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Does tunnel wash water have an impact on vital rates and displacement of Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) in river Årungselva?

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Nature Management

Preface

This thesis was written at the Faculty of Environmental Sciences and Natural Resource Management (MINA) at the Norwegian University of Life Sciences (NMBU) and is part of my master thesis in Nature management.

I am very interested in learning about the different challenges that brown trout faces in watercourses around the fjord Oslofjorden, to potentially improve the environmental conditions of juveniles and maintain good fishing opportunities for the general public. This assignment therefore looked very exciting.

I would like to thank my supervisor Thrond O. Haugen for the tremendous help with the fieldwork, statistics and writing of the thesis. I would also like to thank Marianne-Isabelle Falk, Elina Lungrin, Adrian Dahle, Sander Lomsdalen, and James Armstrong for all the help with the fieldwork. I would also like to thank the Norwegian Public Roads Administration (NPRA) for financial support of the water sample analyses. Furthermore, I would like to thank Eirin Torgersen, Kai Gundersen, and Ola Rosing Eide from the NPRA for all the information related to tunnel washing routines and the functionality of the Vassum sedimentation pond. Finally, I wish to thank my family for the immense support during the time I spent working on the thesis.

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Abstract

Earlier studies on runoff water from roads and tunnels have demonstrated that such water hold toxic substances that can be harmful to aquatic biota. River Årungselva, which flows into the inner part of Bunnefjorden close to Oslo, Norway, receives discharges from the Vassum sedimentation pond, which in turn receives tunnel wash water irregularly from three tunnels: Nordby, Smiehagen, and Vassum. The main function of the sedimentation pond is to remove contaminants from the tunnel wash water through sedimentation processes before it flows into Årungselva. Earlier studies have revealed that the growth and survival of Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) from Årungselva are lower below the outlet point of the Vassum sedimentation pond than above it. These studies have indicated that salmonids below the outlet point may be adversely affected by runoff from the sedimentation pond due to insufficient treatment of various contaminants. This thesis is a follow-up study to those previous studies.

The aim of this study was to investigate whether there were differences in the concentration of contaminants, growth, survival, and movement between salmonids located above and below the outlet point of the Vassum sedimentation pond to investigate the potential effects of tunnel washing. These surveys were investigated through electric fishing, PIT-tagging, and recapture (detection) of salmonids, and water samples. Electric fishing and PIT-tagging was performed once during September 2020 with three capture rounds on five different stations, two above and three below the outlet point. PIT-tagged individuals were detected in two rounds with a mobile antenna, one round in February and one round in March 2021. The water samples were taken above and below the outlet point, and before and during full washing of the tunnels Nordby, Smiehagen and Vassum in spring 2021.

A total of 405 individuals of Atlantic salmon and 31 individuals of brown trout were caught during one round of electrofishing in September 2020. Of these, 242 Atlantic salmon and 13 brown trout were PIT-tagged; 183 individuals were detected once and 122 were detected twice on the mobile antenna in February and March, respectively. Lower size-specific monthly survival was found for individuals below the outlet point compared with those above it. In addition, a higher degree of movement was found for individuals just below than individuals above and far below the outlet point. These results were found despite lower densities just below the outlet point. Water samples above and below the outlet point did not exhibit significant differences during full washings of the tunnels, although some heavy metals below the outlet point had marginally higher values in some samples.

These results support findings from earlier studies that juvenile salmonids below the outlet point experience poorer conditions compared with individuals above it. Furthermore, this study did not adequately support that those poorer conditions found for salmonids below the outlet point were due to discharges from the Vassum sedimentation pond during tunnel washing. This was due to great variation found for various habitat variables, with sections just below the outlet point having poorer habitat conditions for Atlantic salmon than above it and further downstream.

Sammendrag

Tidligere studier på avrenningsvann fra veier og tunneler har vist at slikt vann inneholder giftige stoffer som kan være skadelig for vannlevende organismer. Årungselva, som renner ut i den indre delen av Bunnefjorden nær Oslo, mottar utslipp fra Vassum sedimentasjonsdam som igjen mottar vaskevann uregelmessig fra tre tunneler: Nordby, Smiehagen og Vassum. Sedimentasjonsdammen har som hovedfunksjon å fjerne forurensninger fra tunnelvaskvannet gjennom sedimenteringsprosesser før det renner ut i Årungselva. Tidligere studier har avdekket at veksten og overlevelsen hos Atlantisk laks (*Salmo salar*) og ørret (*Salmo trutta*) fra Årungselva er lavere nedstrøms utløpspunktet fra sedimentasjonsdammen enn oppstrøms. Disse studiene har indikert at laksefisk nedstrøms utløpspunktet kan påvirkes negativt av utslipp fra sedimentasjonsdammen på grunn av utilstrekkelig rensing av forskjellige kontaminanter. Denne oppgaven er en oppfølgingsstudie til de tidligere studiene.

