trout in Årungselva, looking at the transcription of mRNA of a selected set of genes in gills and liver of brown trout both inhabiting above and below location of the outlet point. When comparing fish living above and below the outlet point, there were few differences in transcription of genes. However, the level of transcription was higher in the fish sampled in the above location. For example, a higher transcription level of CYP1A was observed for fish above outlet point.

Skarsjø (2015) did a similar physiological biomarker study, but found no higher level of CYP1A, and neither higher EROD activity in the gills. However, Skarsjø (2015) did find a higher biliary concentration of PAH (1-OH-phenanthrene and 1-OH-pyrene) and higher EROD activity in liver from brown trout located above outlet point. The contamination of PAH's was also apparent in fish exposed to tunnel wash water in a laboratory setting where uptake of three-rings PAH's were continuously high during 25 days of exposure. In addition, juvenile brown trout from laboratory and field sampling were also investigated for bioavailable lead, but there was no biomarker response for either (Skarsjø 2015).

Both Skarsjø (2015) and Dybwad (2015) could not find any differences in contamination level of brown trout above and below outlet point, suggesting that both fish above and below the outlet point are exposed to similar level of pollution. Therefore, another pollution pattern may be suggested other than pollution exposure only from the tunnel wash water. Both authors propose that the result could reflect an exposure to continuous pollution deriving from runoff water from roads in surrounding areas.

In order to provide a linkage between the physiological effects of contamination with the physical effects on growth Meland et al. (2010) measured the length of 0+ parr above and below location of the outlet point. The result revealed that 0+ individuals below the outlet point were 21 % shorter than individuals above the outlet point. Such discrepancy in growth between upper and lower river site was not reported before establishment of the tunnels and sedimentation pond. There was neither any difference in number of captured fish, suggesting that density dependent effect is less likely to be responsible for the observed growth reduction. As there is no other anthropogenic input between the upper and lower site, Meland (2010) suggest that this result could reflect the long-term effect on fish growth by exposure of chemical components from the Vassum sedimentation pond and runoff from nearby roads.

In the Meland (2010) study, recording of migration between site above and below the outlet point of Vassum was not conducted, nor was analyzation of habitat quality and water quality assessed – and the study was only restricted to 0+ brown trout. In my study, I will conduct an *in situ* experiment that investigate the findings of Meland (2010) further by looking at these aforementioned variables. I will include both Atlantics salmon and brown trout for estimation of both survival and growth effects on sites above and below the outlet point of Vassum sedimentation pond.

The objective of this study is to compare (i) survival, growth and migration of juvenile Atlantic salmon and brown trout above and below a sedimentation pond (Vassum) outlet point, (ii) measure population size for stations above and below outlet point, (iii) estimate the effect of total fish length, temperature, water discharge on survival and migration, (iv) estimate the effect of physicochemical habitat on survival and migration between station above and below outlet point through habitat characterization, and water sampling.

I hypothesize that the release of pollution to Årungselva from the Vassum sedimentation pond will impose a lower survival and growth rate for fish located below the outlet point relative to fish located above, and that the release of pollution will work as a migration barrier for fish residing above and below the outlet point.

Materials and Methods

Study area

The small river Årungselva runs from Lake Årungen and into the fjord Bunnefjorden (Figure 1). The stream is approximately 2.5 km in length and drains an area of 52 km^2. The water discharge varies from 0 m^3 s^{-1} to 25 m^{3}s^{-1} throughout the year, where the highest discharge rates occurring in the flooding periods of autumn and spring. There can be periods of drought during July and August, where large segments of the stream can be dried out. The lowest section of the stream is supplied with groundwater, thus preventing these areas from completely drying out during this time of the year (Borgstøm & Heggenes 1988).

Figure 1: Map of Oslofjorden with specific study area marked with blue circle. Top right: Overview map of Norway with Oslofjorden marked in blue circle.

In the middle course of the river, tunnel wash water is released from a sedimentation pond into the stream through a drainpipe. This sedimentation pond (Vassum) receives tunnel wash water from the Nordby tunnel, Smiehagen tunnel and Vassum tunnel (Figure 2). As these three tunnels are each washed four times per year, the sedimentation pond will receive wash water every month. Subsequently, the wash water from the sedimentation pond is discharged into Årungselva when the sedimentation pond is full. In addition to wash water discharge from the sedimentation pond, Årungselva will receive runoff from road constructions in surrounding areas.

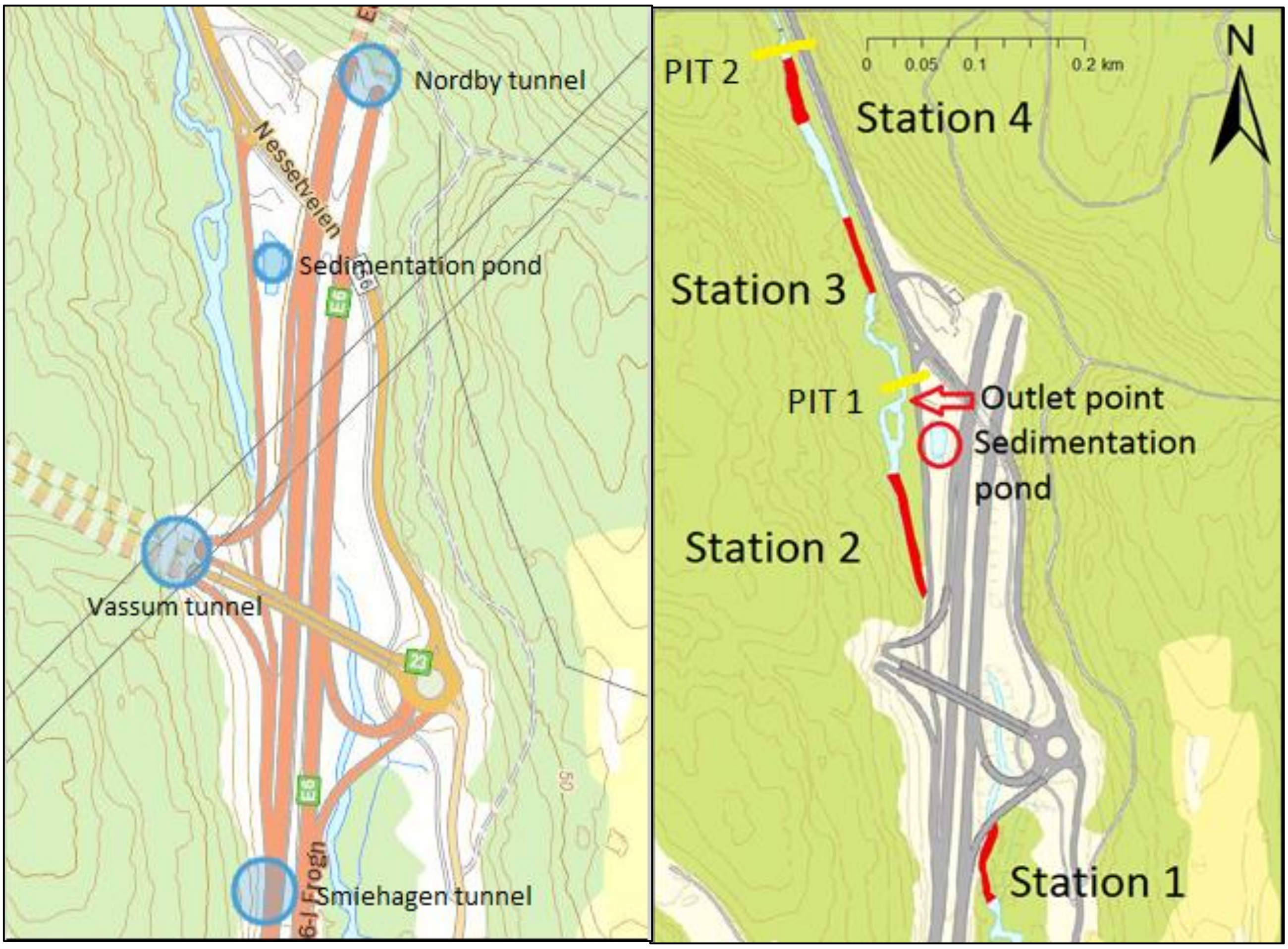


Figure 2: Left map: Blue rings presents the location of tunnels that undergoes tunnel wash treatment. Right map: the selected stations for *in situ* study with outlet point marked with an arrow, and PIT antennas marked in yellow line.

Sampling of fish was conducted in four different stations; two stations above (station 1 and 2) and two stations below (station 3 and 4) the outlet point of Vassum sedimentation pond (Figure 2). Electrofishing were performed regularly on each station for fish sampling. All stations measured 50 meter in river length.

Study species: Atlantic salmon and brown trout in smaller streams

Sympatric Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) overlaps in habitat use in streams (Heggenes et al. 1995, 1996). Brown trout is competitively and morphological different from the Atlantic salmon, which is an important factor why these two species partially occupy different stream microhabitats (Jonsson & Jonsson 2011). Brown trout is the most aggressive and dominant specie and is therefore best abled to occupy the most suitable habitat and maintain a higher growth in rivers. Thus, brown trout determines the niche width of Atlantic salmon in rivers, where Atlantic salmon have a more restricted use of habitat in the presence of the more aggressive brown trout (Van Zwol et al. 2012).

In larger rivers, the spatial use between parr of Atlantic salmon and brown trout differ according to water depth. Brown trout parr occupy shallow areas along the marginal areas of the river, while the larger adult individuals prefer to stay in the deeper pools with low water velocity. However, in smaller rivers the spatial selection according to water depth is different. In smaller rivers where the habitat along the stream transect is less complex in depth, brown trout parr will use the whole cross-section of the stream, while parr of Atlantic salmon will occupy areas of intermediate water depth and will not move into the deeper pools. These deeper pools are usually occupied by larger brown trout that are more competitive. Thus, parr of sympatric Atlantic salmon have a narrower niche selection towards water depth in small rivers than in larger rivers (Heggenes et al. 1999, Jonsson & Jonsson 2011). For example, in larger river the range of water depth used by Atlantic salmon parr can reach 3 m, while in smaller rivers parr do not stay in water depths above 40 cm when brown trout is present (see review in Heggenes (1999)). Beside water depth - bed substratum, shelter availability and water velocity will also have an influence on the spatial distribution of Atlantic salmon and brown trout in small rivers (Bremset & Berg 1999).

Particularly in shallow water in small rivers, interspecific competition between Atlantic salmon and brown trout can restrict the habitat use of Atlantic salmon. Both the species can be restrained in growth and survival because the increased competition will reduce feeding rate of the fish while having additional metabolic cost of defending territories (Jonsson & Jonsson 2011). In addition to the costs from interspecific competition, intraspecific competition will affect growth and survival within each species. Whether the intraspecific competition will affect growth or survival will depend according to the density of the population. At lower population densities, density dependent processes will act on the individual growth most likely due to increased exploitative competition. At higher population densities, interference competition due to limited space is more likely to influence mortality and the emigration rate within a population (Jenkins et al. 1999, Imre et al. 2005; Bohlin et al. 2002; Lobón-Cerviá and Mortensen 2006)

Both Atlantic salmon and brown trout undergo a metamorphosis called smolt, a physiological transformation process that prepare the fish for sea migration. Physiological transformation processes that takes place during smolting include morphological characteristics, salinity tolerance, buoyancy, metabolism, visual pigments, and behavior. These changes in physiology and behavior prepare the smolt for downstream migration and a life in the sea. At what age the parr decide to undertake smoltification depend on size and previous growth. In general, fast-growing individuals tends to smolt at an earlier age than slow growing parr. Additionally, there is population-differences in time of smolting related to genetic adaptation to the environmental condition (Jonsson & Jonsson 2011).

Within populations of Atlantic salmon and brown trout there can be both anadromous and non-anadromous individuals. However, Atlantic salmon have a stronger tendency towards anadromy than brown trout. These variations in life strategy within populations relates to juvenile growth rate and environmental condition, and is an example of phenotypic plasticity (Jonsson and Jonsson 1993; Klemetsen et al. 2003). Individuals that mature at parr-stage are non-anadromous individuals that stay in the river until spawning. This type of life history strategy is most common in populations where the opportunity for sneak fertilization is good. The non-anadromous life history pattern is either temporarily or permanent depending on specie. In Atlantic salmon, mature parr are only temporarily non-anadromous as they smolt and moves to the sea after spawning. In contrast, mature parr of brown trout remains stationary after spawning (Jonsson & Jonsson 2011).

Capture and handling of the fish

In this study I used a portable backpack electrofishing apparatus (Steinar Paulsen: 1983 FA2 No. 7, 700/1400 volt, 35-70 Hz, pulsed-DC). The catchability is affected by various environmental factors (Bohlin et al. 1989, Borgstrøm and Qvenild 2000) and fish species (Bohlin et al. 1989). The catchability will also depend on the size of the fish were likelihood for capture increase exponentially with the size of the fish (Bohlin et al. 1989). It is also possible that the recent captured fish is easier to recapture and that catch probability can be due to individual differences in behavior (Bohlin & Sundström 1977; Forseth & Forsgren 2009). Electrofishing is usually operated in smaller rivers where water depth and discharge does not pose any restrictions on fish catchability (Bohlin et al. 1989).

Electric fishing was performed by at least two persons – the fisherman and one assistance. The fisherman (person equipped with the electric fishing-apparatus) walks in front and perform regularly electroshock in intervals of 5-10 seconds, while the assistance walks behind carrying a black 1-liter bucket were the captured fish is stored. The assistant has to make sure that the water in the bucket is renewed frequently so that the fish will not experience shortage of oxygen and/or temperature stress. This is especially important during the warmest months in summer.

We walked upwards the stream in a meandering line in every station in order to cover the whole area. When the fish was caught within the electromagnetic field it reached a narcotic condition. Usually fish responds with random swimming at the lowest voltage gradient when positioned in the periphery of the electromagnetic field. When the fish is in closer proximity to the anode, the voltage gradient will increase and the fish will suddenly change behavior and start to move towards the anode (positive electro taxis) (Bohlin et al. 1989). At closer distance to the anode, the fish will go into a sleep state, what is called “electronarcosis” (Sternin et al. 1972). The fish is then caught by a hand net. Both the fisherman and the assistant are equipped with hand net to capture the electroshocked fish (Figure 3).

Figure 3: Electrofishing conducted at station 3 in winter at lower water discharges. A handhold net is held close to the anode to capture any stunned fish.

After capture, the fish was anesthetized by benzocaine before analyzing and tagging procedure. The benzocaine was mixed in a 10 L bucket of water in proper concentration (5 – 7 ml pr. 10 L of water) and the fish was kept in the bucket until the fish was considered sedated (no response when gently pressing the caudal peduncle). The fish was first length measured using a measuring board and determined by specie and life stage (parr, pre-smolt, smolt, mature). The length was measured in mm precision from the snout to the tip end of the tail (total length), and the determination of species and life stage was done visually. Additionally, individuals larger than 12cm were scale- sampled for subsequent determination of age and growth trajectory. The scales were sampled by carefully pulling them off with the non-edged side of the scalpel blade in the area above the lateral line between the adipose and the dorsal fin (Devries & Frie 1996; Jonsson 1976). The scales were stored and dried in small envelopes on which information about tag code, date of capture/recapture, and station number the individual was captured.

An ethanol-disinfected PIT tag was injected in the body cavity of the fish, right beneath the dorsal fin (

Figure 4). By placing the PIT tag in the body cavity of the fish the weight of the tag will be placed on the center of gravity of the fish (Bridger & Booth 2003). A scalpel was used to incise the skin and the tag was injected without the use of a tag injector. The smaller fish (<12cm) were injected with a 12 mm tag (HDX ISO 11784/11785), while the larger fish was injected with a 23 mm tag (ISO 11784/11785 compatible, Oregon RFID). The 23 mm PIT tag was restricted to individuals above 12 cm in order to avoid harm to internal organs and disturbance of swimming equilibrium and swimming performance (Acolas et al. 2007; Larsen et al. 2013; Ombredane et al. 1998). After tagging, I identified the injected tag with a handheld HDX/FDX reader (Oregon RFID Datatracer reader, http://www.oregonrfid.com) that displays the 12-digit numerical code of the tag. This devise was also used to identify recaptured individuals.

In total, six sampling round was carried out in this study (from 28.11.2014 to 27.10.2015) (Appendix Table 11), and a total of 253 individuals were caught and tagged.

Figure 4: A 23 mm tag PIT tag injected to the body cavity of the fish.

PIT telemetry

Two “swim through loop” antennas were mounted next to each other right below the outlet of Vassum sedimentation pond (Figure 5). A “swim through loop” antenna is an antenna that encircles the river vertically with the upper part of the antenna loop lying some centimeters above the watershed and where the lower part of the looped antenna is bolstered along the streambed (Kroglund et al. 2012**)**. The antennas were positioned in proximity to each other in order to observe whether the fish was migrating upstream or downstream from the outlet. The direction of movement is possible to record by observing the time differentiation of passage between the two antennas. The antenna also enabled me to observe whether migration was affected by the frequent release of tunnel wash water from the sedimentation pond and/or were affected by other environmental factors such as water temperature or water discharge. In addition to the antennas mounted at the outlet point, a third “swim through loop” antenna was mounted on the downstream end of station 4 (Figure 6). This antenna was mounted here primarily to observe the time of migration of smolt in the spring.

Figure 5: PIT antenna 1, mounted right below the outlet point.

Figure 6: PIT antenna 2, mounted on the downstream end of station 4

The PIT antennas were connected to individual antenna reader boxes (TIRIS RI-CTL MB2A; Oregon RFID, USA) via remote tuner boards. The reader was charged with energy from an external battery (110Ah 12V battery ATM battery), which supply and generate electric current through the antenna to produce an electromagnetic field. The reader identifies the PIT tag when it passes through the antenna coil. The tag is activated when the electromagnetic field induces energy to the cobber coil of the tag. This energy is used to transmit radio frequent energy back to the reader. The reader is able to decode this radio frequency into an alphanumerical code that is unique to each tag. The data is stored on a program that gives information about the tag code, identification number of the coil, time and date (Downing et al. 2001; Gibbons & Andrews 2004; Zydlewski et al. 2006).

The external battery had to be replaced and recharged weekly during winter-spring period. In summer and autumn period, we used a solar panel to recharge the battery.

In order to read data from the antenna reader, I connected a lap top to the reader and used the program "Telnet" to transfer data from the reader to the lap top. The reader provides information about the tag code of the passed individual along with date and time of the passage.

As the detection efficiency of the antenna varies with the hydraulic and general environmental conditions, it is important to take into account these characteristics when considering the detection efficiency of the antenna (Burnett et al. 2013; Castro-Santos et al. 1996). The hydraulic conditions interfering with the antenna is particularly related to water depth (Zydlewski et al. 2006). In this study, the upper and lower antennas were mounted on different water depths. The upper antenna was mounted in deeper waters where the distance from the bottom to the surface antenna loop measured 1.4 m. The lower antenna was positioned right before a run section and the distance from the bottom to the surface antenna loop measured 0.8 m.

Scale sampling for age- and growth-determination

The circullii (growth rings) on the sampled scales were used to determine growth and age of the individuals (Figure 7). The wider and narrow circullii on the scale represent the growth in summer and winter, respectively. The last winter circullus was used as a "check" for the transition between winter and summer growth. Growth was back-calculated using the distance from the focus of the scale to the outer layer of the scale as a measurement of total growth rate. Additionally, measurement of the distance from the focus to each completed year of life was used to find growth rate for each year of life. The back calculation of growth is made possible as the growth rate of the scale represents the growth rate of the fish. A low fish growth rate will be reflected by short-distance growth of circullii, while high fish growth rate will be represented by wide-distance growth of circullii on the scale (Borgstrøm 2000).

Close-up picture of scales was taken with a stereomicroscope (Leica S8APO) with a built-in camera (Leica DFC 320). Program "Image pro express 6.3" were used to measure and calculate growth on the basis of scale picture.

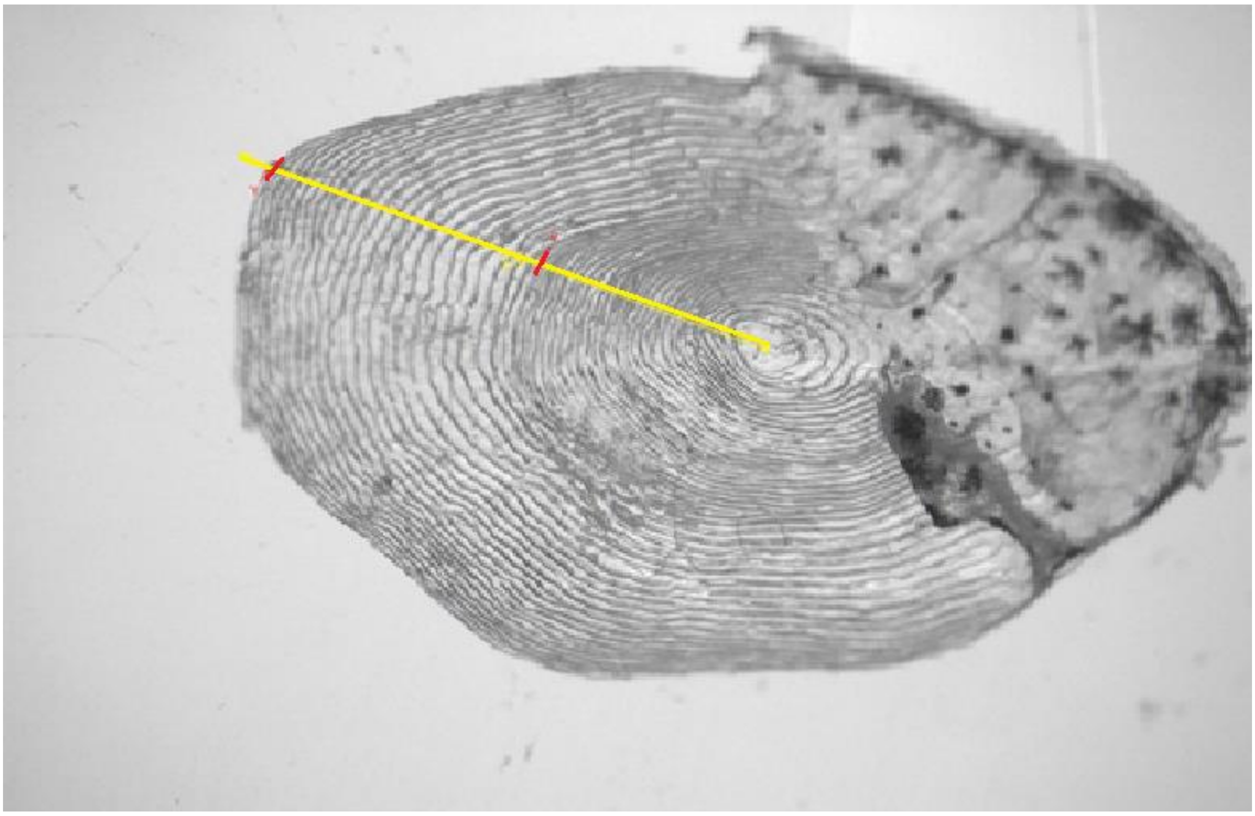


Figure 7: Image of a scale of 1+ Atlantic salmon caught in August, with a total length of 19 cm. The yellow line represents the longest axe of the scale, from the focus to the end of the scale. The red lines crossing the yellow line marks the winter zone. Growth was back-calculated using the distance of the longest axe of the scale as a measurement of total growth rate.