Målet med denne studien var å undersøke om det var forskjeller i konsentrasjonen av ulike kontaminanter, vekst, overlevelse og bevegelse mellom laksefisk lokalisert oppstrøms og nedstrøms utløpspunktet fra Vassum sedimentasjonsdam for å undersøke de potensielle effektene av tunnelvask. Disse undersøkelsene ble utført gjennom elektrisk fiske, PIT-merking og gjenfangst (deteksjon) av laksefisk og vannprøver. Elektrisk fiske og PIT-merking ble utført én gang i løpet av september 2020 med tre fangstrunder på fem forskjellige stasjoner, to over og tre under utløpspunktet. PIT-merkede individer ble detektert i to runder med en bærbar antenne, én runde i februar og én runde i mars 2021. Vannprøvene ble tatt oppstrøms og nedstrøms utløpspunktet, og før og under full vask av tunnelene Nordby, Smiehagen og Vassum våren 2021.

Totalt 405 individer av Atlantisk laks og 31 individer av ørret ble fanget under én runde med elektrofiske i september 2020. Av disse ble 242 Atlantisk laks og 13 ørret PIT-merket; 183 individer ble oppdaget én gang og 122 ble oppdaget to ganger på den bærbare antennen i februar og mars. Lavere størrelsesspesifikk månedlig overlevelse ble funnet for individer nedstrøms utløpspunktet enn oppstrøms. I tillegg ble det funnet en høyere grad av forflytning for individer rett nedstrøms enn individer oppstrøms og lenger nedstrøms utløpspunktet. Disse resultatene ble funnet til tross for lavere tettheter rett nedstrøms utløpsstedet. Vannprøver tatt oppstrøms og nedstrøms utløpspunktet viste ikke tydelige forskjeller under tunnelvask, selv om noen tungmetaller under utløpspunktet hadde marginalt høyere verdier i noen prøver.

Disse resultatene støtter funn fra tidligere studier om at juvenile individer av laksefisk nedstrøms utløpspunktet opplever dårligere forhold sammenlignet med individer oppstrøms utløpspunktet. Videre støttet ikke denne studien tilstrekkelig at de dårligere forholdene som ble funnet for laksefisk nedstrøms utløpspunktet var på grunn av utslipp fra Vassum sedimentasjonsdam under tunnelvask. Dette skyldtes stor variasjon funnet for ulike habitatvariabler, med strekninger rett nedstrøms utløpspunktet som hadde dårligere habitatforhold for Atlantisk laks enn oppstrøms og lenger nedstrøms utløpspunktet.

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1. Introduction

It is well known that disturbances by human beings are threatening biodiversity in many areas of the world. The seven main threats to biodiversity are “habitat destruction, habitat fragmentation, habitat degradation (including pollution), global climate change, the overexploitation of species for human use, the invasion of exotic species, and the increased spread of disease” (Primack, 2012, p. 79). Habitat degradation in the form of pollution of aquatic ecosystems is basically caused by human-related alterations, such as agricultural and urban activities, in the catchment of a specific water body (Carpenter et al., 2011). This includes runoff water from roads, which can be a serious source of pollution to the aquatic environment (e.g., Grung et al., 2016; Mahrosh et al., 2014; Meland et al., 2010a; Sandahl et al., 2007). This is because runoff water from roads often contains, in addition to natural nutrients and particles, various organic and inorganic contaminants (Amundsen & Roseth, 2004; Snilsberg et al., 2002). In this context, tunnel wash water often has higher concentrations of contaminants than runoff water from roads. This may be due to the fact that contaminants become more concentrated over time between washing events and air dust collects in the tunnel (Paruch & Roseth, 2008). Yet, in relation to road runoff, much less research has been conducted on the effect of tunnel wash water on the aquatic environment (Barbosa et al., 2007; Meland et al., 2010c).

Many of the highways and associated tunnels established since 2000 have associated sedimentation ponds for decontaminating runoff water from road pavement, nearby constructions, and tunnel wash (Andersson et al., 2018; Sun et al., 2018). Sedimentation ponds remove pollutants through sedimentation and degradation (Åstebøl & Hvitved-Jacobsen, 2014); however, the uptake of dissolved substances into plant biomass and the adsorption of substances on solid surfaces can also be substantial during the process (Grung et al., 2016; Weiss et al., 2006). Although sedimentation ponds capture a high proportion of road contaminants, great variation has been found in how effectively sedimentation ponds can capture contaminants. Potential exists for such ponds to release a “cocktail” of contaminants into receiving water courses (Meland et al., 2010b; Starzec et al., 2005; Vollertsen et al., 2009; Wium-Andersen et al., 2011).

The outlet point of sedimentation ponds is usually linked to downstream water courses (water recipients) and pond overflow can expose aquatic organisms in the downstream watercourses.

There is broad agreement that fish are a good bioindicator for testing for changes in the aquatic environment due to different anthropogenic stressors such as pollution from contaminants (e.g., Authman et al., 2015; Chovanec et al., 2003; van der Oost et al., 2003); therefore, fish are frequently used as bioindicators in aquatic ecotoxicological studies. When water bodies are more or less contaminated, direct toxic effects are possible in fish, mainly through "direct uptake from the gills or skin (bioconcentration)" or through uptake from digestion of contaminated food (biomagnification; van der Oost et al., 2003, p. 65). Toxic effects can be lethal or sublethal, with sublethal effects being of great concern since they are widespread and have the potential to change fish communities. This can occur through internal detoxification processes, which can further change the behavior (e.g., predator avoidance, foraging, and competition) in a negative manner, or by changing other physiological processes (e.g., decreased reproductivity; Beyer et al., 2014; Kime, 1999; Scott & Sloman, 2004). This makes fish an excellent bioindicator due to their ability to accumulate various toxicants in their tissues, although the concentrations of various contaminants in fish (xenobiotics) are determined by the balance of "uptake, storage and elimination" (Chovanec et al., 2003, p. 643). The effects of pollution can also have an indirect (or secondary) effect on fish stocks, although they are tolerant of the direct effects of toxicants. That is, even if the pollution does not significantly affect a particular species directly, it can affect the competitor, prey, or parasite, which in turn will make the abundance of the particular species either increase or decrease (Fleeger et al., 2003; Preston, 2002).

To document effects of contaminants on fish, it is possible to use a "top-down" approach for describing the patterns observed in higher biological levels such as populations and communities (Munkittrick & McCarty, 1995). By sampling or observing organisms in their natural habitat, it is possible to find patterns that indicate the effects of anthropogenic contamination (Adams, 2003; Kendall et al., 2001). When conditions in rivers are characterized by pollution coming from a single outlet source (point source pollution), it is possible to compare individuals below the outlet point with individuals above (reference site) through observations and/or sampling in field studies (Armon & Starosvetsky, 2014; Baker, 1991; Cairns, 1986). Furthermore, there is often a lack of movement data on fish that have been exposed to discharges of contaminants below an outlet point relative to fish that reside above in field studies. This is interesting as fish exposed to contaminants usually exhibit avoidance behavior against contaminants (Tierney, 2016).

This thesis is a follow-up study to earlier studies conducted to investigate the effects of tunnel wash water on the stock of Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) in River Årungselva (Dybwad, 2015; Meland et al., 2010b; Meland et al., 2010c; Skarsjø, 2015; Solberg, 2016). The study area consisted of three tunnels and the road sections between them, which are directed to a single sedimentation pond (Vassum) for decontamination processes after stormwater and tunnel wash runoff. Overflow water from the sedimentation pond is further directed to Årungselva. Therefore, studies have investigated whether overflow episodes have negative impacts on salmonids that live in the river, which would indicate that the sedimentation pond is not working adequately. Meland et al. (2010b) found that the growth of 0+ parr of brown trout in the river was 21 % shorter below the outlet point of the sedimentation pond compared with 0+ brown trout above the outlet point. Both Dybwad (2015) and Skarsjø (2015) have investigated various biomarkers in brown trout, and their results indicated that brown trout in the river were affected both by runoff from the highway and runoff from the sedimentation pond. This was based on individuals above the outlet point but below the highway sections having higher values of some biomarkers compared with individuals below the outlet point. Solberg (2016) explored the effects of contaminants on the individual growth, survival, and movement of Atlantic salmon and brown trout in Årungselva. He found lower size-adjusted survival in both species below the outlet point compared with above it. In addition, he found lower length-at-age among 0+ parr of brown trout and 1+ parr of Atlantic salmon, and lower length at first winter for Atlantic salmon parr below the outlet point compared with those in above sections.