Fish density

In order to keep stress at a minimum, density was measured utilizing a one-pass sampling strategy. Fish density for each station was calculated on the basis of number of captured individuals in all capture round, divided by the area of the station (river length*average width of five transects)

Water sampling, CTD and loggers

Water samples were taken above and below the outlet point. All water samples were sent for analyzation to Rambøll Analytics in Lahti, Finland. Several different anion and cation metals were measured (Appendix Table 13-17).

Water temperature (°C) and discharge (measured as pressure, kPa) was measured using a Hobo water level logger (U20L-04) that was placed at station 4 (Appendix**,** Figure 21-22). The logger measured both variables once per hour.

Different physiochemical variables (turbidity, water temperature, conductivity, oxygen saturation) were measured with a EXO2 CTD-sonde (https://www.ysi.com/EXO2; Appendix**, (**Figure 22-25)

Habitat characteristics

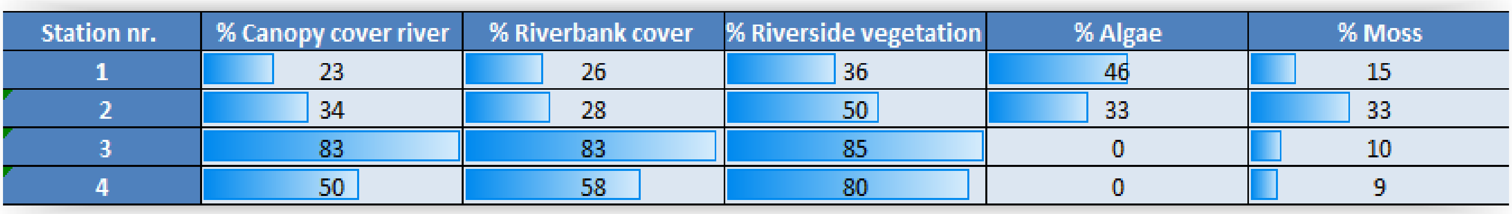
I took into account the hydrophysiological conditions and quality of habitat for the different stations and compared these with each other to find any differences or common denominators in water depth, water velocity, substrate and vegetation cover.

The mean river width and depth is higher for station 4 than for all the other stations (Table 2). The lower water velocity on this station reflects this. Station 1 have the highest number of pools with still water >2m^2, however pools in station 4 are of greater size, and makes up a larger proportion of the river area. Although number of riffles was not counted for in this assessment, it should be mentioned that station 1 have a higher amount of riffled areas compared to the other stations.

Station 3 and 4 have a higher percentage of overhanging vegetation (canopy cover) over the river, providing shaded conditions (Table 1)**.** This is reflected by the lower percentage of algae and moss growing on bed substratum and riverbank rocks**.** Although overhanging vegetation is substantial for station 3 and 4, number of woody debris (trunks or branches lying in the water with diameter >10 cm and with length >1 m**,**) is much larger in station 4. These woody debris form natural impoundments and eddies in the river.

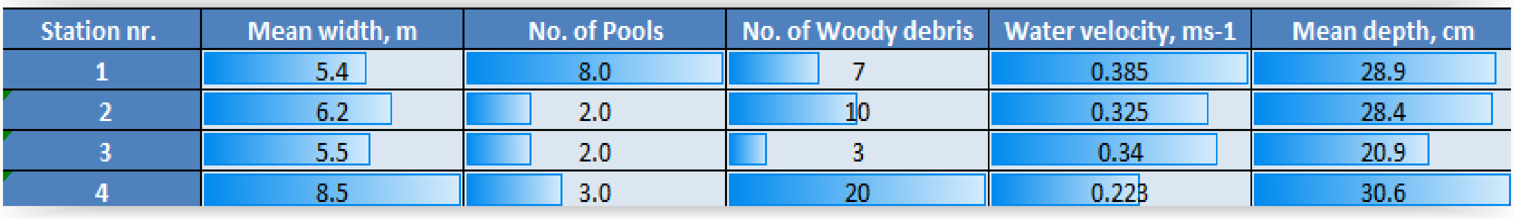
There is a higher proportion of substrate with coarse size >250 mm on stations 1 and 2 (above location)(Table 3, Figure 8). Percentage of cobbles with coarse size between 100 – 250 mm does not seems do differ significantly between station 1, 2 and 3. In station 4, the stream consists mostly of slow flowing area and the substrate is dominated by fine-grained particles (0 – 2 mm). However, there are some areas on station 4 with scattered distribution of larger rocks and boulders (>250 mm substrate). In station 3, larger rocks and boulder are absent, and substrate consist mostly of pebbles (20-100 mm) and cobbles (100-250 mm)

Table 1:Canopy cover= percent cover of branches across the river, Riverbank cover= percent cover of branches over the riverbank, Riverside vegetation=percent cover of branches over the riverbank, Algae= percent cover of algae on the



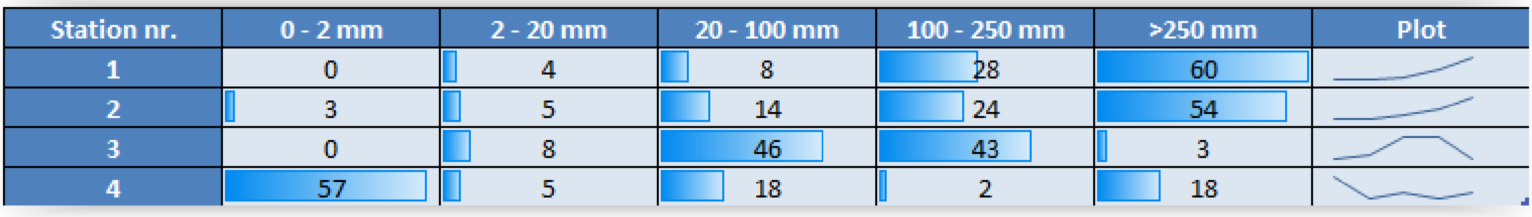
Station nr.	% Canopy cover river	% Riverbank cover	% Riverside vegetation	% Algae	% Moss
1	23	26	36	46	15
2	34	28	50	33	33
3	83	83	85	0	10
4	50	58	80	0	9

Table 2: Mean width = average width of five transect, No. of Pools = number of pools with still water >2m², No. of Woody debris= branches with diameter >10 cm and length >1m, Mean depth= average depth of five points along a transect



Station nr.	Mean width, m	No. of Pools	No. of Woody debris	Water velocity, ms-1	Mean depth, cm
1	5.4	8.0	7	0.385	28.9
2	6.2	2.0	10	0.325	28.4
3	5.5	2.0	3	0.34	20.9
4	8.5	3.0	20	0.223	30.6

Table 3: Substrate composition: substratum were categorized and given a percentage after how much they constitute of the total substrate for each station



Station nr.	0 - 2 mm	2 - 20 mm	20 - 100 mm	100 - 250 mm	>250 mm	Plot
1	0	4	8	28	60	
2	3	5	14	24	54	
3	0	8	46	43	3	
4	57	5	18	2	18	

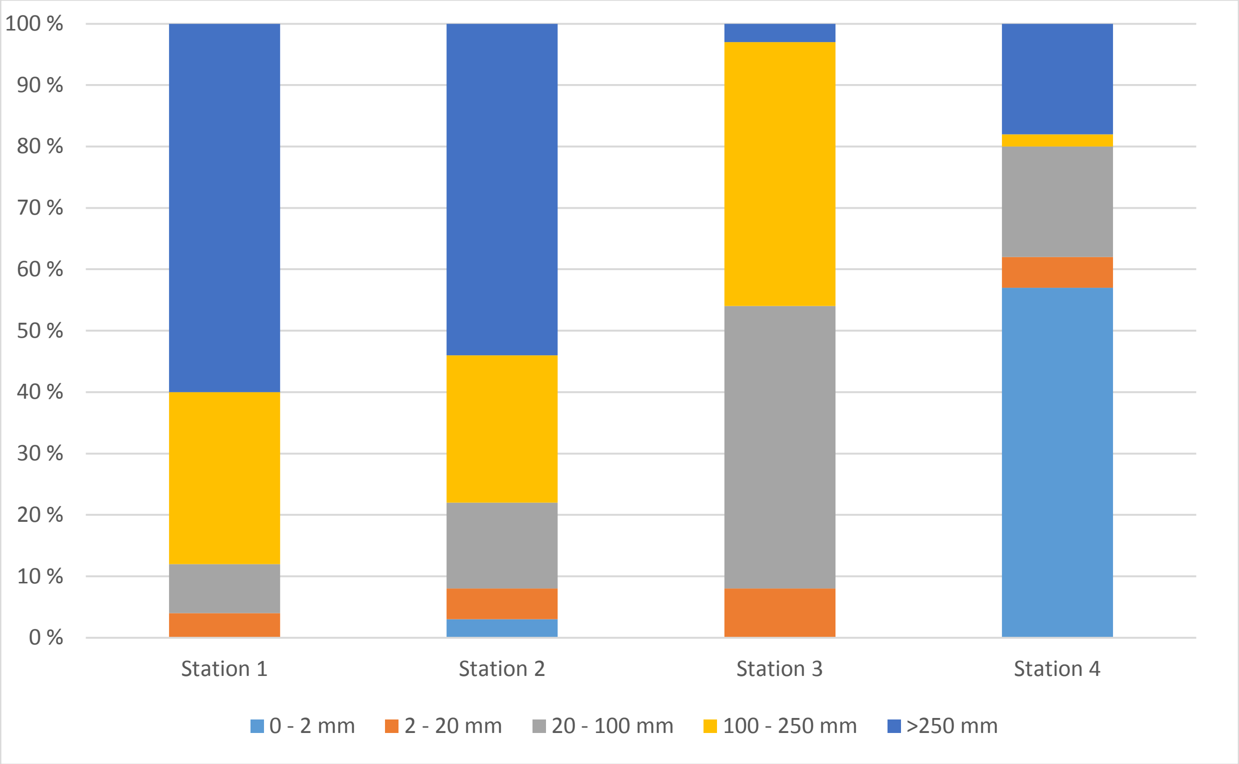


Figure 8: Distribution of substratum with different grain size for each station. A substantially higher percentage of particles with larger grain size (>250 mm) were observed in stations 1 and 2 (stations at above location). At station 4, fine-grained particles with grain size between 0 – 2 mm dominated the bed substratum.

Quantitative analyses

Capture-mark-recapture analysis

Mark-recapture data were analyzed in MARK, version 8.0 (White & Burnham 1999). Because there were no inter-station migrations in this study, except for smolt migration, I had to reject the multistrata analysis approach (e.g., Conditional Arnason-Schwartz) - which the study was originally designed for. Instead, data were organized and analyzed according to a simpler live recapture data structure: the Cormack-Jolly-Seber model (CJS; Cormack 1964; Jolly 1965; Lebreton et al. 1992; Seber 1965). The CJS model is based on likelihood estimation of recapture probabilities (p) and “apparent survival” probabilities (φ). The survival is labelled as “apparent” as non-migrated individuals not detected in the study area will be estimated as mortalities. For individuals where emigration can be accounted for, information outside migration event can be right censored to include data about aliveness until the emigration event. This was done for individuals that migrated as smolt in spring. This information was retrieved from the PIT antennas. Individuals capture history were constructed based on information from tagging and recapture obtained from both registration of electric fish sampling round and detection from PIT antennas (Figure 9). The parametrization embedded species and above/below as grouping effects

A CJS analysis is conducted based on individual capture histories that comprise an array of 1s and 0s, one number for each sampling occasion. A “1” denotes that the individual has been recaptured at a given occasion and a “0” that it was not recaptured. Under the assumptions that all capture histories are independent and individuals within a group (e.g., age group and/or station) behave similarly probabilities for recapture and apparent survival can be estimated at given occasions/periods using the maximum log likelihood method (Lebreton et al. 1992).

Parameters were fitted using the maximum log likelihood method. All parameters can in theory be estimated as being constant over all occasions/periods or time dependent. In addition, and more ecologically relevant, the parameters can be estimated as functions of covariates of interest. These covariates can both be occasion-specific (e.g., density, water discharge) and individual-specific (e.g., size). The most supported model structure was selected based on AICc (Burnham and Anderson 1998).

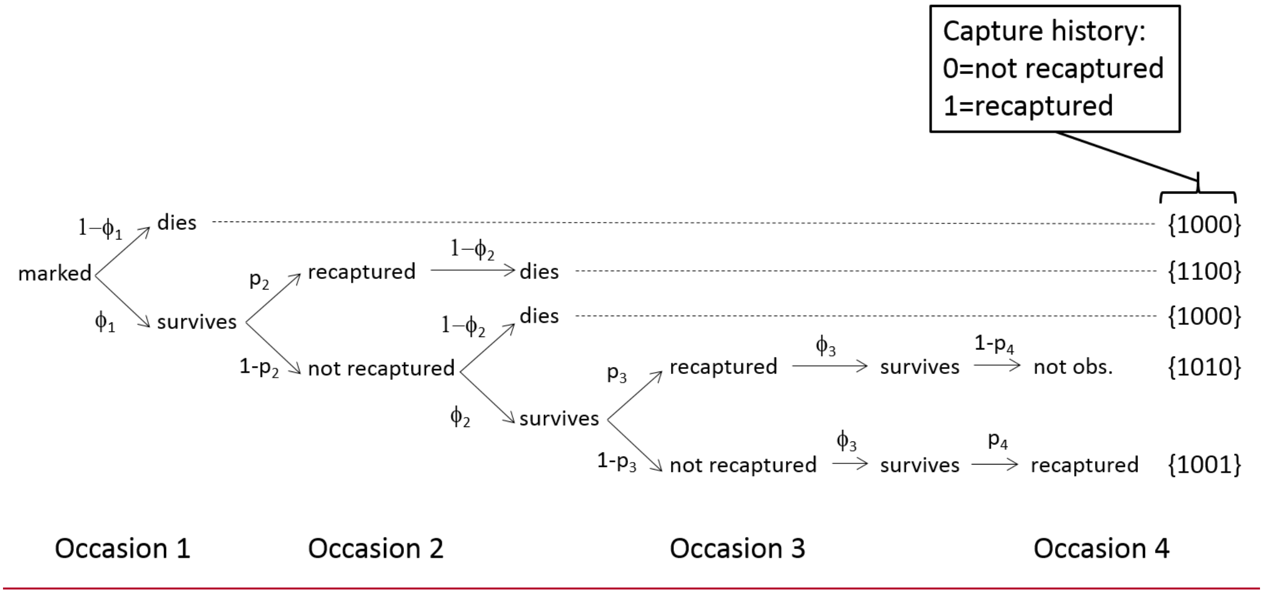


Figure 9: CJS-based fate diagram for five individuals with different fates and their corresponding capture histories. φ is apparent survival and p is recapture probability.

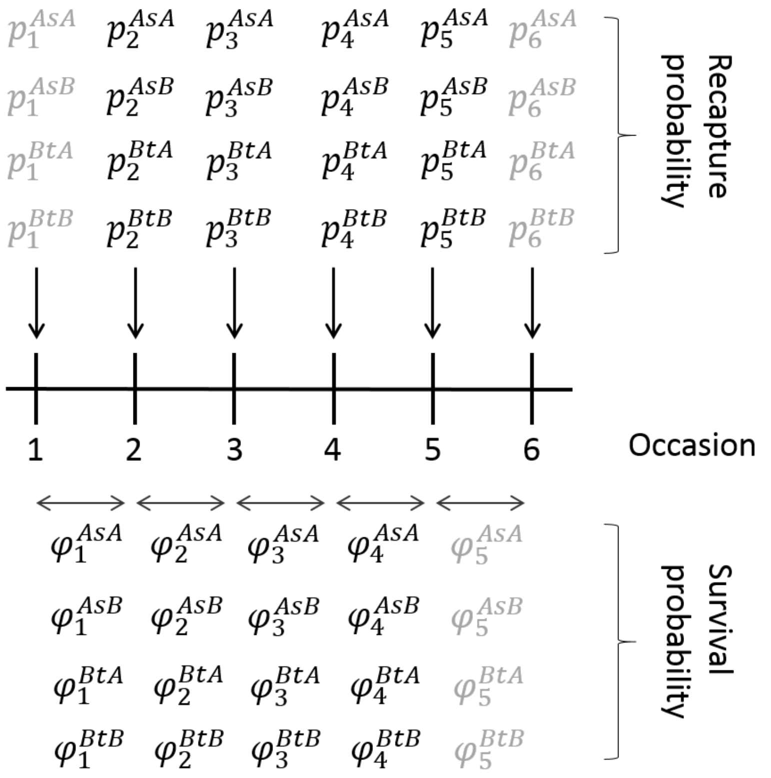


Figure 10: Parametrization of a fully time and group dependent CJS-model pertinent to this study. In total, 40 parameters can be estimated in theory. The p1-parameters cannot be estimated due to lack of necessary preceding capture information. The last-occasion parameters of both ϕ and p cannot be estimated separately since separation of capture probability from mortality will need future information about aliveness (i.e., no recapture can result both from mortality as well as no recapture despite alive). Instead, the product between the two parameters is estimated. Parameters in grey colour indicate not (separable) estimable. Up-right letters indicate group (e.g., AsA=Atlantic salmon Above; BtB=Brown trout Below).

Statistical analyses

Comparisons of first-year growth, first winter back-calculated length and growth increment of recaptures between upstream and downstream individuals were performed using generalized linear models with corresponding analysis of variance (McCullagh & Nelder 1989). These analyses were performed using the glm procedure in R, version 3.2.1 (R Develoment Core Team, 2015). Model selection was based on Akiake's Information Criterion (Akaike 1974). The 10 models with the lowest AIC-value were selected and further treated in program R, version 3.2.1 (R Development Core Team 2015)

Results

Length distribution

In total, 520 individuals were (re)captured in river Årungselva. Total (re)capture between each species were 249 and 271 individuals of Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*), respectively (Appendix, Table S1).

The length distributions of Atlantic salmon and brown trout were divided into capture rounds (Figure 11). Capture in winter (capture round 2) consisted mostly of 1+ and 2+ individual of Atlantic salmon and 1+individuals of brown trout. Capture of 0+ individuals of Atlantic salmon and brown trout did not occur until capture round 4 (August), while few individuals of 1+ brown trout were captured during this round and the successive rounds. Capture of 1+ individuals of Atlantic salmon occurs in all capture rounds. The length of both 0+ parr of Atlantic salmon and 0+ parr of brown trout from capture round 4 to capture round 6 (August – October) does not increase substantially towards autumn period. There were few large individuals of brown trout captured across capture round 4 – 6 that were mostly mature parr that remained stationary in the river.

In general, there were few captures of both species in winter-spring period (capture round 1-3), and a substantially higher number of captured individuals in summer-autumn period (capture round 4 – 6).