The following questions and hypotheses were addressed in this study:

1. Are there any differences in 0+ size, survival, and movements between juvenile salmonids in Årungselva located above and below the outlet point of the Vassum sedimentation pond?
2. Does the Vassum sedimentation pond adequately remove contaminants from runoff water from tunnel wash before it enters Årungselva?

I hypothesized that juvenile salmonids below the outlet point suffered both lethal and sublethal effects from discharges from the outlet point in the terms of reduced growth; had lower survival; and moved more up- and downstream compared with individuals above and far below the outlet point. In addition, I hypothesized that sections below the outlet point had higher concentrations of contaminants than sections above it due to the insufficient removal of contaminants from tunnel wash water in the Vassum sedimentation pond.

2. Materials and methods

2.1. Study area

The study was conducted in Årungselva, which originates from the lake Årungen and empties into the inner part of the fjord Bunnefjorden (Figure 1). The length of the river is 2.5 km and the drainage area is 52 km^2. The river discharge vary between seasons from 0 m^3 s^{-1} to 25 m^3 s^{-1}, with stretches of the river potentially dried up in late summer, while spring and autumn are characterized by increased water flow. Although reaches of the upper part of the river may be dried up during periods of drought, the lower parts of the river may still retain a minimum water flow from groundwater discharge (Borgstrøm & Heggenes, 1988).

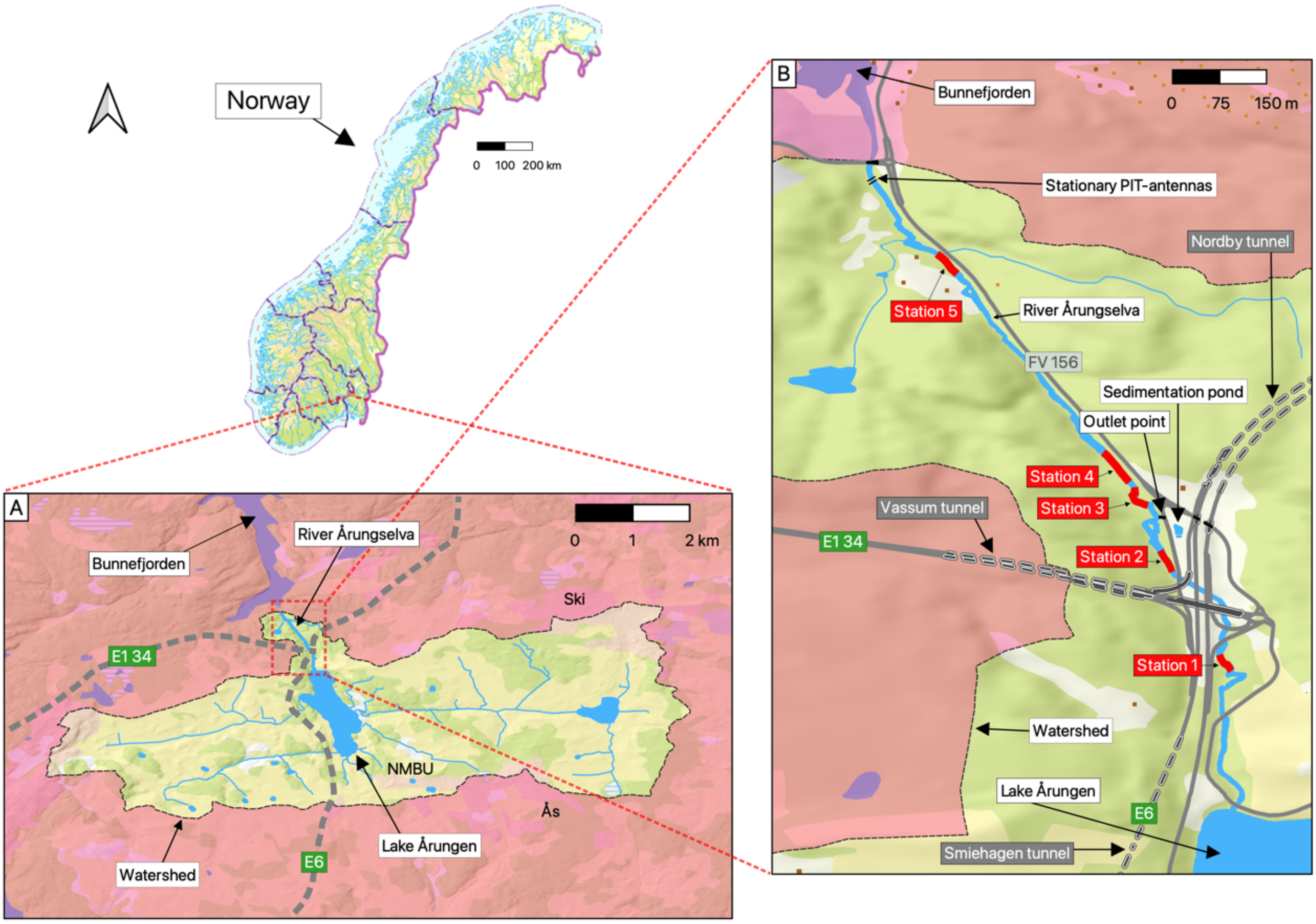

Figure 1*. Location of the study area in Norway, catchment of river Årungselva (A), and river Årungselva (B). Sampling stations (red lines), tunnels (gray dashed lines (B)), river Årungselva (blue line (A)), stationary PIT-antennas and outlet point (black points (B)) and sedimentation pond (blue polygon (B)). Map source: The Norwegian Mapping Authority.*

Approximately 900 m downstream of the lake Årungen outlet (airline distance), a sedimentation pond established in spring 2000 receives tunnel wash water from the Nordby, Smiehagen and Vassum tunnels as well as runoff from 17,000 m^2 of road surfaces from the areas between the tunnels (Meland et al., 2010b; Snilsberg et al., 2002; Åstebøl et al., 2012). In accordance with the road map of the Norwegian Public Roads Administration (NPRA, 2020), the Nordby tunnel was opened to traffic in 1993 and has a length of 3860 m (four lanes); the Smiehagen tunnel was opened to traffic in 1999 and has a length of 923 m (two lanes); and the Vassum tunnel was opened to traffic in 2000 and has a length of 368 m (four lanes). According to the NPRA´s washing plan for 2019–2021 (Appendix B), the Nordby and Smiehagen tunnels should have approximately two full washings and four half washings each year, whereas the Vassum tunnel should have five half-washings and two full washings during the same period.

Washing is performed by three trucks, where the first truck sweeps and removes dirt and particles from the tunnel before the next truck adds water and detergent, whereas the third truck flushes the surfaces. Finally, the sweeping truck drives through the tunnel one more time to sweep and suck up water and sludge after the flushing (Gundersen, NPRA, 2021; Snilsberg et al., 2002; Torp & Meland, 2013). The container of the sweeping truck used to be emptied in a place that drains further into the sedimentation pond (Snilsberg et al., 2002), but today only excess water in the sweeping truck is released into road grates, which further flows through gullies before being released into the sedimentation pond (Gundersen, NPRA, 2021). The use of detergent in the wash water varies, but is usually 0.2–5 % of the total wash water used (Garshol et al., 2016). Based on estimates with flushes using low-pressure nozzles, the water used during a full wash of a two-lane tunnel is approximately 40–70 L/m, whereas washing of the walls only (i.e., a half wash) is estimated to use 20–30 L/m. Water used in a two-tube tunnel with four lanes is estimated to be 80–140 m^3/km for a full wash and 60 m^3/km for a wall wash (Åstebøl et al., 2012; Åstebøl & Hvitved-Jacobsen, 2014). Furthermore, the water that runs offs into the sedimentation pond from the washing process is estimated, dependent on weather conditions, to be between 70–90 % of the washing water used, as much of the water evaporates, infiltrates into cracks, and adsorbs into surfaces, or disappears through the actions of the truck that sweeps and sucks (Torp & Meland, 2013). Wash water from the Smiehagen and Vassum tunnels drains into the pond by fall, whereas wash water from the Nordby tunnel is pumped into the pond (Garshol et al., 2016; Åstebøl et al., 2012).