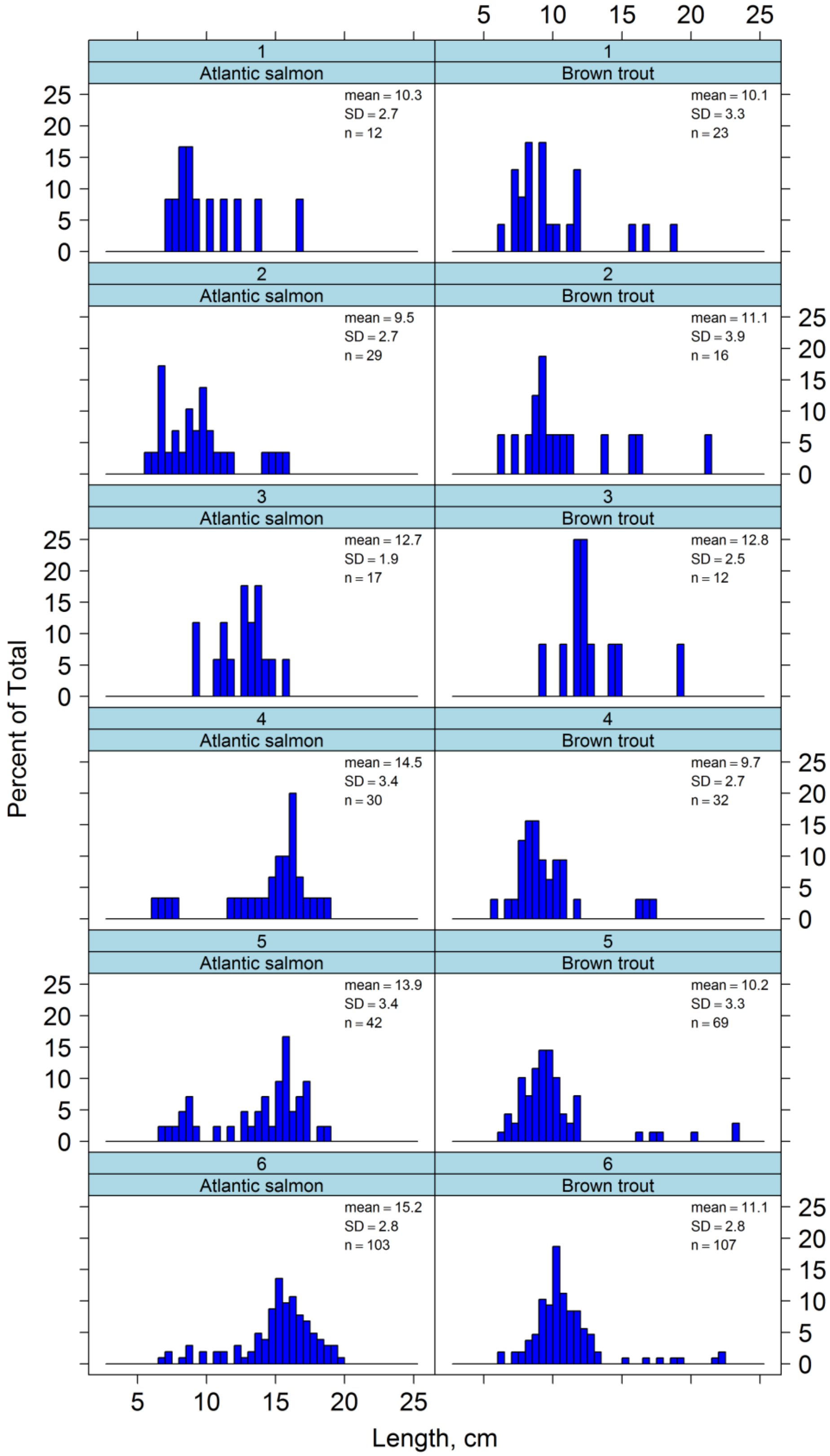
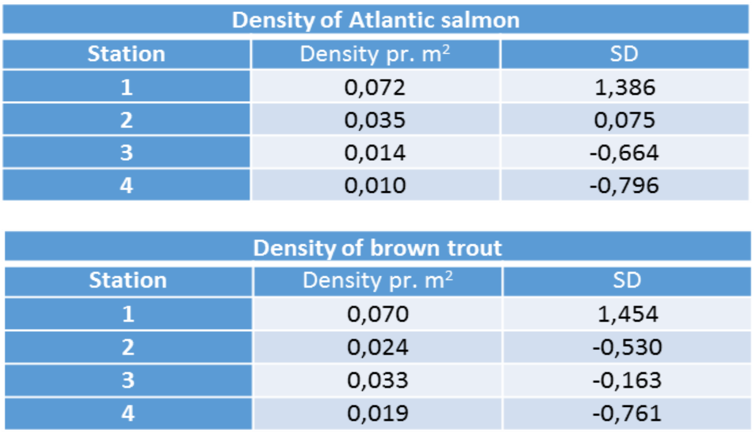


Figure 11: Histogram showing round specific lengths given in percentage of total capture for the respective capture rounds. Round and species are displayed in figure headers. A higher number of captured individual was obtained in capture round 4 to capture round 6 (August – October).

Fish density

A substantially higher density of both Atlantic salmon and brown trout were obtained for station above (station 1 and 2) compared to stations below the outlet point (station 3 and 4) (Table 4). In general, the number of captured individuals for both species decrease downstream the river. Station 4, located below outlet point, had a substantially lower density of fish than any other stations.

Table 4: Density for each species between stations were obtained using a one-pass sampling strategy. Fish density follows a downstream trend, where density of both Atlantic salmon and brown trout decrease downwards the river from station 1(upper) to station 4 (lower).



Density of Atlantic salmon		
Station	Density pr. m^2	SD
1	0,072	1,386
2	0,035	0,075
3	0,014	-0,664
4	0,010	-0,796

Density of brown trout		
Station	Density pr. m^2	SD
1	0,070	1,454
2	0,024	-0,530
3	0,033	-0,163
4	0,019	-0,761

Recapture probability

In total, 253 individuals were PIT tagged after six capture events, whereof 75 individuals were resighted.

Recapture was most parsimoniously modeled with above-below outlet point effect, and varied according to fish total length and capture rounds (Table 5). Recapture probability was negatively correlated with fish total length above and below outlet point during capture round 2 (January-Mars) and capture round 4 (May-August) (Figure 12). Recapture probability was positively correlated with fish total length above and below outlet point in round 3 (Mars-May). In capture round 5 and 6, there was a weaker correlation between recapture probability and fish total length compared to capture round 3.

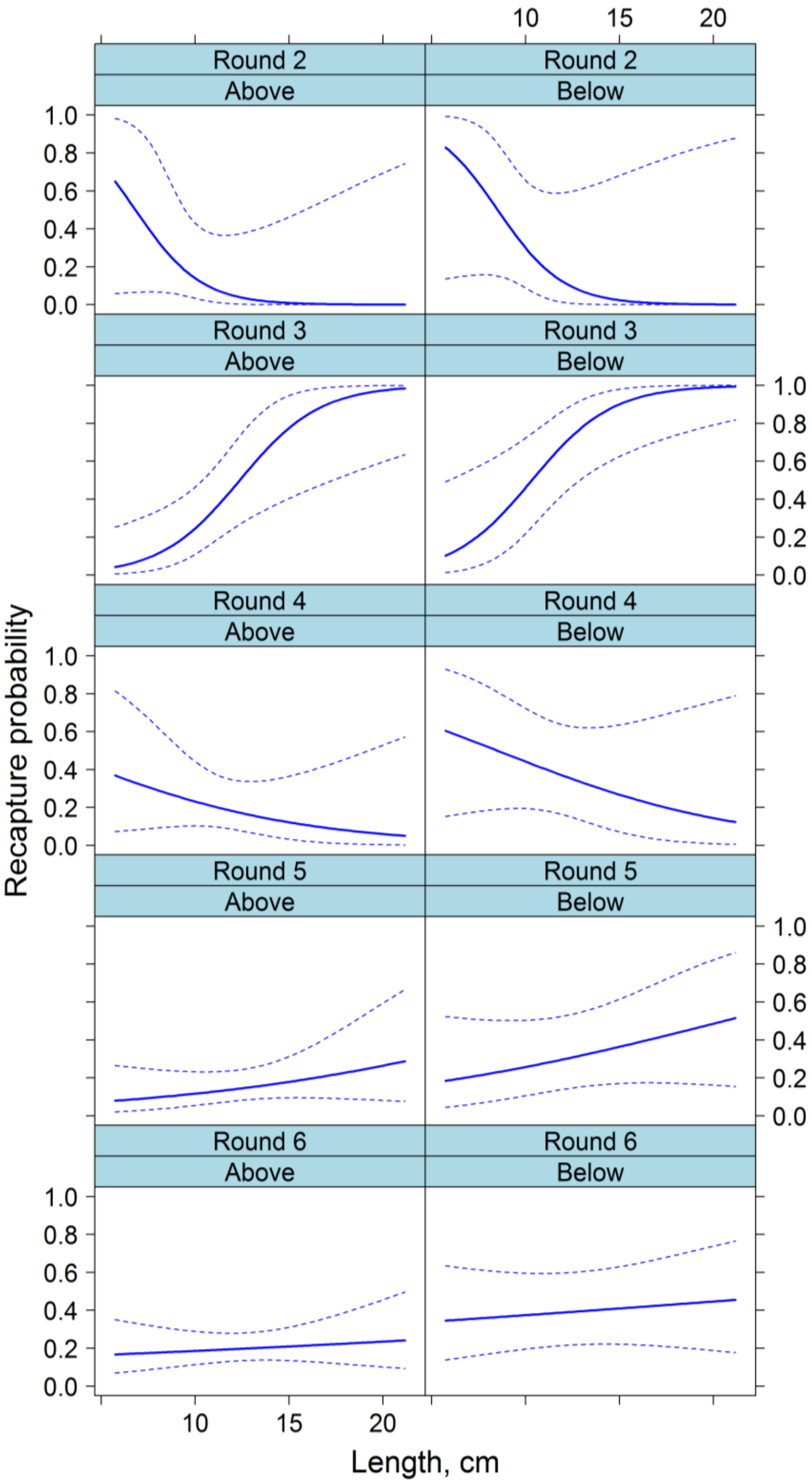


Figure 12: Predicted recapture probability for both brown trout and Atlantic salmon for each capture round as a function of fish total length. Estimates were retrieved from the most supported CJS model displayed in Table 5. Rounds and above-below location are displayed in figure headers. Recapture probability increase with decreasing length for capture round 2 and capture round 4. In capture round 3, recapture probability increase with the length of the fish. In capture round 5 and 6. there is a weak correlation between recapture probability and fish length. Dashed lines represent 95 % confidence bounds

Monthly survival probability

According to the most supported CJS model (Table 5 and Table 6), there was a high support for above and below (treatment) differentiation in length-specific monthly survival for both Atlantic salmon and brown trout. Survival probability decreased with decreasing total length for both fish above and below outlet point, but survival probability was lowest for the smaller individual at stations below outlet point. Survivorship for the smallest fish is close to 60 % and 50 % for station above and below outlet point, respectively. Increase in survival probability with increasing fish total length was most significant for fish above outlet point, presented by a steeper curve. However, confidence intervals for monthly survival is large. At stations above, fish reach 100% survivorship when they have reached length >15cm, while fish below do not reach 100% survivorship until they have reached a length >20 cm.

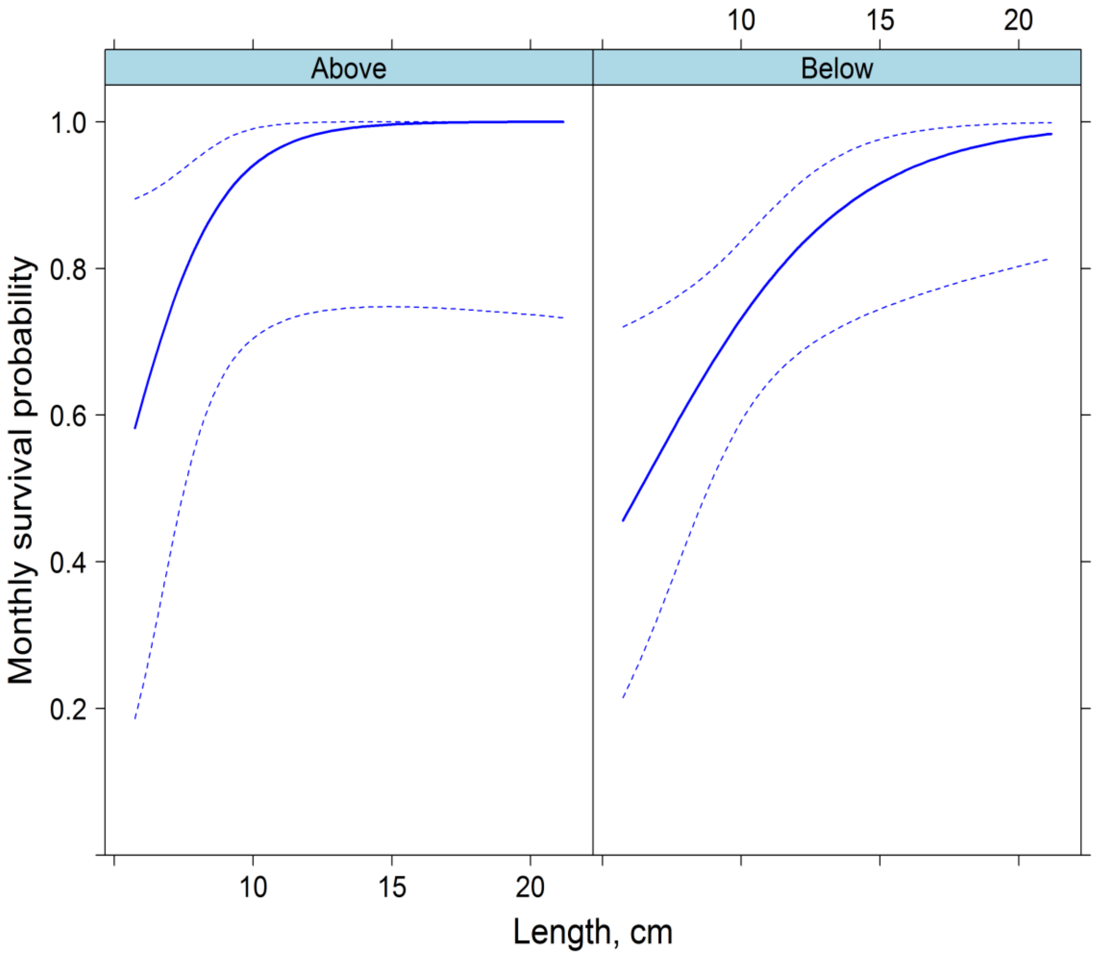


Figure 13: Monthly survival probability as a function of fish total length. Survival correlates with fish size, where survivorship increase more with fish total length at above location, represented by a steeper curve. Survivorship is lower for the smallest fish at below location, represented by a greater downward curve. Dashed lines represent 95 % confidence bounds.

Table 5: Model selection table for the ten most supported Cormack-Jolly-Seber models that had the lowest AICc values. Treatment=above and below effect on survival and recapture probability, round=capture round, season=winter, summer and autumn, Num. par=number of parameters estimated.

Model	**AICc**	**Delta AICc**	**AICc Weights**	**Model Likelihood**	**Num. Par**	**Deviance**
{phi(treatment*length)p(treatment+round*length)}	434.4511	0	0.871	1	15	402.6733
{phi(treatment+season*length)p(treatment+round*length)}	440.1363	5.6852	0.05076	0.0583	18	401.5745
{phi(treatment+length)p(treatment+round*length)}	442.8854	8.4343	0.01284	0.0147	15	411.1077
{phi(treatment*round*length)p(treatment*length)}	442.9043	8.4532	0.01272	0.0146	13	415.5661
{phi(treatment*length)p(treatment*length)}	442.9917	8.5406	0.01217	0.014	8	426.4718
{phi(treatment+season*length)p(treatment*length)}	444.1135	9.6624	0.00695	0.008	11	421.15
{phi(specie*length)p(treatment+sason*length)}	444.3578	9.9067	0.00615	0.0071	11	421.3943
{phi(season+treatment*length)p(treatment+length)}	444.469	10.0179	0.00582	0.0067	7	430.0662
{phi(treatment*length)p(treatment+season*length)}	444.7191	10.268	0.00513	0.0059	11	421.7556
{phi(treatment+season*length)p(treatment*length)}	444.8141	10.363	0.00489	0.0056	11	421.8506

Table 6 logit parameter estimates for the most supported CJS model as shown in Table 5. φ survival probability, p=recapture probability.

Parameter	coefficient	Estimate	SE	LCI	UCI
φ	Intercept	1.5574405	0.4052499	0.7631507	2.3517304
φ	length	2.3425252	1.5123237	-0.6216294	5.3066798
p	length*round	0.9963622	0.4130029	0.1868765	1.8058479
p	length*round	1.0548577	1.1768346	-1.2517382	3.3614536
p	length*round	-1.9901266	1.2013135	-4.3447011	0.3644479
p	length*round	-0.965125	0.4458804	-1.8390506	-0.0911994
p	length*round	2.7767528	1.2842977	0.2595293	5.2939762
p	length*round	1.4480044	1.2842099	-1.069047	3.9650558
p	length*round	1.1312019	1.25485	-1.3283042	3.590708
p	length*round	1.5361257	1.232996	-0.8805465	3.9527979
p	length*round	-2.0548549	1.4499608	-4.8967781	0.7870683
p	length*round	1.7000343	0.6339156	0.4575596	2.9425089
p	length*round	-0.557171	0.5866323	-1.7069703	0.5926282
p	length*round	0.3606777	0.326084	-0.2784469	0.9998023
p	length*round	0.1071165	0.2279242	-0.339615	0.553848

Migration

In total, 184 individuals were PIT tagged after six capture events (76 individuals of Atlantic salmon and 108 individuals of brown trout).

There was no spatial movement among stationary individuals above and below the outlet point during the study period, i.e. no detection of stationary individuals at PIT antenna 1. At PIT antenna 2, only two stationary individuals (719440, 719448) were detected (Appendix, Table S1). However, both PIT antennas were able to detect smolt individuals that migrated to the sea during spring. In total, 18 smolt were detected on antenna 2 (Table 7). The average length of these individuals were 14.23 cm at capture date and most of the migration occurred in month of May

(Figure 14). All individuals detected on the PIT antennas was injected with a 23 mm PIT tag. Average temperature and water pressure during the migration period was 10.6 °C and 105.9 kPa, respectively.

Table 7:Migration dates at which the individual was detected on PIT antenna 2. Station=station at which the individual was captured and tagged, ID=tag number, BT=brown trout, AS=Atlantic salmon, Length=length at capture date.

Tagging station	Capture date	ID	Specie	Length	Migration date
1	16.03.2015	40708	Brown trout	13.7	01.06.2015
2	09.01.2015	1684173	Brown trout	16.9	02.05.2015
1	16.03.2015	40707	Atlantic salmon	12	09.05.2015
1	16.03.2015	40709	Atlantic salmon	15.8	10.05.2015
3	17.02.2015	1684833	Brown trout	12	07.05.2015
3	17.02.2015	40700	Atlantic salmon	12.4	04.05.2015
3	17.02.2015	40702	Brown trout	15.9	12.05.2015
3	17.02.2015	40703	Atlantic salmon	16.6	29.04.2015
4	16.03.2015	40704	Brown trout	11.5	17.05.2015
3	16.03.2015	40710	Atlantic salmon	15.3	23.05.2015
3	16.03.2015	40714	Atlantic salmon	14.2	29.04.2015
3	16.03.2015	40712	Brown trout	15.9	29.04.2015
3	16.03.2015	40706	Atlantic salmon	14.7	01.05.2015

3	16.03.2015	40713	Brown trout	16.5	06.05.2015
1	16.03.2015	40707	Atlantic salmon	12	10.05.2015
1	16.03.2015	40709	Atlantic salmon	15.8	11.05.2015
1	28.11.2014	40744	Atlantic salmon	13.7	12.05.2015
1	28.11.2014	40743	Atlantic salmon	11.3	13.05.2015

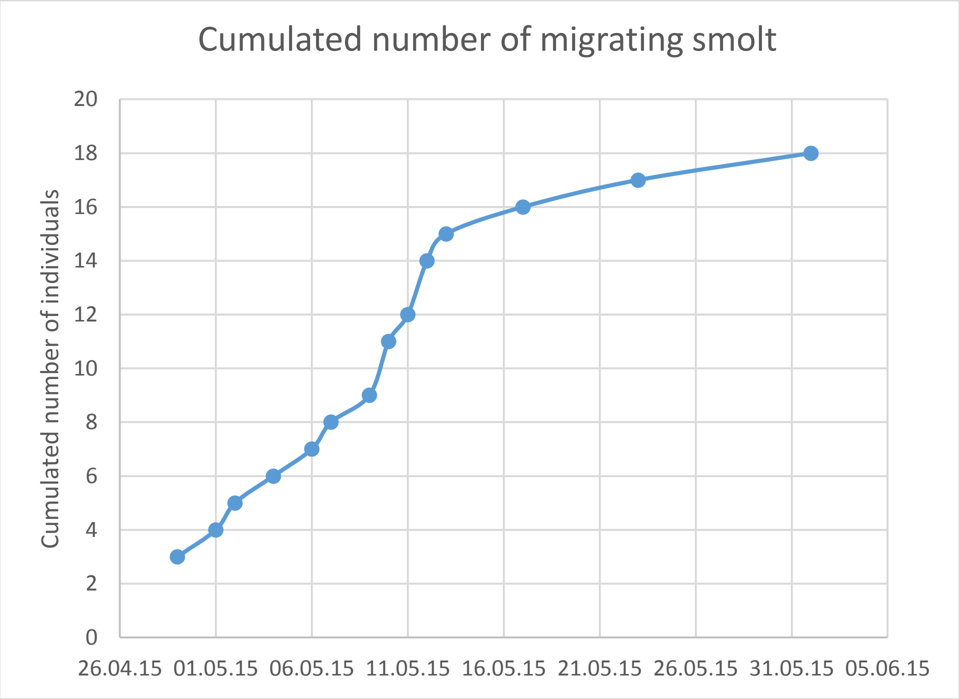


Figure 14: The graph show the cumulated number of individuals detected on PIT antenna 2 within late April to early June. Most of the migrated smolt were detected at mid-May.

Differences in length-at-age

Length-at-age in fish above outlet point increased more in total length between capture events. For brown trout 0+ parr, lengths were larger for individuals located above the outlet point across capture round 4 to capture round 6 (August – October), revealed as an additive effect in the fitted linear model (Table 8, Figure 15). For Atlantic salmon 1+ parr, length increased across round 4 to 6 as well (Table 9, Figure 16). However, individual length of 1+ parr of Atlantic salmon for stations below outlet point increase more from capture round 4 to capture round 6 than individuals at above location. Thus, there is only marginally differences in length between individuals above and below outlet point at capture round 6.

In this study, there were too few captured individuals of 0+ Atlantic salmon to statistically analyze.

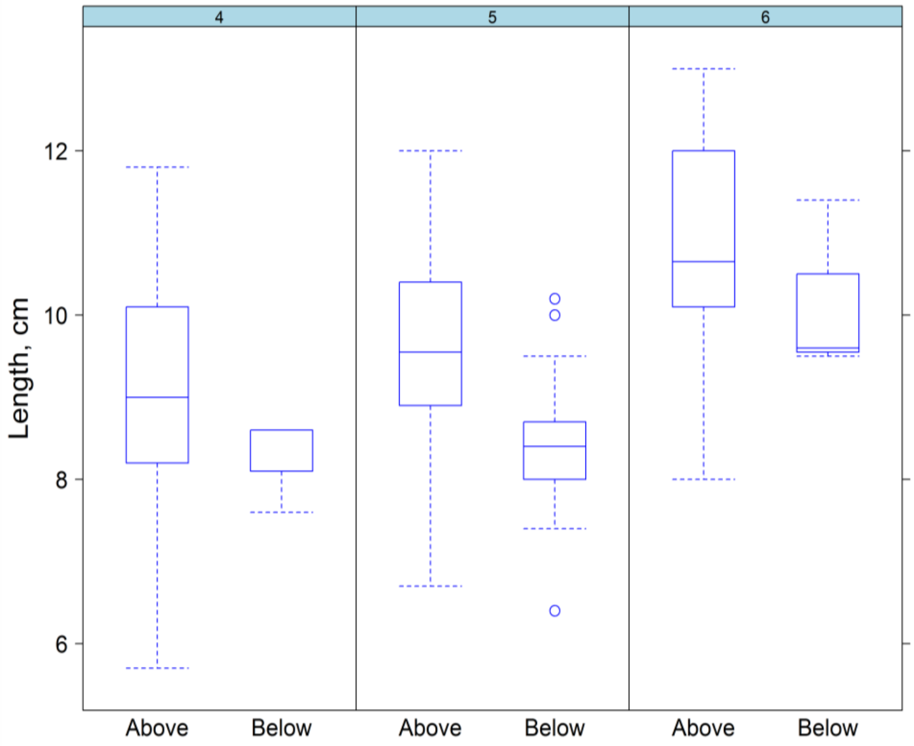
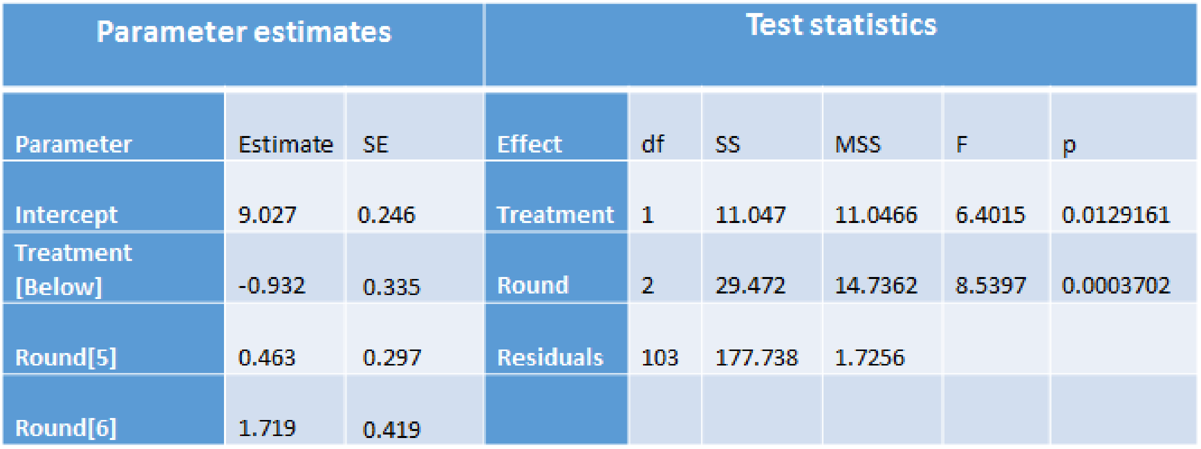


Figure 15: Round-wise length distributions of 0+ parr of brown trout above and below outlet point.. Rounds are displayed in figure panel headers. Boxes entails 50 % of the observations; horizontal lines within the boxes represents the medians; whisker represents the 10th and 90th percentiles; the circles outside the whiskers represents the outliers.

Table 8: Length at 0+ analysis of brown trout: parameter estimates and corresponding anova results for the most supported model. Effect levels are provided in square brackets and default level (intercept) constitute stations above



Parameter estimates			Test statistics					
Parameter	Estimate	SE	Effect	df	SS	MSS	F	p
Intercept	9.027	0.246	Treatment	1	11.047	11.0466	6.4015	0.0129161
Treatment [Below]	-0.932	0.335	Round	2	29.472	14.7362	8.5397	0.0003702
Round[5]	0.463	0.297	Residuals	103	177.738	1.7256		
Round[6]	1.719	0.419						

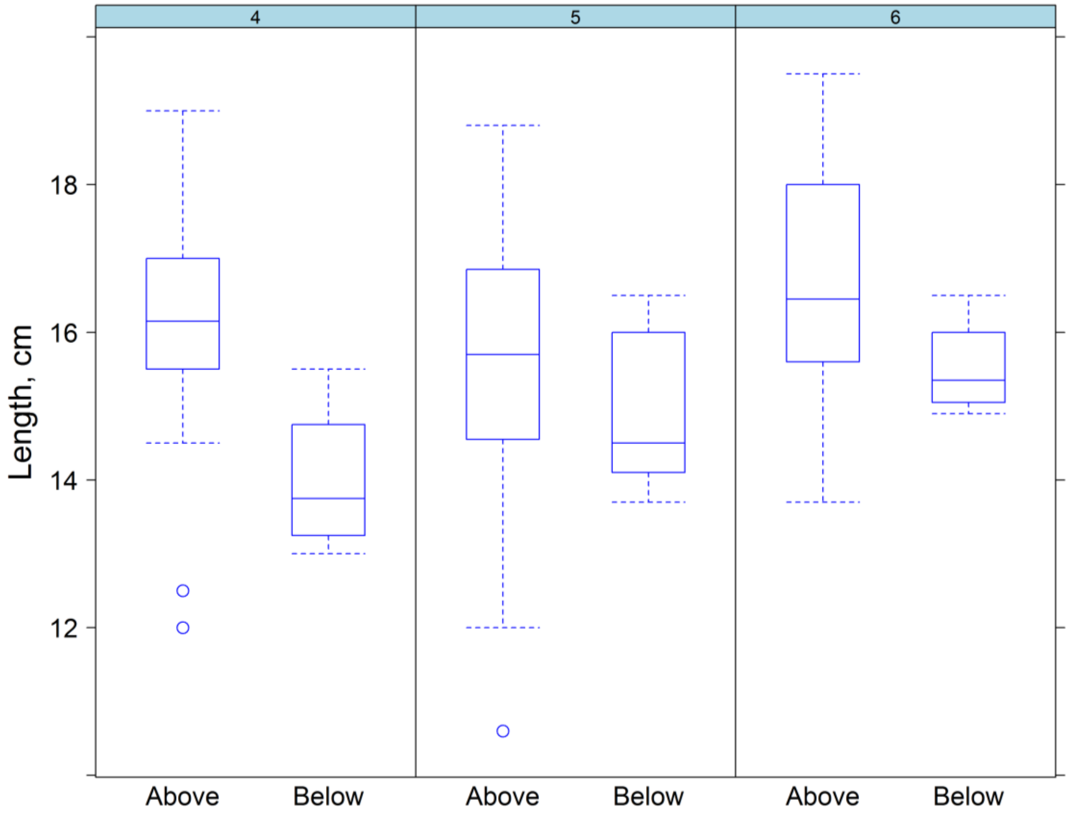
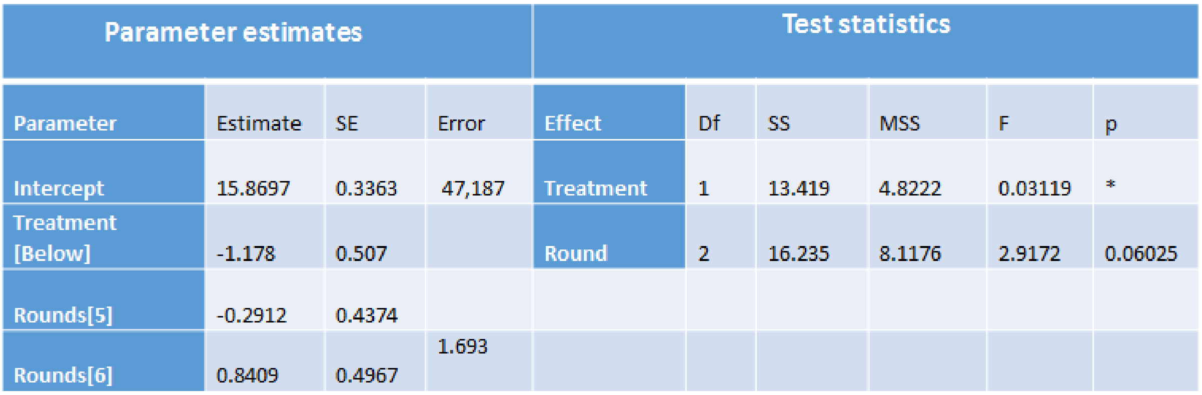


Figure 16: Boxplot showing lengths of 1+ parr of Atlantic salmon above and below outlet point, revealed as an additive effect in the fitted linear model. Boxes entails 50 % of the observations; horizontal lines within the boxes represents the medians; whisker represents the 10th and 90th percentiles; the circles outside the whiskers represents the outliers.

Table 9: Length at age 1+ analysis of Atlantic salmon from capture round 4 to 6: parameter estimates and corresponding anova results for the most supported linear model. Fit statistics: $F_{3,103}=7.827$, $p<0.0001$; $R^2=0.19$. The intercept represents mean length in above station in round 4



Parameter estimates				Test statistics					
Parameter	Estimate	SE	Error	Effect	Df	SS	MSS	F	p
Intercept	15.8697	0.3363	47,187	Treatment	1	13.419	4.8222	0.03119	*
Treatment [Below]	-1.178	0.507		Round	2	16.235	8.1176	2.9172	0.06025
Rounds[5]	-0.2912	0.4374							
Rounds[6]	0.8409	0.4967	1.693						

Back calculated length

There were differences in back calculated length of Atlantic salmon parr between above and below outlet point, were individuals at above location obtained a greater length at first winter (one-way ANOVA, F=11.38, df=1, 35, p=0.0018)(Figure 17). In contrary, back calculated length of brown trout parr show a greater length at first winter for individuals below than above location of the outlet point (Figure 18). However, number of back calculated length in brown trout above outlet point were too few (n=2) to allow for statistical testing.

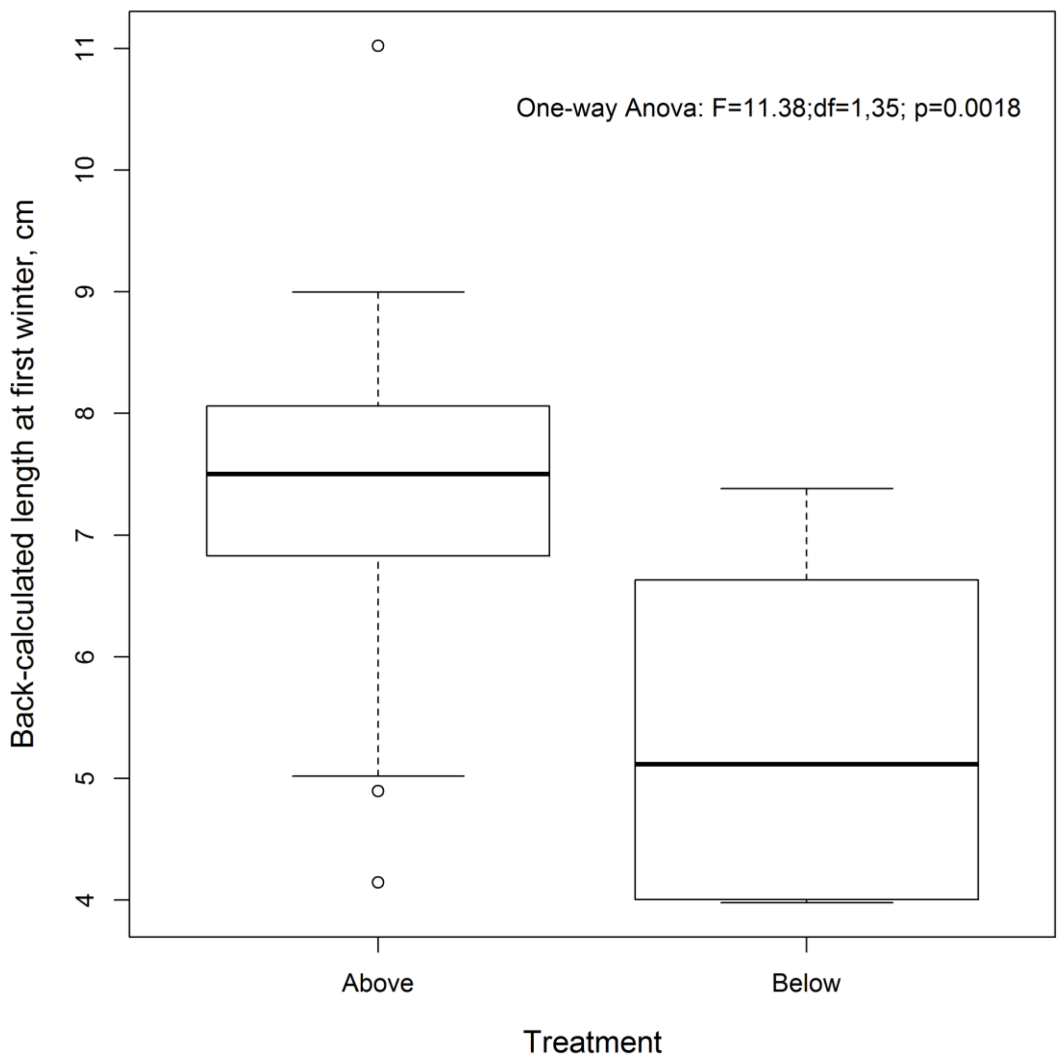


Figure 17: Boxplot showing above-below back-calculated length distribution in 1+ parr of Atlantic salmon. A greater length was obtained for 1+ parr of Atlantic salmon at first winter in above location. Boxes entails 50 % of the observations; horizontal lines within the boxes represents the medians; whisker represents the 10^{th} and 90^{th} percentiles; the circles outside the whiskers represents the outliers.

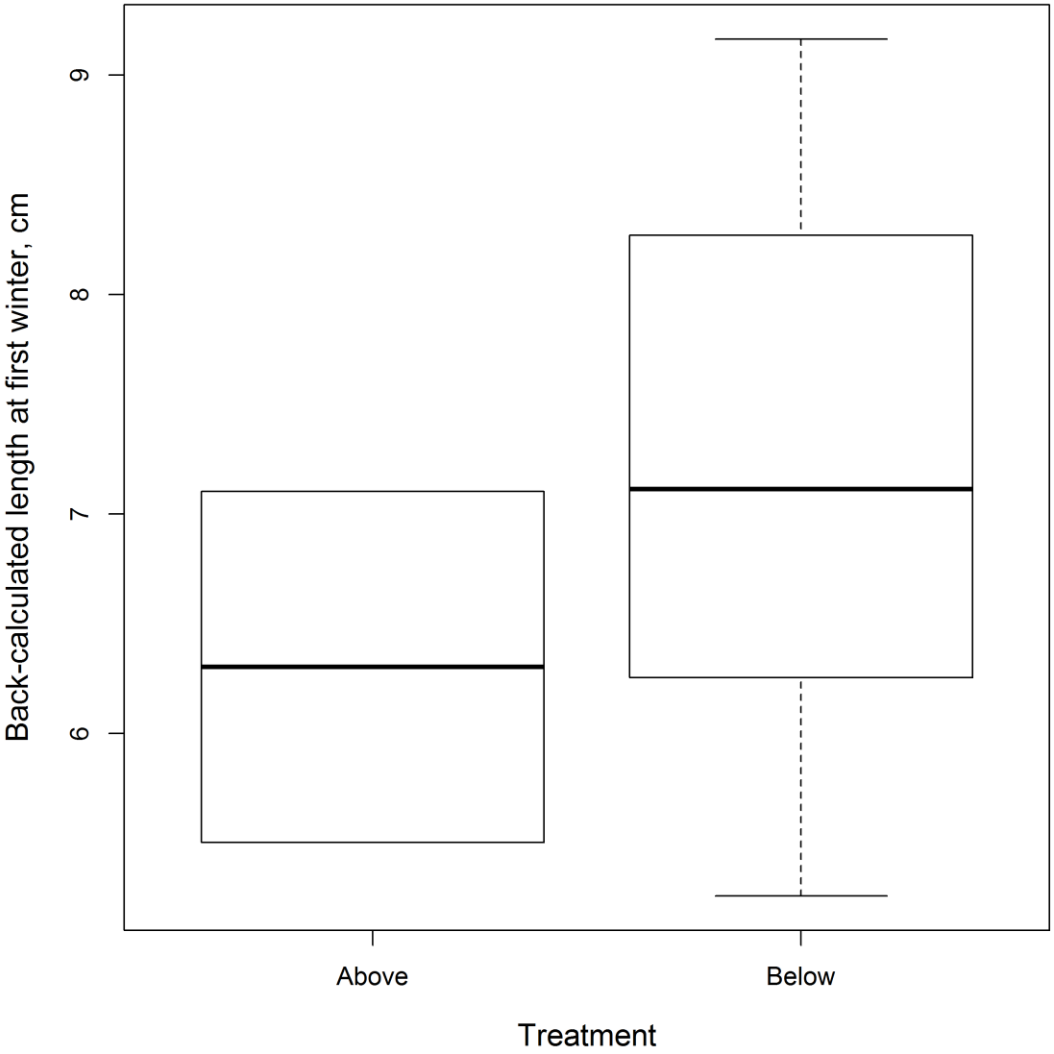


Figure 18: Boxplot showing above-below back-calculated length distribution in 0+ parr of brown trout. Length at first winter is greater for 0+ brown trout at above location compared to 0+ at below location.. Boxes entails 50 % of the observations; horizontal lines within the boxes represents the medians; whisker represents the 10th and 90th percentiles; the circles outside the whiskers represents the outliers.

Length increment of recaptured fish

The length increment data show little evidence for variation in length increment of recaptured fish above and below outlet point (Figure 19). However, response pattern of length increment towards amount of degree-days is similar for fish above and below outlet point, where recaptured individuals that were recaptured within the greatest amount of degree day had the highest growth rate. Due to low amount of recaptured individuals below outlet point (number of observations: Atlantic salmon=4, brown trout= 4) compared to recaptured individuals above outlet point, the model could not be statistically tested.

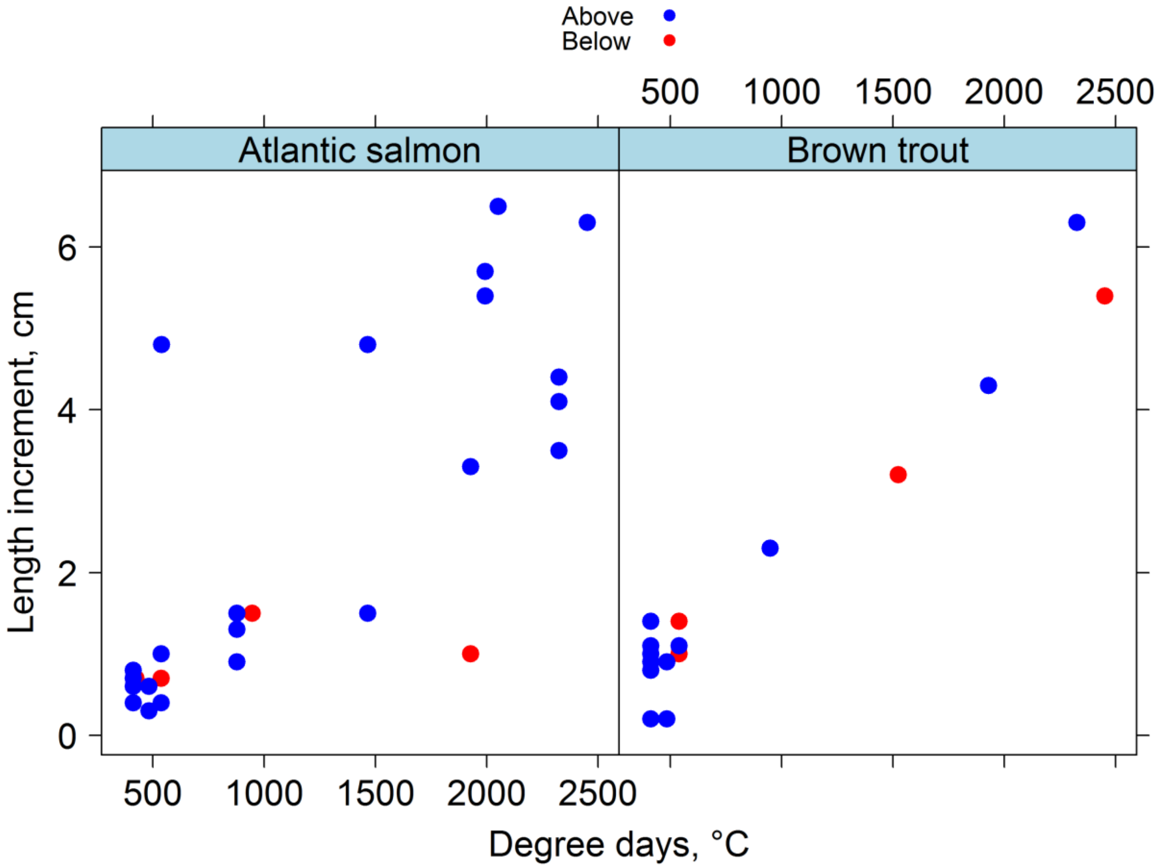


Figure 19: Scatter plot showing length increment as a function of degree-days for Atlantic salmon and brown trout above and below outlet point. An upward trend in growth was observed for recaptured individual that was (re)captured within the greatest amount of degree-days

Water chemistry

There were significant differences, all in favor of larger values below outlet point, between above and below measurements of chloride, sulphate and uranium (Table 10). There was a clear tendency, but non-significant (p=0.12), towards higher sodium concentrations below outlet point than above (difference in favor below: .1454,529±672,351

Table 10: One-way anova results for tests of differences between above and below outlet point in water chemesty variables. diff is the effect coefficient representing the mean difference between above and corresponding below measurements. Positive values indicate that below values are higher than above values. SE is the corresponding standard error. Significant comparisons are given in bold-faced letters.

One-way anova			
Variable	p-value	diff	SE
Chloride	**0,047**	**3,484**	**1,221**
Fluoride	0,116	0,007	0,003
Sulphate	**0,025**	**1,189**	**0,366**
Aluminum	0,938	-5,007	45,868
Antimony	NA	NA	NA
Arsenic	NA	NA	NA
Barium	0,894	0,147	0,785
Beryllium	NA	NA	NA
Mercury	NA	NA	NA
Phosphorus	NA	NA	NA
Silver	NA	NA	NA
Cadmium	NA	NA	NA
Potassium	0,818	37,862	116,834
Calcium	0,35	654,71	495,257
Cobolt	NA	NA	NA
Chromium	NA	NA	NA
Copper	0,831	0,026	0,086

One-way anova			
Variable	p-value	diff	SE
Lead	NA	NA	NA
Magnesium	0,831	35,87	119,418
Manganese	0,588	-4,375	5,734
Molybdenum	NA	NA	NA
Sodium	*0,129*	*1454,529*	*672,351*
Nickel	NA	NA	NA
Silicon	0,985	0,005	0,183
Iron	0,989	1,168	58,228
Selenium	NA	NA	NA
Zinc	NA	NA	NA
Thallium	NA	NA	NA
Tin	NA	NA	NA
Titanium	0,963	0,087	1,327
Uranium	**0**	**0,186**	**0,025**
Vanadium	NA	NA	NA
Tungsten	NA	NA	NA

Discussion

This study has documented a lower size-adjusted survival in both brown trout and Atlantic salmon at below locations compared to fish at above locations of the outlet point. Additionally, data on length-at-age data and back-calculated data show that fish at above location have a higher growth rate than fish at below locations of the outlet point. Apart from downstream migrations of smolt during spring, there was no within-stream movements of individuals. Below-locations were found to have lower fish densities than above-locations, and water chemistry data were only found to differ for chloride, sulphate and uraniumLength distribution

Capture was lower at capture round 1 - 3 (January - May) and higher at capture round 4 – 6 (August – October). Capture in these round consisted mostly of 1+ and 2+ smolt individuals of Atlantic salmon (*Salmo salar)* and brown trout (*Salmo trutta*). Most of these individuals migrated to the sea in spring, in-between capture round 3 (May) and capture round 4 (August). The catches of 1+ parr of Atlantic salmon remained consistent across all capture rounds, suggesting that most 1+ parr of Atlantic salmon does not smolt during their second growth year.

Catches of 0+ individual of both Atlantic salmon and brown did not occur until capture round 4 (August) as individual within this age class are probably too small to be stunned by the electrofishing apparatus in previous capture rounds. For brown trout, catches are skewed towards smaller individuals across capture rounds 4 - 6 compared to catches across capture rounds 1 – 3. This is probably caused by the downstream smolt migration of 1+ and 2+ individuals during spring, and the subsequent increase of catchability of 0+ parr as they increase in length towards summer-autumn period (e.g., Borgstrøm and Skaala 1993).

According to Vincent (1971) the optimal temperature range for electrofishing is between 0 – 10 ^{o} C. At higher temperatures the fish is harder to capture due to increased metabolism, resulting in higher mobility and increased swimming performance. (Forseth & Forsgren 2009). This study obtained a higher capture rate in the summer-autumn period (capture round 4 - 6) compared to the winter-spring period (capture round 1 - 3) when temperatures were above 10 °C. Lower capture efficiency in winter-spring period could derive from technical difficulties with the electrofishing apparatus in the winter period. During the first two sampling rounds a different electrofishing apparatus was used than for the remainder rounds. The apparatus was swapped as I observed individuals that were not chocked using the first apparatus. Clearly, these circumstances have affected catchability for the first two sampling rounds. However, since this sampling bias should affect catchability in the same way across sampling sites, below and above outlet point comparisons should remain valid.

Differences in growth

Individuals of 0+ parr of brown trout and 1+ parr of Atlantic salmon at below location had a lower length-at-age than respective cohorts in above location of the outlet point. In addition, back calculated length data show that Atlantic salmon parr at above location had a greater length at first winter (median 7.5 cm) than parr salmon below outlet point (median= 5 cm).

These growth findings support other *in situ* studies that have found difference in growth within river with a known pollution gradient. For example, Adams et al. (2012) demonstrated that redbreast sunfish *(Lepomis auritus*) living near point-pollution sources in the river had lower age-specific size (length and weight) and a larger proportion of smaller fish within population. The toxic effect was explained as a direct effect upon the lipid metabolism and dynamic at contamination, and as an indirect effect upon prey availability. Coghlan & Ringler (2005) found similar toxic effect upon growth within a juvenile Atlantic salmon population, inhabiting different river sites with a known pollution gradient. In the study of Brotheridge (1998), brown trout living in river location near an old smelters site had both lower length and weight than brown trout distributed further away from the smelter. In this study, heavy metal contamination caused a reduction in growth through food contamination and through exposure to high levels of metals dissolved in the water.

As the tunnel wash water contains both organic and inorganic components (Meland et al. 2010), it is likely that the observed reduction in growth could be due to several toxic effect acting upon processes associated with metabolism, metabolic trade-off associated with detoxifying processes (Lawrence & Hemingway 2003), as well as processes that reduces energy uptake through altered behavior (e.g. feeding behavior and social interaction) (Lett et al. 1976; Sloman et al. 2002). These direct effect of toxicity, in addition to indirect toxic effect on prey availability, were not accounted for in this study.

Lower growth a below location of the outlet point could be related to higher concentration measured of chloride and sodium. These components are likely to derive from road salt on the roads in the surrounding area. Higher concentration of road salt has also been found in the tunnel wash water, where concentration of sodium and chloride was 48 to 33 times higher than in the river water, respectively (Meland 2010). A higher concentration of road salt could cause alteration in blood physiology in fish, as was found for rainbow trout (*Oncorhynchus mykiss*) (Vosyliene & Jankaite 2006). A higher concentration of sodium and chloride could also cause a reduction in growth and survival of post fertilized eggs (Mahrosh et al. 2014). However, this study only covered the effect of survival and growth of parr - and not the embryonic stage.

Density dependent effect on growth could have taken place in stations at above location where density was substantially higher than for station located below outlet point. This could result not only in reduction growth, but also an increase in the variance in growth and size (CV) between individuals (Jonsson & Jonsson 2011). Despite the fact that fish density was higher in stations at above location of the outlet point, growth was higher at these stations than stations below outlet point. This result strengthens the hypothesis of a pollution effect on growth in fish below outlet point.

Beside potential pollution effect and density-dependent effect, growth is influenced by several other abiotic and biotic factors. For river-living salmonids, foraging successes and subsequent growth is influenced by the local current, depth and substrate conditions, and the amount of available drifting prey that varies within river. For example, difference in growth rate due to within-river abiotic and biotic variations was observed for juvenile Atlantic salmon (Arnekleiv et al. 2006; Heggberget et al., 1986; Lund & Heggberget, 1985). Arnekleiv et al. (2006) found a higher growth of juvenile Atlantic salmon occupying the upper stretch of the river were availability of preys were higher. Other studies have also found a higher growth rate among Atlantic salmon in the upper part of the river (Heggberget et al., 1986; Ugedal et al., 1998) and a higher growth of salmonid species living in rivers right below lakes (Lillehammer, 1973; Lillehammer & Saltveit, 1979; Frankiewicz et al., 1993). In river Årungselva, fish receives large amount of drifting prey from Lake Årungen (Borgstrøm & Heggenes 1992), and it is likely that fish located above outlet point receives a larger amount of drifting prey, than fish below outlet point.

Pollution-induced changes in somatic growth rate of parr and smolt can lead to increased size-dependent mortality later in life. Especially during the period of smoltification it is critical that the individual have reached a certain size before the transition from freshwater to seawater. Pollutions stressors during parr-smolt stage can also impair certain physical and physiological changes that are necessary for survival later in life (Barton 2002). The olfactory system is such an organ that is especially vulnerable at the smolt stage as much of the olfactory imprinting is under development at this stage of life**.** (Hansen et al. 1999). It is also possible that individuals that are affected by pollution stress during smoltification could have reduced survival at sea. For example, Kroglund and Finstad (2003) and Kroglund (2012) revealed that Atlantic salmon exposed to aluminium in acidic water during smoltification had reduced survival while at sea. In addition, brown trout smolt that reaches a lower length as smolt showed a higher mortality rate at sea compared to smolt with greater length due to difference in behavior (Ruud 2015).

Differences in survival

Monthly survival probability was higher for fish located above than fish located below outlet point. This result supports the finding of Coghlan & Ringler (2005) who also found a lower survivorship of juvenile Atlantic salmon population exposed to higher level of pollution in in a river with gradient levels of pollution. In this study, the pollution derived from non-point sources from urban, agricultural and sewage areas. In river Årungselva, it is also likely that both fish located above and below outlet point are also exposed to non-point source pollution from road construction in nearby sites, as suggested by the various biomarker results of Dybwad (2015) and Skarsjø (2015)

Monthly survival probability was lower for smaller individuals than larger individuals both above and below outlet point. Exposure to pollution from tunnel wash water could be more severe for smaller individuals as smaller fish have a general lower lipid content. Higher lipid content means that more xenobiotics will be store in the lipid tissue and dilute any toxic effect associated with contamination (Farkas et al. 2003). Larger individuals also have a better ability to cope with pollution, as the lipid reserves serves as energy buffer and helps to lower the stress effect, which occur when the individual are going through physiological strains associated with contamination (Adams et al. 1992; Heugens 2001).

Seasonal condition on survival probability due to toxic effect could also have taken place. In general, fish are more susceptible to toxic effect of pollution at winter when food is scarce and condition factor is lower (Farkas et al. 2003) In addition to seasonal conditional-dependent toxic effect, there are seasonally variation in physiological processes that could have an impact upon the toxic effect at contamination. (Heugens 2001).

The reduced survival probability for smaller individuals aligns with the “big better hypothesis” which states that larger individuals are less susceptible to stress from starvation and physical stress from the environment (Sogard 1997). Especially during winter, survival probability is lower for smaller fish than for larger fish, as smaller fish are more susceptible to chronical stress of starvation owing to higher loss of fat reserves (Berg & Bremset 1998; Pickering and Potteringer 1988). Lower condition of smaller fish and the potential effect of density dependence on growth may also translate into density dependence effect on survival during the winter months (Jenkins et al. 1999).

Differences in fish density

Higher densities of fish were found at stations located above the outlet point (station 1 and 2) compared to the station below outlet point (station 3 and 4). Station 1 in particular had a higher density of both Atlantic salmon and brown than any of the other stations. The decline in fish density followed a downstream trend where station 4 (below location) had the lowest overall fish density. The lower fish densities in below-stations may have resulted from the documented lower survival in these stations. Even though survival may be lower in below stations due to pollution exposure, densities may, independent of this, be lower in these stations due to poorer habitat quality. In particular, differences in abiotic factors, such as water depth, substrate and water velocity, might have influenced the abundance of fish between stations above and below outlet point.

Particularly in smaller rivers, substratum is an important factor explaining habitat selection in sympatric species of Atlantic salmon and brown trout (Bremset & Berg 1999**),** and this might explain the discrepancy in fish density in stations above and below outlet point locations. There is reason to expect that fish density in station 4 to be low as substrate conditions in this station does not provide suitable condition for neither Atlantic salmon nor brown trout. Large sections of station 4 consisted of slow flowing areas containing substrate of fine-grained material, such as silt and clay. Both Atlantic salmon and brown trout tend to rather avoid such substratum that have a low grain size, especially Atlantic salmon avoid substratum below the size of pebbles (<16mm) (Heggenes 1999). Brown trout can make use of substratum with finer particle size such as silt, sand and fine gravel, but are often found in lower abundance in such areas (Heggenes 1999; Jonsson & Jonsson 2011). Station 1 and 2 (above location) had a higher amount of larger rocks and boulders (>250 mm) and a higher amount of cobbles (100-250 mm). This provides areas of sheltering habitat with lower water velocity, which are important habitats for both Atlantic salmon and brown trout (Heggenes 1999).

Water depth is also a variable that to a large extent determines the abundance and spatial selection of habitat of Atlantic salmon and brown trout in small streams (Berg & Bremset 1998), particularly for brown trout where there is a strong correlation between individual body length and preferred water depth (Heggenes 1999). In small streams where there is a lack of habitat with deep water areas, there is often high competition among larger individuals of brown trout for space (Heggenes et al. 1999). In period of drought, this could affect survival and growth (Conallin et al. 2014; Vøllestad & Olsen 2008). In this study there were no significant difference in water depth between the stations. However, water depth can be a limiting factor for brown during drought periods occurring in summer in river Årungselva (Borgstrøm & Heggenes) that could affect brown trout density (Vøllestad & Olsen 2008).

In this study, densities of Atlantic salmon and brown trout were too low to suggest any effect on survival and growth rate. Higher densities could have led to downstream migration of smaller, subordinate individuals through interference competition from larger, more dominant individuals (Newman 1993). This could have taken place in stations above outlet point. However, there were no detection of smaller fish on PIT antenna 1 (Antenna positioned between above-below location) and all recaptured individuals were captured within same station they were first captured. Thus, only small scale migration to adjacent areas could have taken place.

Migration

Pollution-induced changes in the environment can cause migration of individuals from a pollution site to a non-pollution site (Spromberg et al. 1998), and density dependent processes when population have reached its carrying capacity can affect the rate of emigration (Jonsson & Jonsson 2011). In this study, there were no migration of parr between stations located above and below outlet point (i.e., no detection of individuals in PIT antenna 1 apart from smolt migrants). The findings also show the absence of migration in the station between the above and below locations, as all fish was recaptured at the station they initially was captured. This high site fidelity of individuals of Atlantic salmon and brown trout in Årungselva aligns with the “restricted-movement paradigm” of stream-living fish (Gerking 1959; Gowan et al. 1994). Other studies have also found this non-migratory living in brown trout (Vøllestad et al. 2012) and Atlantic salmon (Roussel et al. 2004).

In this study, smolt migration was recorded at both PIT antennas (PIT 1 and PIT 2). Most of the downstream migration occurred in mid-May when the water temperature was on average 10. 6 °C. This result supports the finding of Martin et al. (2011) that observed a higher downstream migration rate of Atlantic salmon within temperature range of 7.5 ^{o}C to 13.5 ^{o}C.

Smolt that were detected on the antenna had an average length of 14.23 cm at capture data, and all individuals were tagged with a 23 mm PIT tag. As there was no detection on the antennas of smaller individuals employed with 12 mm PIT tag, and due to the fact that 12 mm PIT tag have a lower detection range, it could be that smaller individuals passed the antenna undetected.

Recapture probability

In this study**,** higher recapture probability was obtained for smaller individuals in capture round 2 in the winter period (January - Mars). Hassve (2012) also found a higher recapture probability in winter for smaller individuals of brook charr (*Salvelinus fontinalis*). Usually, parr in winter are hiding in the substrate during winter, and they are in general more difficult to capture with the electrofishing apparatus as they are capable of attaining electrotaxis without being forced to the water surface. Especially the smallest parr are difficult to capture in winter as they are able to remain within interstices of the substrate after they have been stunned (Borgstrøm & Skaala 1983). Thus, based on these fact, it is difficult to point directly to the cause of a higher recapture probability in the capture round 2, in the winter period.

A higher recapture probability for smaller fish was also found in capture round 4, i.e. in the summer period (May – August). This could be a result of migration of larger smolt to the sea during the spring, and the subsequent higher capture efficiency of 0+ parr when they grow in length towards summer.

There is a positive correlation between high recapture probability and increased fish length in capture round 3 (Mars – May), while in capture round 5 (Sepember) and capture round 6 (October) recapture probability was less positive with increasing fish length. In general, electrofishing is size selective whereas the catchability tends to be higher for larger than smaller individuals, due to a higher voltage gradient for larger individuals (Borgstrøm & Skaala, 1993). Larger fish could be harder to capture at higher temperature because of increased metabolism, which results in higher mobility and increased swimming performance (Forseth & Forsgren 2009). This could explain the higher capture efficiency of larger individuals in capture round 3 in spring (Mars – May) when temperatures are lower than in summer-autumn period.

In general, there was a low recapture rate for all capture rounds, suggesting a large population size.

Further research

This study has documented spatial variation in individual growth and survival in brown trout and Atlantic salmon juveniles that support the hypothesis of negative effects from tunnel wash water and/or runoff water from roads. However, since the results may also support effects from other differences in physical habitat and since no clear water pollutant was identified (other than chloride), future research should strive to separate confounding environmental variables from potential unique effects imposed by water chemistry. Future research could look at behavioral effect of exposure to tunnel wash water. Pollution-induced behavioral effect is important to study as they serve as link between physiological and biochemical changes and changes that occur higher up in the biological organization level (population and community level). These behavioral effects can be interlinked to many processes such as predator avoidance, intra- and interspecific competition, and reproductive and social behavior that can affect growth and survival rate. (Dell'Omo 2002).

For example, it is likely that tunnel wash water could affect the behavior of fish through avoidance behavior, as avoidance responses are often initiated by low sublethal doses of xenobiotics. Thus, future studies could conduct an *in situ* looking at avoidance responses towards tunnel wash water release. There has been conducted several laboratory experiments on fish avoidance response. However, the result on avoidance response is expected to be more variable when the study is conducted in the field, rather than as a laboratory experiment, as the latter do not take in to account all the factors that directly or indirectly influence the degree of avoidance response. Svecevičius

(1999) study of avoidance behaviour in vimba and rainbow trout is an example of a field experiment conducted as an *in situ* experiment. A similar study could be conducted in Årungselva Other suggestions:

- Continue mark recapture study for further estimation of survival, growth and migration so as to separate potential year-specific effect from unique pollution effects
- Perform similar *in situ* studies in other river system that are affected by release of tunnel wash water and road run off, so as to study the generality of pollution effects
- Measure the amount of drifting prey in locations above and below outlet point, so as to separate potential food availability induced differences in growth from pollution effects
- Study lipid metabolism and lipid dynamic of fish above and below outlet point
- Measure small-scale migration to find differences in movement and explorative behavior, so as to quantify potential small-scale exposures to runoff water than registered in the current study
- Study the effect of tunnel wash water on embryonic development, so as to evaluate eventual delayed effects on growth and survival
- Study whether tunnel wash water could exalt migration of adult individuals
- Study whether exposure to tunnel wash water could cause receptor loss in the olfactory system
- Study the effect of tunnel wash water on feeding behavior

Conclusion

In conclusion, this study has documented, and supported previous findings of reduced growth and survival below the Vassum sedimentation pond outlet point in juvenile Atlantic salmon and brown trout. Since no differences in water chemistry variables, with the exception of chloride, sulphate and uranium, was found, and since the observed differences fits well in with differences in physical habitat characteristics, the relative impairment role of tunnel wash water pollution remains enigmatic for these Årungselva fish populations.

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Appendix

Table S1. Mark-recapture data from 28.11.2014 – 27.10.2015

Station	Date	Serie	ID	Species	Length	Stage	Sex	recap	Rounds
1	28.11.2014	226000	719395	l	9	p			1
1	28.11.2014	2280000	40743	l	11.3	ps			1
1	28.11.2014	226000	719360	l	10.3	p			1
1	28.11.2014	2280000	40744	l	13.7	s			1
1	28.11.2014	226000	719351	ø	7.8	p			1
1	28.11.2014	226000	719312	l	9.1	p			1
2	09.01.2015	36000	1684173	ø	16.9	s			1
2	09.01.2015	226000	719369	l	8	p			1
3	09.01.2015	36000	1684833	ø	12	ps			1
3	09.01.2015	226000	719383	ø	8.4	p			1
3	09.01.2015	226000	719308	ø	7.6	p			1
3	09.01.2015	226000	719396	ø	10.3	ps			1
3	09.01.2015	226000	719315	ø	7.4	p			1
3	17.02.2015	2280000	40702	ø	15.9	s			1
3	17.02.2015	2280000	40703	l	16.6	s			1
3	17.02.2015	226000	719362	ø	9.2	p			1
3	17.02.2015	36	1684833	ø	11.8	ps		1	1
3	17.02.2015	226000	719382	ø	11.1	ps			1
3	17.02.2015	226000	719333	ø	7.2	p			1
3	17.02.2015	226000	719322	ø	9.5	ps			1
3	17.02.2015	226000	719352	l	7.4	p			1
3	17.02.2015	226000	719383	ø	8.5	ps		1	1
3	17.02.2015	226000	719355	l	8.5	p			1
3	17.02.2015	226000	719332	ø	6.1	p			1
3	17.02.2015	2280000	40700	l	12.4	s			1
3	17.02.2015	226000	719377	ø	8.1	p			1
3	17.02.2015	226000	719325	ø	9.4	p			1
3	17.02.2015	226000	719305	ø	7.3	p			1
4	17.02.2015	226000	719307	ø	8.4	p			1
4	17.02.2015	2280000	40701	ø	18.9	s			1
4	17.02.2015	226000	719380	ø	11.6	s			1
4	17.02.2015	226000	719331	ø	9.5	ps			1
4	17.02.2015	226000	719397	ø	9.7	ps			1
4	17.02.2015	226000	719381	l	8.9	p			1
4	17.02.2015	226000	719350	l	8.3	p			1
1	16.03.2015	2280000	40708	ø	13.7	s			2
1	16.03.2015	2280000	40707	l	12	s			2

1	16.03.2015	226000	719401	l	10.6	ps			2
1	16.03.2015	2280000	40705	ø	21.2	s			2
1	16.03.2015	226000	719433	l	9.8	ps			2
1	16.03.2015	2280000	40709	l	15.8	s			2
1	16.03.2015	226000	719483	l	10.1	ps			2
1	16.03.2015	226000	719480	l	9.6	p			2
1	16.03.2015	226000	719443	l	11.5	s			2
1	16.03.2015	226000	719404	l	10	p			2
1	16.03.2015	226000	719446	l	9	p			2
1	16.03.2015	226000	719445	l	9.2	p			2
1	16.03.2015	226000	719405	l	9.8	p			2
2	16.03.2015	226000	719490	l	6.9	p			2
2	16.03.2015	226000	719419	l	6.8	p			2
2	16.03.2015	226000	719431	l	6.8	p			2
2	16.03.2015	226000	719413	l	7.7	p			2
2	16.03.2015	226000	719472	l	6	p			2
2	16.03.2015	226000	719492	l	7.8	p			2
2	16.03.2015	226000	719468	l	7.2	p			2
2	16.03.2015	226000	719410	l	6.2	p			2
2	16.03.2015	226000	719448	l	8.3	p			2
3	16.03.2015	2280000	40713	ø	16.5	s			2
3	16.03.2015	2280000	40712	ø	15.9	s			2
3	16.03.2015	226000	719467	ø	10.1	p			2
3	16.03.2015	2280000	40714	l	14.2	s			2
3	16.03.2015	226000	719450	ø	7.3	p			2
3	16.03.2015	226000	719434	l	6.9	p			2
3	16.03.2015	226000	719382	ø	11	p		1	2
3	16.03.2015	2280000	40706	l	14.7	s			2
3	16.03.2015	2280000	40710	l	15.3	s			2
3	16.03.2015	226000	719362	ø	9.2	p		1	2
3	16.03.2015	226000	719444	ø	9	p			2
3	16.03.2015	226000	719479	l	10.1	p			2
3	16.03.2015	226000	719442	l	9.1	p			2
3	16.03.2015	226000	719471	l	9	p			2
3	16.03.2015	226000	719383	ø	8.7	p		1	2
3	16.03.2015	226000	719407	l	7	p			2
3	16.03.2015	226000	719332	ø	6.1	p		1	2
4	16.03.2015	226000	719484	ø	9.1	p			2
4	16.03.2015	2280000	40704	ø	11.5	ps			2
4	16.03.2015	226000	719475	ø	9.5	p			2
4	16.03.2015	226000	719487	ø	10	p			2

4	16.03.2015	226000	719307	ø	8.5	p		1	2
4	16.03.2015	226000	719440	l	8.6	p			2
1	26.05.2015	2280000	40746	l	11.7	ps			3
1	26.05.2015	226000	719477	l	11.4	ps			3
1	26.05.2015	2280000	40747	l	13.2	ps			3
1	26.05.2015	2280000	40748	ø	11.7	ps			3
1	26.05.2015	2280000	40749	l	13	ps			3
1	26.05.2015	2280000	40755	l	16	ps			3
1	26.05.2015	2280000	40753	l	14	ps			3
1	26.05.2015	2280000	40754	ø	19.2	ps			3
1	26.05.2015	2280000	40751	ø	15	ps			3
1	26.05.2015	226000	719409	l	13.5	ps			3
1	26.05.2015	226000	719421	ø	12.3	ps			3
1	26.05.2015	226000	719494	l	13	ps			3
1	26.05.2015	226000	719491	L	13	ps			3
1	26.05.2015	226000	719428	l	14	ps			3
1	26.05.2015	226000	719480	l	14.4	ps		1	3
4	26.05.2015	226000	719441	l	11.3	ps			3
4	26.05.2015	2280000	40745	ø	14.2	ps			3
4	26.05.2015	226000	719425	ø	11.6	ps			3
4	26.05.2015	226000	719439	ø	12.4	ps			3
4	26.05.2015	226000	719408	l	15	ps			3
4	26.05.2015	226000	719420	ø	12.7	ps			3
4	26.05.2015	226000	719465	ø	11.6	ps			3
2	26.05.2015	226000	719454	ø	12.5	ps			3
2	26.05.2015	226000	719403	l	10.7	ps			3
2	26.05.2015	226000	719473	ø	11	ps			3
2	26.05.2015	226000	719423	l	13.7	ps			3
2	26.05.2015	226000	719474	ø	9.4	p			3
2	26.05.2015	226000	719417	l	9.1	p			3
2	26.05.2015	226000	719498	l	9.2	p			3
1	18.08.2015	2280000	40739	l	16.5	ps			4
1	18.08.2015	2280000	40738	l	15.8	ps			4
1	18.08.2015	30800000	4732	ø	42		hann		4
1	18.08.2015	2280000	40767	l	16.5	ps			4
1	18.08.2015	226000	719477	l	16.2	ps		1	4
1	18.08.2015	2280000	40766	l	16.4	ps			4
1	18.08.2015	2280000	40765	l	16.1	ps			4
1	18.08.2015	2280000	40747	l	16.5	ps			4
1	18.08.2015	2280000	40740	l	17	ps			4
1	18.08.2015	2280000	40769	l	17.9	ps			4

1	18.08.2015	2280000	40755	l	17.5	ps		1	4
1	18.08.2015	2280000	40737	l	15.5	ps			4
1	18.08.2015	2280000	40768	l	14.7	ps			4
1	18.08.2015	2280000	40772	l	18.2	ps			4
1	18.08.2015	2280000	40770	l	19	ps			4
1	18.08.2015	226000	719402	ø	10.6	ps			4
1	18.08.2015	226000	719485	ø	9.2	p			4
1	18.08.2015	226000	719464	ø	8.5	p			4
1	18.08.2015	226000	719424	ø	9.1	p			4
1	18.08.2015	226000	719437	l	6.8	p			4
1	18.08.2015	226000	719406	ø	9.1	p			4
1	18.08.2015	226000	719497	ø	9.7	p			4
1	18.08.2015	226000	719462	ø	9.8	p			4
1	18.08.2015	226000	719435	l	7.6	p			4
1	18.08.2015	226000	719427	ø	7.8	p			4
1	18.08.2015	226000	719476	ø	10.1	p			4
1	18.08.2015	226000	719400	ø	8.5	p			4
1	18.08.2015	226000	719429	ø	10.4	p			4
1	18.08.2015	226000	719447	ø	7.5	p			4
1	18.08.2015	226000	719493	ø	5.7	p			4
1	18.08.2015	226000	719458	l	7.5	p			4
1	18.08.2015	2280000	40730	l	17	s			4
1	18.08.2015	2280000	40735	l	14.5	s			4
1	18.08.2015	2280000	40736	l	15.9	s			4
1	18.08.2015	226000	719486	ø	9	p			4
1	18.08.2015	226000	719433	l	15.5	s			4
1	18.08.2015	2280000	40733	l	14.7	s			4
1	18.08.2015	2280000	40734	ø	11.8	ps			4
1	18.08.2015	226000	719416	ø	11	ps			4
1	18.08.2015	226000	719461	ø	8.2	p			4
1	18.08.2015	226000	719469	ø	8.8	p			4
1	18.08.2015	226000	719495	ø	10.2	p			4
1	18.08.2015	226000	719466	ø	10.7	p			4
1	18.08.2015	226000	719401	l	16	s		1	4
1	18.08.2015	226000	719470	ø	9	p			4
1	18.08.2015	226000	719455	l	6.3	p			4
1	18.08.2015	226000	719452	ø	8.5	p			4
1	18.08.2015	226000	719426	ø	8.2	p			4
1	18.08.2015	226000	719482	ø	7	p			4
4	21.08.2015	2280000	40745	ø	17.4	ps		1	4
4	21.08.2015	2280000	40762	l	14	ps			4

4	21.08.2015	2280000	40771	l	13	ps			4
4	21.08.2015	226000	719453	ø	7.6	p			4
3	21.08.2015	226000	719463	ø	8.6	p			4
3	21.08.2015	226000	719362	ø	16.1	ps			4
3	21.08.2015	2280000	40760	ø	17	ps			4
3	21.08.2015	2280000	40759	l	15.5	ps			4
3	21.08.2015	2280000	40758	l	13.5	ps			4
3	21.08.2015	226000	719478	ø	8.6	p			4
2	21.08.2015	226000	719412	l	12	ps			4
2	21.08.2015	226000	719432	ø	7.8	p			4
2	21.08.2015	226000	719457	ø	8	p			4
2	21.08.2015	226000	719472	l	12.5	ps			4
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1	14.09.2015	2280000	40764	l	17.3	ps			5
1	14.09.2015	2280000	40742	l	16.8	ps			5
1	14.09.2015	2280000	40756	ø	12	ps			5
1	14.09.2015	2280000	40741	l	17.2	s			5
1	14.09.2015	226000	719489	ø	9.1	p			5
1	14.09.2015	2280000	40750	l	16	ps			5
1	14.09.2015	226000	719418	ø	10.3	p			5
1	14.09.2015	226000	719499	ø	10.6	p			5
1	14.09.2015	226000	719456	ø	9.3	p			5
1	14.09.2015	226000	719454	l	9.2	p			5
1	14.09.2015	226000	719426	ø	9.1	p		1	5
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1	14.09.2015	226000	719481	l	9	p			5
1	14.09.2015	226000	719436	l	7	p			5
1	14.09.2015	226000	719438	l	9	p			5
1	14.09.2015	226000	719449	l	8.1	p			5
1	14.09.2015	2280000	40774	ø	12	ps			5
1	14.09.2015	2280000	40777	ø	20.2	s	hann		5
1	14.09.2015	2280000	40769	l	18.5	s			5
1	14.09.2015	226000	719446	l	16	s		1	5
1	14.09.2015	2280000	40776	l	15.2	ps			5
1	14.09.2015	226000	719334	ø	10.3	ps			5
1	14.09.2015	226000	719330	ø	11.2	ps			5
1	14.09.2015	2280000	40752	l	15.6	ps			5
1	14.09.2015	2280000	40736	l	16.2	ps		1	5
1	14.09.2015	2280000	40731	ø	11.9	ps			5
1	14.09.2015	2280000	40775	l	17.2	ps			5
1	14.09.2015	226000	719360	ø	10.3	ps		1	5

1	14.09.2015	226000	719379	ø	10.6	ps			5
1	14.09.2015	2280000	40757	l	15.3	ps			5
1	14.09.2015	2280000	40763	l	15.7	ps			5
1	14.09.2015	226000	719375	ø	9.9	p			5
1	14.09.2015	226000	719327	ø	8	p			5
1	14.09.2015	226000	719357	ø	10.4	p			5
1	14.09.2015	226000	719389	ø	8.1	p			5
1	14.09.2015	226000	719314	ø	9.9	p			5
1	14.09.2015	226000	719339	ø	9.3	p			5
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1	14.09.2015	226000	719390	ø	6.7	p			5
1	14.09.2015	226000	719313	ø	9.8	p			5
1	14.09.2015	226000	719300	ø	9.1	p			5
1	14.09.2015	226000	719336	ø	10	p			5
1	14.09.2015	226000	719370	ø	8.7	p			5
1	14.09.2015	226000	719311	ø	7.8	p			5
1	14.09.2015	226000	719337	ø	9.1	p			5
1	14.09.2015	226000	719328	ø	7.4	p			5
1	14.09.2015	226000	719329	ø	10.4	p			5
1	14.09.2015	226000	719384	l	8.7	p			5
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1	14.09.2015	2280000	40782	l	17.3	ps			5
1	14.09.2015	226000	719340	ø	11.1	ps			5
1	14.09.2015	2280000	40783	l	18.8	s			5
1	14.09.2015	226000	719324	ø	10.4	p			5
1	14.09.2015	2280000	40781	l	15.1	ps			5
1	14.09.2015	2280000	40779	l	15.5	ps			5
1	14.09.2015	226000	719363	ø	11	ps			5
1	14.09.2015	226000	719310	ø	9.7	p			5
1	14.09.2015	226000	719356	ø	10	p			5
1	14.09.2015	226000	719306	l	8.2	p			5
1	14.09.2015	226000	719358	ø	9	p			5
1	14.09.2015	226000	719406	ø	9.3	p		1	5
1	14.09.2015	226000	719353	ø	8.2	p			5
1	14.09.2015	226000	719343	ø	8	p			5
1	14.09.2015	226000	719317	ø	11.6	p			5
1	14.09.2015	226000	719374	ø	6.8	p			5
1	14.09.2015	226000	719309	ø	9.7	p			5

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4	14.09.2015	2280000	40780	l	14.5	ps			5
4	14.09.2015	2280000	40789	l	14.1	ps			5
4	14.09.2015	226000	719408	l	16	ps		1	5
4	14.09.2015	2280000	40788	ø	16.5	ps			5
4	14.09.2015	226000	719301	ø	10.2	p			5
4	14.09.2015	2280000	40771	l	13.7	ps			5
4	14.09.2015	226000	719392	ø	8.6	p			5
4	14.09.2015	226000	719349	ø	10	p			5
4	14.09.2015	226000	719347	ø	7.6	p			5
4	14.09.2015	226000	719326	ø	8.2	p			5
4	14.09.2015	226000	719304	ø	8	p			5
3	14.09.2015	2280000	40761	ø	18	s	hann	1	5
3	14.09.2015	2280000	40786	ø	17.2	s	hann		5
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3	14.09.2015	226000	719388	ø	7.4	p			5
3	14.09.2015	226000	719303	ø	8.4	p			5
3	14.09.2015	226000	719372	ø	8.7	p			5
3	14.09.2015	226000	719338	ø	6.4	p			5
3	14.09.2015	226000	719345	ø	8.1	p			5
3	14.09.2015	226000	719391	ø	8.6	p			5
3	14.09.2015	226000	719316	l	7.1	p			5
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2	14.09.2015	2280000	40718	ø	12	ps			5
2	14.09.2015	2280000	40719	l	15.7	ps			5
2	14.09.2015	2280000	40773	l	13.7	ps			5
2	14.09.2015	226000	719342	ø	9.4	ps			5
2	14.09.2015	2280000	40715	l	13	ps			5
2	14.09.2015	2280000	40716	l	14.9	ps			5
2	14.09.2015	226000	719367	ø	9.1	p			5
2	14.09.2015	2280000	40717	l	13.5	ps			5
2	14.09.2015	226000	719348	ø	9	p			5
2	14.09.2015	2280000	40721	l	12.7	ps			5
2	14.09.2015	2280000	40720	l	12	ps			5
2	14.09.2015	226000	719321	ø	7.8	p			5
2	14.09.2015	226000	719393	ø	8.9	p			5
2	14.09.2015	226000	719354	ø	10	p			5
2	14.09.2015	226000	719318	ø	9.8	p			5
2	14.09.2015	226000	719364	ø	9	p			5
2	14.09.2015	226000	719399	l	8	p			5
2	14.09.2015	226000	719371	ø	7	p			5

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1	14.10.2015	226000	719401	l	17.5	ps		1	6
1	14.10.2015	2280000	40740	l	18.5	ps		1	6
1	14.10.2015	2280000	40748	ø	18	ps		1	6
1	14.10.2015	226000	719491	L	16.5	ps		1	6
1	14.10.2015	226000	719360	l	18.5	ps	hann	1	6
1	14.10.2015	2280000	40746	l	16.1	ps		1	6
1	14.10.2015	2280000	40737	l	16.4	ps	hann	1	6
1	14.10.2015	2280000	40747	l	17.3	ps		1	6
4	27.10.2015	2280000	40787	l	16.5	ps		1	6
4	27.10.2015	226000	719425	ø	17	ps		1	6
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4	27.10.2015	226000	719440	l	14.9	ps	hann	1	6
4	27.10.2015	226000	719349	ø	11.4	ps		1	6
4	27.10.2015	226000	719392	ø	9.6	p		1	6
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3	27.10.2015	226000	719345	ø	9.5	p		1	6
2	27.10.2015	2280000	40716	l	15.3	ps		1	6
2	27.10.2015	226000	719498	l	15.5	ps		1	6
2	27.10.2015	226000	719432	ø	10.1	ps		1	6
2	27.10.2015	2280000	40773	l	13.7	ps	hann	1	6
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4	27.10.2015			l	16.7	ps	hann		6
4	27.10.2015			l	16.2	ps			6
4	27.10.2015			ø	10.4	ps			6
4	27.10.2015			ø	22	ps			6
4	27.10.2015			ø	19.2	ps			6
4	27.10.2015			l	16.6	ps			6
4	27.10.2015			l	18	ps	hann		6
4	27.10.2015			l	15	ps			6
4	27.10.2015			l	17.3	ps			6
4	27.10.2015			ø	13.2	ps			6
4	27.10.2015			ø	10.2	p			6
4	27.10.2015			ø	10.8	p			6
4	27.10.2015			l	17.5	ps	hann		6
4	27.10.2015			ø	9	p			6
4	27.10.2015			ø	11.2	p			6
4	27.10.2015			ø	10.1	p			6

4	27.10.2015			l	15.6	ps			6
4	27.10.2015			ø	22.2	ps			6
4	27.10.2015			ø	9.1	p			6
4	27.10.2015			ø	10.3	p			6
4	27.10.2015			ø	10.3	p			6
4	27.10.2015			ø	10.5	p			6
4	27.10.2015			l	15.2	ps	hann		6
4	27.10.2015			l	10.9	ps			6
4	27.10.2015			ø	9.5	p			6
4	27.10.2015			ø	12	ps			6
4	27.10.2015			ø	9.2	p			6
4	27.10.2015			ø	9.3	p			6
4	27.10.2015			ø	9.8	p			6
4	27.10.2015			ø	9.3	p			6
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3	27.10.2015			ø	11.3	p			6
3	27.10.2015			l	16.3	ps			6
3	27.10.2015			l	14	ps			6
3	27.10.2015			ø	12.5	ps			6
3	27.10.2015			ø	13	ps			6
3	27.10.2015			ø	19	ps			6
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3	27.10.2015			ø	10.6	p			6
3	27.10.2015			ø	11.1	p			6
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3	27.10.2015			l	17	ps			6
3	27.10.2015			l	8.6	p			6
3	27.10.2015			l	16.3	ps			6
3	27.10.2015			ø	8.5	p			6
3	27.10.2015			ø	9.7	p			6
3	27.10.2015			l	14.9	ps			6
3	27.10.2015			ø	10	p			6
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3	27.10.2015			ø	11	p			6
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2	27.10.2015			ø	10.4	p			6
2	27.10.2015			ø	8.6	p			6

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2	27.10.2015			l	16.6	ps			6
2	27.10.2015			l	14	ps			6
2	27.10.2015			l	15.6	ps			6
2	27.10.2015			ø	9	p			6
2	27.10.2015			ø	9.5	p			6
2	27.10.2015			l	11.3	p			6
2	27.10.2015			l	15.3	ps			6
2	27.10.2015			l	16.8	ps			6
2	27.10.2015			l	15.2	ps			6
2	27.10.2015			ø	9.9	p			6
2	27.10.2015			ø	12.2	ps			6
2	27.10.2015			l	12.3	ps			6
2	27.10.2015			ø	22.5	ps	hann		6
2	27.10.2015			l	14.2	ps	hann		6
2	27.10.2015			ø	10.5	p			6
2	27.10.2015			l	15.3	ps			6
2	27.10.2015			l	16.3	ps	hann		6
2	27.10.2015			ø	11.1	p			6
2	27.10.2015			ø	10.6	p			6
2	27.10.2015			l	16.2	ps	hann		6
2	27.10.2015			ø	10.1	p			6
2	27.10.2015			l	14	ps			6
2	27.10.2015			l	13.2	ps	hann		6
2	27.10.2015			l	15	ps			6
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2	27.10.2015			l	14.3	ps			6
2	27.10.2015			ø	10.5	p			6
2	27.10.2015			ø	11.3	p			6
2	27.10.2015			l	17	ps	hann		6
2	27.10.2015			ø	11.8	ps			6
2	27.10.2015			l	17.4	ps	hann		6
2	27.10.2015			l	15.3	ps	hann		6
2	27.10.2015			ø	9.1	p			6
2	27.10.2015			l	12.8	ps	hann		6
2	27.10.2015			l	13.5	ps	hann		6
2	27.10.2015			l	17	ps	hann		6
2	27.10.2015			ø	10.8	p			6
2	27.10.2015			l	14.6	ps			6
2	27.10.2015			l	14.5	ps	hann		6

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2	27.10.2015			l	15	ps			6
2	27.10.2015			l	7.3	p			6
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2	27.10.2015			ø	12	ps			6
2	27.10.2015			l	12.1	p			6
2	27.10.2015			ø	9.6	p			6
2	27.10.2015			ø	9	p			6
2	27.10.2015			ø	8.8	p			6
2	27.10.2015			ø	10.5	ps			6
2	27.10.2015			ø	11.1	ps			6
2	27.10.2015			l	13.7	ps			6
2	27.10.2015			ø	11	p			6
2	27.10.2015			ø	8.2	p			6
2	27.10.2015			ø	11.7	ps			6
2	27.10.2015			l	11.2	ps	hann		6
2	27.10.2015			l	10.6	ps	hann		6
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4	07.07.2015	226000	719448	l					4
4	23.08.2015	226000	719440	l					4
4	07.07.2015	226000	719440	l					5
4	26.05.2015	226000	719440	l					3
4	01.06.2015	2280000	40708	ø					3
2	02.05.2015	00036	1684173	ø					3
2	15.04.2015	226000	719365	ø					2
2	09.05.2015	2280000	40707	l					3
2	10.05.2015	2280000	40709	l					3
4	08.05.2015	00036	1684173	ø					3
4	07.05.2015	00036	1684833	ø					3
4	06.05.2015	226000	719484	ø					3
4	04.05.2015	2280000	40700	l					3
4	12.05.2015	2280000	40702	ø					3
4	29.04.2015	2280000	40703	l					3
4	17.05.2015	2280000	40704	ø					3
4	23.05.2015	2280000	40710	l					3
4	29.04.2015	2280000	40714	l					3
4	29.04.2015	2280000	40712	ø					3
4	01.05.2015	2280000	40706	l					3
4	06.05.2015	2280000	40713	ø					3
4	10.05.2015	2280000	40707	l					3
4	11.05.2015	2280000	40709	l					3

4	12.05.2015	2280000	40744	l					3
4	13.05.2015	2280000	40743	l					3
1	14.10.2015			l	19,5	ps			6
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1	14.10.2015			l	16	ps			6
1	14.10.2015			l	17,8		hann		6
1	14.10.2015			l	19,8		hann		6
1	14.10.2015			l	16	ps			6
1	14.10.2015			ø	12,8	p			6
1	14.10.2015			ø	10,5	p			6
1	14.10.2015			l	10	p			6
1	14.10.2015			ø	10	p			6
1	14.10.2015			ø	12,5	ps			6
1	14.10.2015			ø	12,3	p			6
1	14.10.2015			ø	15,5	ps			6
1	14.10.2015			l	10	p			6
1	14.10.2015		40756	ø	13,	ps			6
1	14.10.2015		719499	ø	12	p			6
1	14.10.2015			ø	13,5	ps			6
1	14.10.2015			ø	11,0	p			6
1	14.10.2015			ø	11	p			6
1	14.10.2015			l	15,6	ps			6
1	14.10.2015			l	19	ps			6
1	14.10.2015			l	15,5	ps			6
1	14.10.2015		40757	l	16	ps			6
1	14.10.2015		40763	l	16,5	ps			6
1	14.10.2015			l	19		hann		6
1	14.10.2015			l	18		hann		6
1	14.10.2015			ø	11,7	p			6
1	14.10.2015			ø	10,5	p			6
1	14.10.2015			ø	13,0	p			6
1	14.10.2015			l	17,8		hann		6
1	14.10.2015			l	18,5	ps			6
1	14.10.2015			ø	11	p			6
1	14.10.2015			ø	12	p			6
1	14.10.2015		719489	ø	10,1	p			6
1	14.10.2015			ø	11,6	p			6
1	14.10.2015		40731	ø	12	p			6
1	14.10.2015			ø	10,3	p			6
1	14.10.2015			l	9	p			6
1	14.10.2015			ø	9,2	p			6

1	14.10.2015		719311	ø	8	p			6
1	14.10.2015		719327	ø	8,2	p			6
1	14.10.2015			ø	9,5	p			6
1	14.10.2015			l	8,2	p			6
1	14.10.2015			ø	6,5	p			6
1	14.10.2015			l	7	p			6
1	14.10.2015			ø	7,2	p			6
1	14.10.2015			ø	25,7				6
1	14.10.2015			l	16,6	ps			6
1	14.10.2015		40783	l	19,2	ps			6
1	14.10.2015			l	17,8		hann		6
1	14.10.2015			l	18,2		hann		6
1	14.10.2015			l	15,5	ps			6
1	14.10.2015		40781	l	15,7	ps			6
1	14.10.2015			l	15		hann		6
1	14.10.2015			l	15,8	ps			6
1	14.10.2015			ø	11,5	p			6
1	14.10.2015			l	16		hann		6
1	14.10.2015		719363	ø	12,1	p			6
1	14.10.2015		719356	ø	10,8	p			6
1	14.10.2015			l	8,6	p			6
1	14.10.2015			l	17,4		hann		6
1	14.10.2015			l	15		hann		6
1	14.10.2015			ø	11,5	p			6
1	14.10.2015			ø	10,6	p			6
1	14.10.2015			ø	10,2	p			6
1	14.10.2015		719309	ø	10,5	p			6
1	14.10.2015			ø	9,9	p			6
1	14.10.2015			l	7,4	p			6
1	14.10.2015			ø	6,3	p			6
1	14.10.2015			ø	13,0	ps			6
1	14.10.2015			ø	8,4	p			6

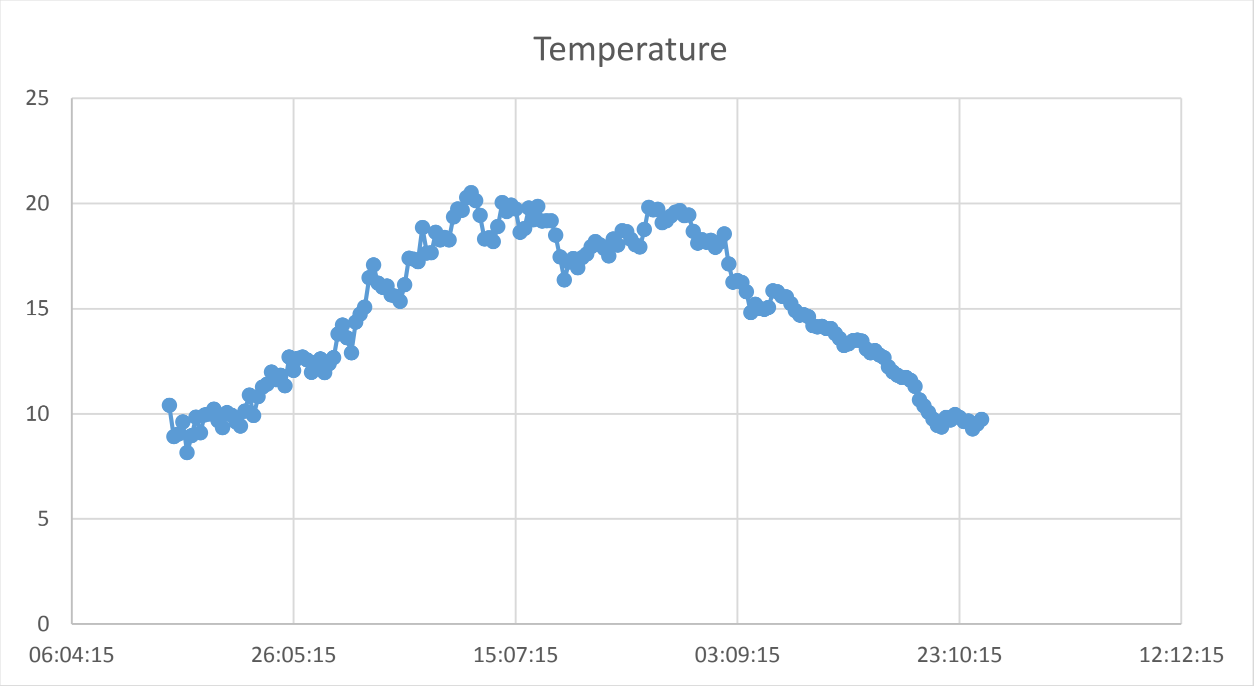


Figure 20: Water temperature measured with a logger on station 4

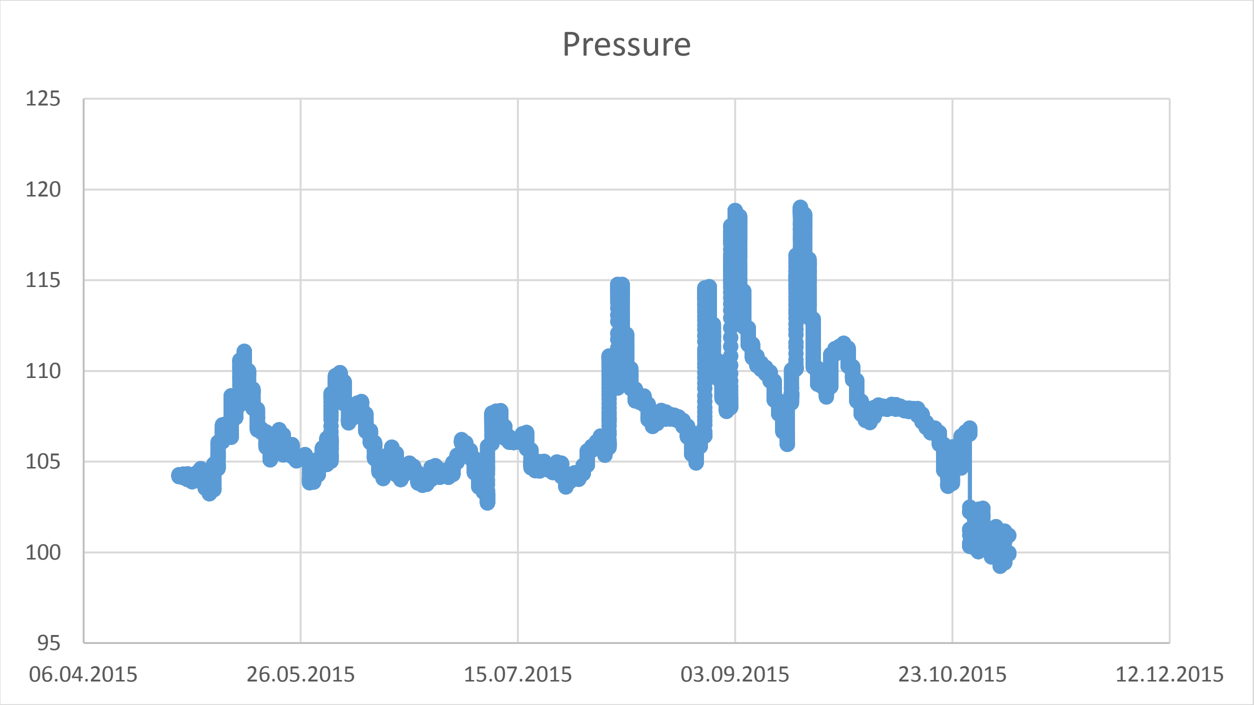


Figure 21: Water pressure measured with a logger on station 4

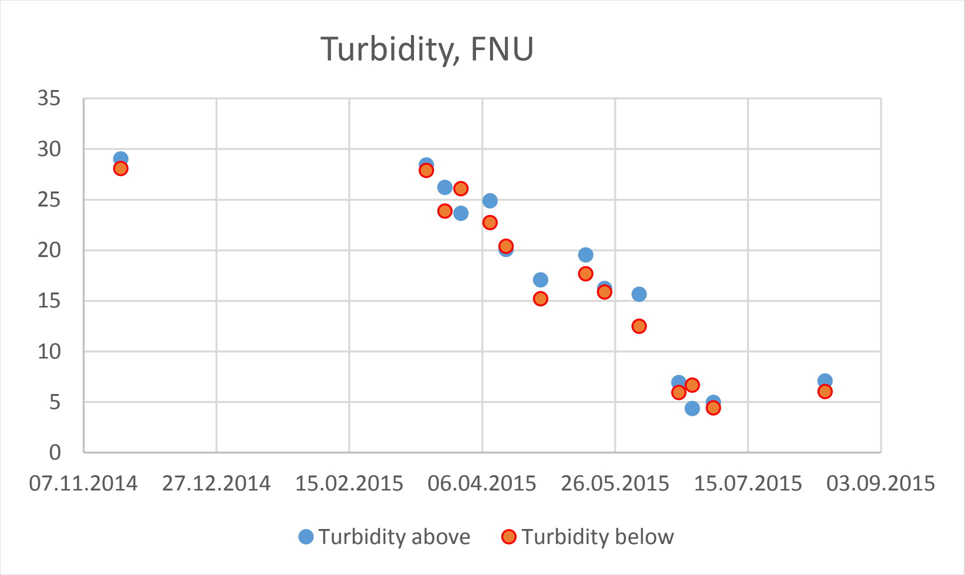


Figure 22: turbidity measured with a CTD-sonde in above and below location.

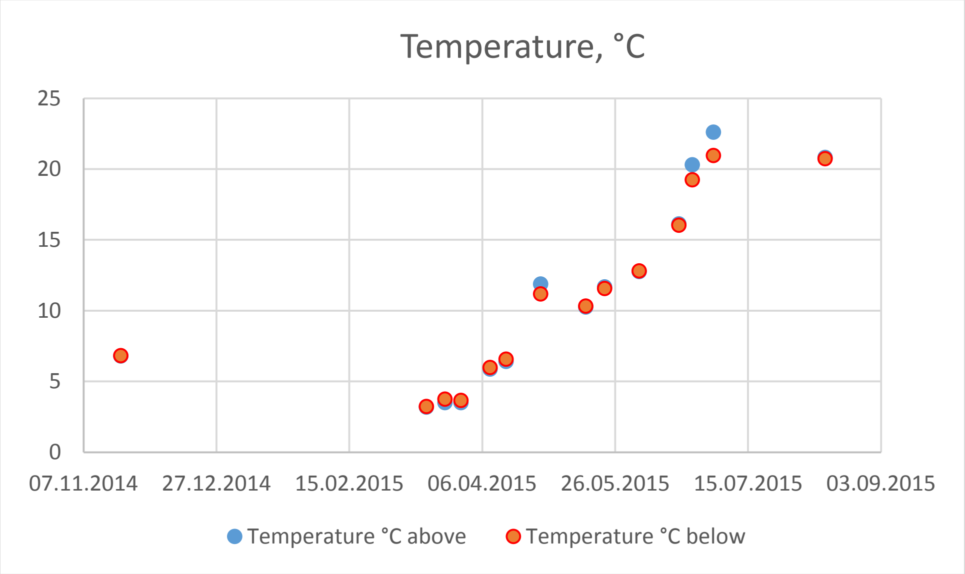


Figure 23: temperature measured with a CTD-sonde in above and below location

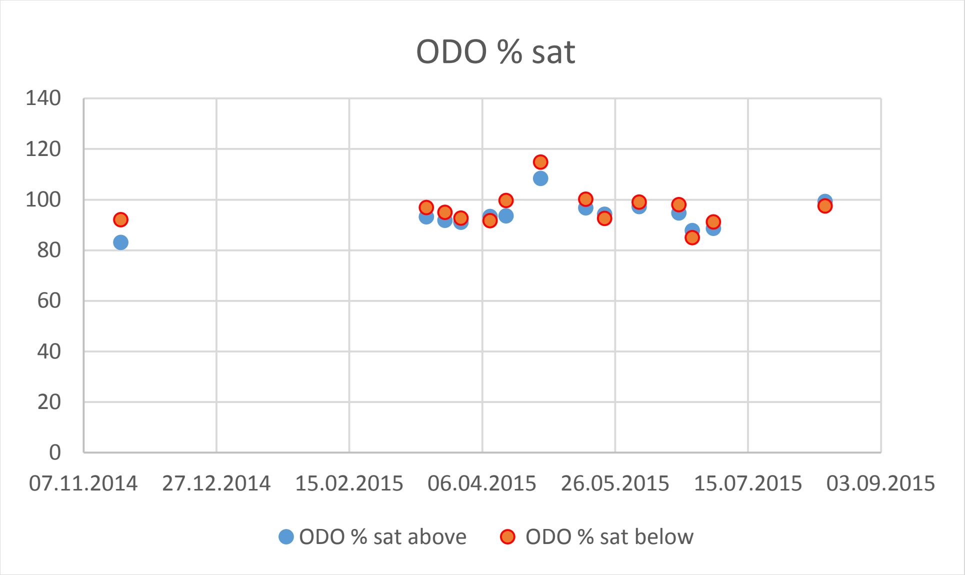


Figure 24: oxygen saturation measured with a CTD-sonde in above and below location

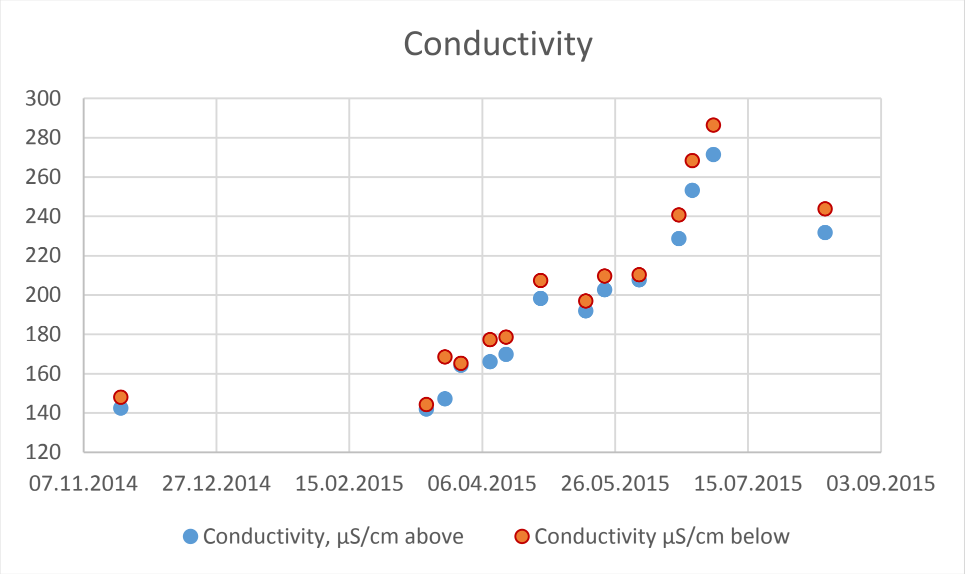
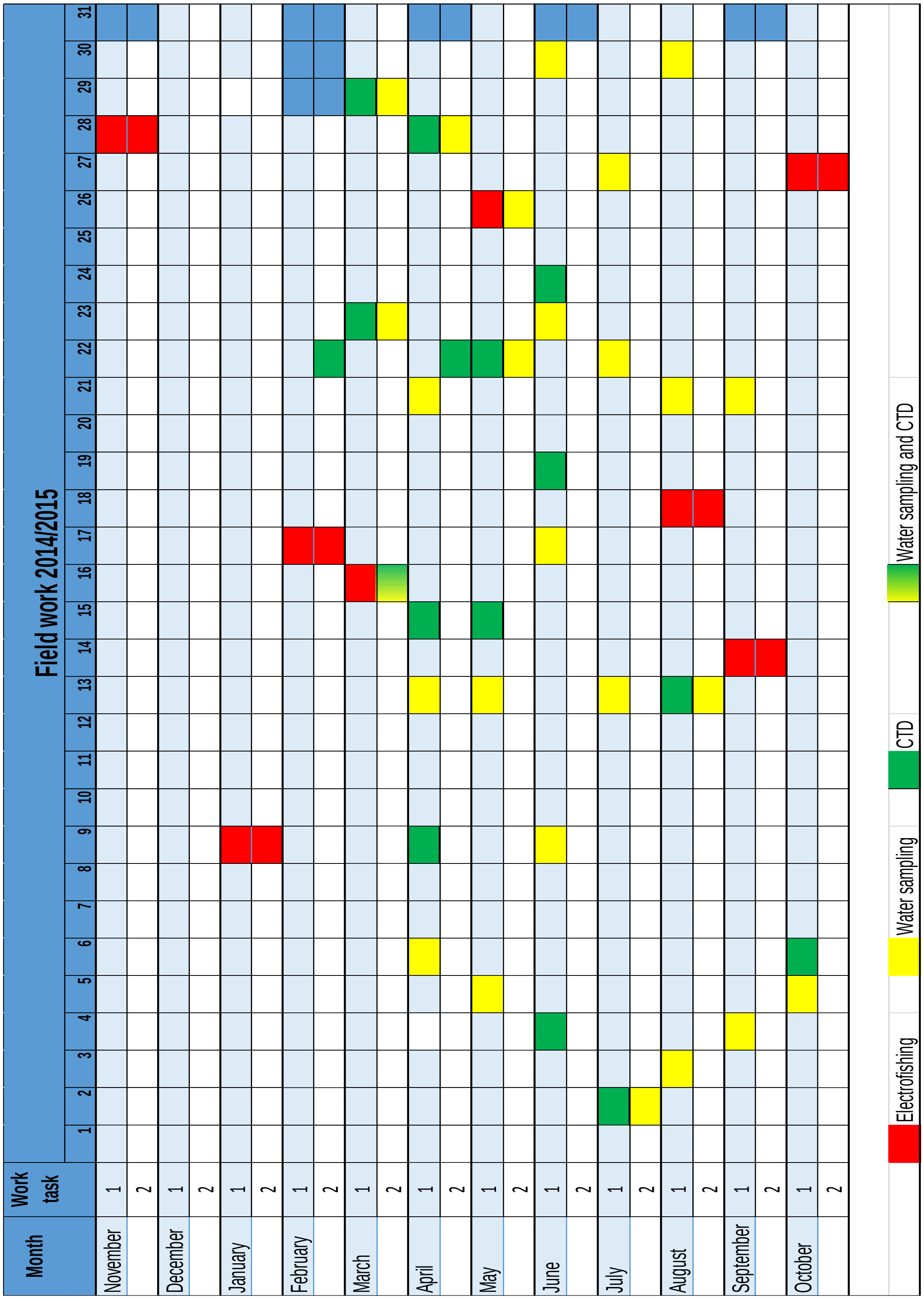


Figure 25: Conductivity measured with a CTD-sonde in above and below location

Table 11



Month	Work task	Field work 2014/2015																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
November	1																												🟥			
	2																												🟥			
December	1																															
	2																															
January	1									🟥																						
	2									🟥																						
February	1																	🟥														
	2																	🟥					🟩									
March	1																🟥							🟩						🟩		
	2																🟩🟨							🟨						🟨		
April	1						🟨			🟩				🟨		🟩						🟨							🟩			
	2																						🟩						🟨			
May	1					🟨								🟨		🟩							🟩				🟥					
	2																						🟨				🟨					
June	1				🟩					🟨								🟨		🟩				🟨	🟩						🟨	
	2																															
July	1		🟩											🟨									🟨					🟨				
	2		🟨																													
August	1			🟨										🟩					🟥			🟨									🟨	
	2													🟨					🟥													
September	1				🟨										🟥							🟨										
	2														🟥																	
October	1					🟨	🟩																					🟥				
	2																											🟥				

🟥 Electrofishing 🟨 Water sampling 🟩 CTD 🟩🟨 Water sampling and CTD

Table 12

River	Station	Date	Chloride	Fluoride	Sulphate	Aluminium	Antimony	Arsenic
Årungselva	above	16.03.2015	31	0,24	12	870	<0,50	<1,0
Årungselva	below	16.03.2015	31	0,24	12	790	<0,50	<1,0
Årungselva	above	23.03.2015	32	0,24	12	790	<0,50	<1,0
Årungselva	below	23.03.2015	37	0,24	13	690	<0,50	<1,0
Årungselva	above	29.03.2015	32	0,24	12	660	<0,50	<1,0
Årungselva	below	29.03.2015	39	0,23	13	720	<0,50	<1,0
Årungselva	above	21.04.2015	35	0,23	13	570	<0,50	<1,0
Årungselva	below	21.04.2015	37	0,24	13	510	<0,50	<1,0
Årungselva	below	28.04.2015	38	0,25	14	420	<0,50	<1,0
Årungselva	above	05.05.2015	36	0,24	14	270	<0,50	<1,0
Årungselva	below	05.05.2015	40	0,24	15	230	<0,50	<1,0
Årungselva	above	13.05.2015	35	0,22	13	270	<0,50	<1,0
Årungselva	below	13.05.2015	36	0,25	14	280	<0,50	<1,0
Årungselva	above	22.05.2015	36	0,23	14	250	<0,50	<1,0
Årungselva	below	22.05.2015	37	0,24	14	200	<0,50	<1,0
Årungselva	above	26.05.2015	36	0,25	14	210	<0,50	<1,0
Årungselva	below	26.05.2015	37	0,23	14	190	<0,50	<1,0
Årungselva	above	09.06.2015	35	0,25	14	210	<0,50	<1,0
Årungselva	below	09.06.2015	35	0,25	14	160	<0,50	<1,0
Årungselva	above	17.06.2015	35	0,25	14	140	<0,50	<1,0
Årungselva	below	17.06.2015	37	0,24	15	100	<0,50	<1,0
Årungselva	above	23.06.2015	31	0,23	13	120	<0,50	<1,0
Årungselva	below	23.06.2015	37	0,25	15	120	<0,50	<1,0
Årungselva	above	30.06.2015	16	0,19	7,5	110	<0,50	<1,0
Årungselva	below	30.06.2015	39	0,25	16	89	<0,50	<1,0
Årungselva	above	02.07.2015	30	0,22	13	160	<0,50	<1,0
Årungselva	below	02.07.2015	35	0,25	14	180	<0,50	<1,0
Årungselva	above	13.07.2015	26	0,26	11	150	<0,50	<1,0
Årungselva	below	13.07.2015	18	0,25	8,9	210	<0,50	<1,0
Årungselva	above	22.07.2015	35	0,24	15	100	<0,50	<1,0
Årungselva	below	22.07.2015	37	0,25	16	88	<0,50	<1,0
Årungselva	above	27.07.2015	23	0,23	11	100	<0,50	<1,0
Årungselva	below	27.07.2015	36	0,23	15	92	<0,50	<1,0
Årungselva	above	03.08.2015	35	0,24	15	77	<0,50	<1,0
Årungselva	below	03.08.2015	37	0,24	16	76	<0,50	<1,0
Årungselva	above	13.08.2015	32	0,25	15	130	<0,50	<1,0
Årungselva	below	13.08.2015	32	0,26	15	130	<0,50	<1,0
Årungselva	above	21.08.2015	33	0,25	15	76	<0,50	<1,0

Årungselva	below	21.08.2015	33	0,24	16	81	<0,50	<1,0
Årungselva	above	30.08.2015	30	0,25	14	130	<0,50	<1,0
Årungselva	below	30.08.2015	30	0,25	15	170	<0,50	<1,0
Årungselva	above	04.09.2015	27	0,24	14	200	<0,50	<1,0
Årungselva	below	04.09.2015	27	0,25	14	220	<0,50	<1,0
Årungselva	above	21.09.2015	15	0,26	8,9	270	<0,50	<1,0
Årungselva	below	21.09.2015	23	0,27	13	260	<0,50	<1,0
Årungselva	above	05.11.2015	23	0,27	14	190	<0,50	<1,0
Årungselva	below	05.11.2015	25	0,28	15	190	<0,50	<1,0

Table 13

River	Station	Barium	Beryllium	Mercury	Phosphorus	Silver	Cadmium
Årungselva	above	29	<0,20	<0,020	<0,10	<0,50	0,041
Årungselva	below	29	<0,20	<0,020	<0,10	<0,50	<0,030
Årungselva	above	28	<0,20	<0,020	<0,10	<0,50	0,033
Årungselva	below	28	<0,20	<0,020	<0,10	<0,50	<0,030
Årungselva	above	28	<0,20	<0,020	<0,10	<0,50	0,044
Årungselva	below	29	<0,20	<0,020	<0,10	<0,50	<0,030
Årungselva	above	26	<0,20	<0,020	<0,10	<0,50	<0,030
Årungselva	below	21	<0,20	<0,020	<0,10	<0,50	<0,030
Årungselva	below	20	<0,20	<0,020	<0,10	<0,50	<0,030
Årungselva	above	22	<0,20	<0,020	0,047	<0,50	<0,030
Årungselva	below	22	<0,20	<0,020	0,048	<0,50	<0,030
Årungselva	above	24	<0,20	<0,020	0,049	<0,50	<0,030
Årungselva	below	24	<0,20	<0,020	0,051	<0,50	<0,030
Årungselva	above	23	<0,20	<0,020	0,05	<0,50	<0,030
Årungselva	below	23	<0,20	<0,020	0,042	<0,50	<0,030
Årungselva	above	18	<0,20	<0,020	0,037	<0,50	<0,030
Årungselva	below	22	<0,20	<0,020	0,042	<0,50	<0,030
Årungselva	above	20	<0,20	<0,020	0,031	<0,50	<0,030
Årungselva	below	19	<0,20	<0,020	0,033	<0,50	<0,030
Årungselva	above	18	<0,20	<0,020	0,026	<0,50	<0,030
Årungselva	below	22	<0,20	<0,020	0,027	<0,50	<0,030
Årungselva	above	22	<0,20	<0,020	0,045	<0,50	<0,030
Årungselva	below	17	<0,20	<0,020	0,035	<0,50	<0,030
Årungselva	above	22	<0,20	<0,020	0,034	<0,50	<0,030
Årungselva	below	12	<0,20	<0,020	0,029	<0,50	<0,030
Årungselva	above	22	<0,20	<0,020	0,036	<0,50	<0,030
Årungselva	below	22	<0,20	<0,020	0,037	<0,50	<0,030
Årungselva	above	21	<0,20	<0,020	0,046	<0,50	<0,030

Årungselva	below	21	<0,20	<0,020	0,053	<0,50	<0,030
Årungselva	above	21	<0,20	<0,020	0,025	<0,50	<0,030
Årungselva	below	21	<0,20	<0,020	0,03	<0,50	<0,030
Årungselva	above	17	<0,20	<0,020	0,024	<0,50	<0,030
Årungselva	below	22	<0,20	<0,020	0,029	<0,50	<0,030
Årungselva	above	20	<0,20	<0,020	0,024	<0,50	<0,030
Årungselva	below	21	<0,20	<0,020	0,023	<0,50	<0,030
Årungselva	above	21	<0,20	<0,020	0,026	<0,50	<0,030
Årungselva	below	21	<0,20	<0,020	0,027	<0,50	<0,030
Årungselva	above	20	<0,20	<0,020	0,037	<0,50	<0,030
Årungselva	below	30	<0,20	<0,020	0,031	<0,50	<0,030
Årungselva	above	21	<0,20	<0,020	0,029	<0,50	<0,030
Årungselva	below	28	<0,20	<0,020	0,032	<0,50	<0,030
Årungselva	above	29	<0,20	<0,020	0,044	<0,50	<0,030
Årungselva	below	24	<0,20	<0,020	0,047	<0,50	<0,030
Årungselva	above	23	<0,20	<0,020	0,064	<0,50	<0,030
Årungselva	below	23	<0,20	<0,020	0,061	<0,50	<0,030
Årungselva	above	22	<0,20	<0,020	0,07	<0,50	<0,030
Årungselva	below	22	<0,20	<0,020	0,066	<0,50	<0,030

Table 14

River	Station	Potassium	Calcium	Cobolt	Chromium	Copper	Lead
Årungselva	above	2900	17000	<0,50	1,6	2,9	0,75
Årungselva	below	2900	17000	<0,50	1,5	2,8	0,75
Årungselva	above	2900	17000	<0,50	1,4	2,8	0,74
Årungselva	below	3000	19000	<0,50	1,3	2,8	0,65
Årungselva	above	2900	17000	<0,50	1,3	2,6	0,64
Årungselva	below	2900	18000	<0,50	1,3	2,7	0,71
Årungselva	above	2600	17000	<0,50	1	3,5	0,5
Årungselva	below	2600	17000	<0,50	<1,0	2,4	<0,50
Årungselva	below	3000	20000	<0,50	<1,0	2,4	<0,50
Årungselva	above	2800	17000	<0,50	<1,0	2,5	<0,50
Årungselva	below	3100	19000	<0,50	<1,0	2,5	<0,50
Årungselva	above	2900	18000	<0,50	<1,0	2,7	<0,50
Årungselva	below	2800	18000	<0,50	<1,0	2,6	<0,50
Årungselva	above	3000	19000	<0,50	<1,0	2,6	<0,50
Årungselva	below	3100	19000	<0,50	<1,0	2,8	<0,50
Årungselva	above	1900	13000	<0,50	<1,0	2,1	<0,50
Årungselva	below	3000	20000	<0,50	<1,0	2,5	<0,50
Årungselva	above	2600	17000	<0,50	<1,0	2,3	<0,50

Årungselva	below	2500	17000	<0,50	<1,0	3	<0,50
Årungselva	above	1600	14000	<0,50	<1,0	1,9	<0,50
Årungselva	below	3100	20000	<0,50	<1,0	2,5	<0,50
Årungselva	above	3200	20000	<0,50	<1,0	2,4	<0,50
Årungselva	below	2000	14000	<0,50	<1,0	2	<0,50
Årungselva	above	3200	20000	<0,50	<1,0	2,3	<0,50
Årungselva	below	1200	9800	<0,50	<1,0	1,7	<0,50
Årungselva	above	2800	18000	<0,50	<1,0	2,8	<0,50
Årungselva	below	3000	19000	<0,50	<1,0	2,8	<0,50
Årungselva	above	3200	19000	<0,50	<1,0	2,7	<0,50
Årungselva	below	2700	18000	<0,50	<1,0	3,6	0,52
Årungselva	above	3200	20000	<0,50	<1,0	2,4	<0,50
Årungselva	below	3300	21000	<0,50	<1,0	2,5	<0,50
Årungselva	above	2400	16000	<0,50	<1,0	2,3	<0,50
Årungselva	below	3400	22000	<0,50	<1,0	2,5	<0,50
Årungselva	above	3300	20000	<0,50	<1,0	2,6	<0,50
Årungselva	below	3400	22000	<0,50	<1,0	2,4	<0,50
Årungselva	above	3400	20000	<0,50	<1,0	2,9	<0,50
Årungselva	below	3400	21000	<0,50	<1,0	2,8	<0,50
Årungselva	above	3500	21000	<0,50	<1,0	2,8	<0,50
Årungselva	below	3500	21000	<0,50	<1,0	2,8	<0,50
Årungselva	above	3600	20000	<0,50	<1,0	2,9	<0,50
Årungselva	below	3600	20000	<0,50	<1,0	3	<0,50
Årungselva	above	3800	19000	<0,50	<1,0	3,3	<0,50
Årungselva	below	3700	19000	<0,50	<1,0	3,3	<0,50
Årungselva	above	3200	17000	<0,50	<1,0	3,3	0,5
Årungselva	below	3600	18000	<0,50	<1,0	3,5	<0,50
Årungselva	above	3900	20000	<0,50	<1,0	3,1	<0,50
Årungselva	below	3900	21000	<0,50	<1,0	3,1	<0,50

Table 15

River	Station	Magnesium	Manganese	Molybdenum	Sodium	Nickel	Silicon
Årungselva	above	3600	68	<1,0	17000	3	4,6
Årungselva	below	3600	62	<1,0	18000	3,2	4,5
Årungselva	above	3700	72	<1,0	18000	2,9	4,4
Årungselva	below	3800	56	<1,0	21000	2,7	4,3
Årungselva	above	3600	82	<1,0	18000	2,7	4,1
Årungselva	below	3700	84	<1,0	21000	2,8	4,4
Årungselva	above	3300	57	<1,0	17000	2,3	4
Årungselva	below	3100	39	<1,0	17000	2,2	3,7

Årungselva	below	3800	34	<1,0	22000	2	3,5
Årungselva	above	3500	39	<1,0	18000	1,7	3,5
Årungselva	below	3800	24	<1,0	22000	1,6	3,4
Årungselva	above	3900	38	<1,0	19000	1,8	3,5
Årungselva	below	3700	40	<1,0	18000	1,7	3,5
Årungselva	above	4000	27	<1,0	19000	1,7	3,4
Årungselva	below	4100	25	<1,0	20000	1,6	3,1
Årungselva	above	2700	19	<1,0	12000	1,3	3,2
Årungselva	below	4100	21	<1,0	20000	1,5	3,2
Årungselva	above	3600	16	<1,0	16000	1,4	3,1
Årungselva	below	3400	17	<1,0	15000	1,5	3
Årungselva	above	2300	12	<1,0	9600	1	2,8
Årungselva	below	4100	12	<1,0	20000	1,4	2,8
Årungselva	above	4200	31	<1,0	18000	1,5	2,6
Årungselva	below	2700	16	<1,0	12000	1,1	2,5
Årungselva	above	4200	17	<1,0	19000	1,4	2,6
Årungselva	below	1700	12	<1,0	8100	<1,0	2
Årungselva	above	3600	19	<1,0	17000	1,5	3,2
Årungselva	below	3900	24	<1,0	19000	1,4	3
Årungselva	above	4000	31	<1,0	17000	1,4	2,6
Årungselva	below	3400	36	<1,0	16000	1,4	2,7
Årungselva	above	4200	13	<1,0	19000	1,3	2,4
Årungselva	below	4300	15	1,1	21000	1,3	2,3
Årungselva	above	3300	17	<1,0	14000	1,3	2,4
Årungselva	below	4500	16	1,1	22000	1,4	2,6
Årungselva	above	4300	17	<1,0	20000	1,3	2,2
Årungselva	below	4400	15	1,1	21000	1,3	2,3
Årungselva	above	4300	12	<1,0	18000	1,7	2,1
Årungselva	below	4200	12	1,1	19000	1,6	2,2
Årungselva	above	4300	21	1	19000	1,4	0,85
Årungselva	below	4400	20	1,2	20000	1,5	1
Årungselva	above	4200	14	<1,0	17000	1,6	1,5
Årungselva	below	4200	17	<1,0	18000	1,5	1,6
Årungselva	above	4000	25	<1,0	15000	1,8	2,1
Årungselva	below	4000	27	<1,0	16000	1,8	2,4
Årungselva	above	3200	64	<1,0	11000	2,1	3
Årungselva	below	3600	59	<1,0	12000	1,9	3
Årungselva	above	4000	140	<1,0	14000	1,9	3,3
Årungselva	below	4100	100	1,2	15000	1,8	3,5

Table 16

River	Station	Iron	Selenium	Zinc	Thallium	Tin
Årungselva	above	1100	<1,0	6,6	<0,50	<1,0
Årungselva	below	980	<1,0	6,5	<0,50	<1,0
Årungselva	above	950	<1,0	6,4	<0,50	<1,0
Årungselva	below	910	<1,0	5,8	<0,50	<1,0
Årungselva	above	850	<1,0	5,7	<0,50	<1,0
Årungselva	below	940	<1,0	6,3	<0,50	<1,0
Årungselva	above	700	<1,0	<5,0	<0,50	<1,0
Årungselva	below	630	<1,0	<5,0	<0,50	<1,0
Årungselva	below	480	<1,0	<5,0	<0,50	<1,0
Årungselva	above	290	<1,0	<5,0	<0,50	<1,0
Årungselva	below	260	<1,0	<5,0	<0,50	<1,0
Årungselva	above	330	<1,0	<5,0	<0,50	<1,0
Årungselva	below	340	<1,0	<5,0	<0,50	<1,0
Årungselva	above	290	<1,0	<5,0	<0,50	<1,0
Årungselva	below	240	<1,0	<5,0	<0,50	<1,0
Årungselva	above	250	<1,0	<5,0	<0,50	<1,0
Årungselva	below	220	<1,0	<5,0	<0,50	<1,0
Årungselva	above	200	<1,0	<5,0	<0,50	<1,0
Årungselva	below	190	<1,0	<5,0	<0,50	<1,0
Årungselva	above	150	<1,0	<5,0	<0,50	<1,0
Årungselva	below	120	<1,0	<5,0	<0,50	<1,0
Årungselva	above	160	<1,0	<5,0	<0,50	<1,0
Årungselva	below	140	<1,0	<5,0	<0,50	<1,0
Årungselva	above	130	<1,0	<5,0	<0,50	<1,0
Årungselva	below	120	<1,0	<5,0	<0,50	<1,0
Årungselva	above	210	<1,0	<5,0	<0,50	<1,0
Årungselva	below	240	<1,0	<5,0	<0,50	<1,0
Årungselva	above	180	<1,0	<5,0	<0,50	<1,0
Årungselva	below	320	<1,0	7,4	<0,50	<1,0
Årungselva	above	110	<1,0	<5,0	<0,50	<1,0
Årungselva	below	110	<1,0	<5,0	<0,50	<1,0
Årungselva	above	140	<1,0	<5,0	<0,50	<1,0
Årungselva	below	120	<1,0	<5,0	<0,50	<1,0
Årungselva	above	92	<1,0	<5,0	<0,50	<1,0
Årungselva	below	96	<1,0	<5,0	<0,50	<1,0
Årungselva	above	140	<1,0	<5,0	<0,50	<1,0
Årungselva	below	140	<1,0	<5,0	<0,50	<1,0
Årungselva	above	93	<1,0	<5,0	<0,50	<1,0

Årungselva	below	99	<1,0	<5,0	<0,50	<1,0
Årungselva	above	150	<1,0	<5,0	<0,50	<1,0
Årungselva	below	170	<1,0	<5,0	<0,50	<1,0
Årungselva	above	240	<1,0	<5,0	<0,50	<1,0
Årungselva	below	260	<1,0	<5,0	<0,50	<1,0
Årungselva	above	330	<1,0	<5,0	<0,50	<1,0
Årungselva	below	310	<1,0	<5,0	<0,50	<1,0
Årungselva	above	320	<1,0	<5,0	<0,50	<1,0
Årungselva	below	320	<1,0	<5,0	<0,50	<1,0

Table 17

River	Station	Titanium	Uranium	Vanadium	Tungsten
Årungselva	above	25	0,58	1,9	<1,0
Årungselva	below	23	0,6	1,7	<1,0
Årungselva	above	22	0,58	1,7	<1,0
Årungselva	below	19	1,1	1,6	<1,0
Årungselva	above	18	0,59	1,5	<1,0
Årungselva	below	22	0,67	1,6	<1,0
Årungselva	above	17	0,59	1,3	<1,0
Årungselva	below	14	0,66	1,2	<1,0
Årungselva	below	11	1	1,1	<1,0
Årungselva	above	7,8	0,54	<1,0	<1,0
Årungselva	below	6,1	0,85	<1,0	<1,0
Årungselva	above	8,2	0,56	<1,0	<1,0
Årungselva	below	8,4	0,56	<1,0	<1,0
Årungselva	above	7,3	0,54	<1,0	<1,0
Årungselva	below	5,4	0,69	<1,0	<1,0
Årungselva	above	6,3	0,42	<1,0	<1,0
Årungselva	below	5,8	0,71	<1,0	<1,0
Årungselva	above	4,8	0,5	<1,0	<1,0
Årungselva	below	4,6	0,59	<1,0	<1,0
Årungselva	above	4	0,38	<1,0	<1,0
Årungselva	below	3,2	0,58	<1,0	<1,0
Årungselva	above	3,6	0,56	<1,0	<1,0
Årungselva	below	3,4	0,49	<1,0	<1,0
Årungselva	above	2,6	0,53	<1,0	<1,0
Årungselva	below	2,3	0,55	<1,0	<1,0
Årungselva	above	5,9	0,49	<1,0	<1,0
Årungselva	below	5,5	0,62	<1,0	<1,0
Årungselva	above	4,6	0,55	<1,0	<1,0

Årungselva	below	12	0,77	<1,0	<1,0
Årungselva	above	2,3	0,55	<1,0	<1,0
Årungselva	below	2,1	0,85	<1,0	<1,0
Årungselva	above	2,4	0,43	<1,0	<1,0
Årungselva	below	2,6	0,83	<1,0	<1,0
Årungselva	above	1,9	0,55	<1,0	<1,0
Årungselva	below	1,8	0,8	<1,0	<1,0
Årungselva	above	4,1	0,53	<1,0	<1,0
Årungselva	below	3,5	0,77	<1,0	<1,0
Årungselva	above	1,8	0,61	<1,0	<1,0
Årungselva	below	2	0,79	<1,0	<1,0
Årungselva	above	3,9	0,52	<1,0	<1,0
Årungselva	below	4,7	0,62	<1,0	<1,0
Årungselva	above	6,4	0,48	<1,0	<1,0
Årungselva	below	6,8	0,54	<1,0	<1,0
Årungselva	above	7,7	0,46	1,1	<1,0
Årungselva	below	7,5	0,54	1,1	<1,0
Årungselva	above	5,1	0,51	1,1	<1,0
Årungselva	below	5,6	0,85	1	<1,0

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