The sedimentation pond is divided into two basins, with the uppermost being a small pre sedimentation magazine (50 m^2) that accumulates coarse sediment, and the lowermost being the main basin (500 m^2) that accumulates more fine sediments (Figure 2; Snilsberg et al., 2002; Åstebøl et al., 2012). The lowermost basin has an adjustable water depth between 0.6 and 1.2 m. To ensure sufficient degradation of detergent substances and sedimentation of smaller particle-bound and dissolved contaminants, a minimum of two weeks must elapse before further discharges from the pond (Åstebøl & Hvitved-Jacobsen, 2014).

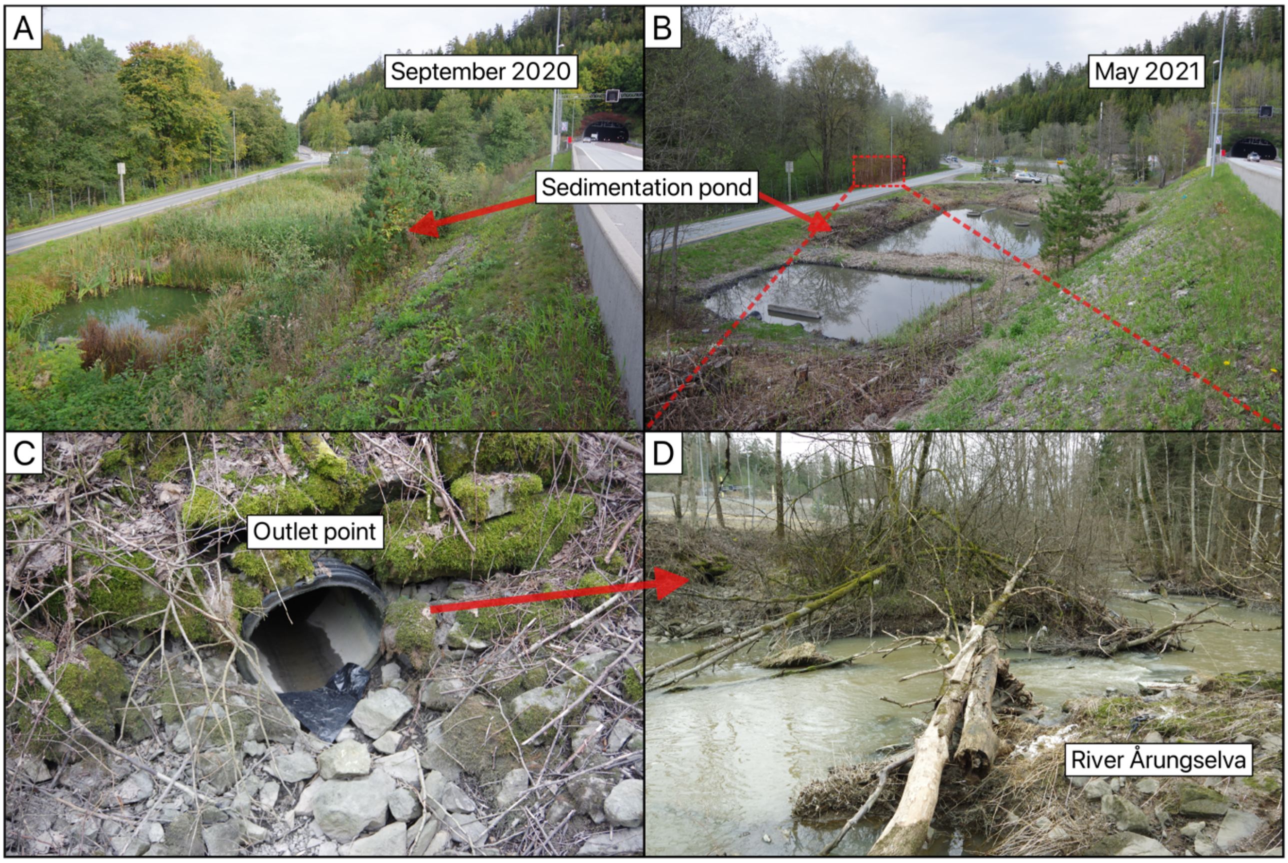

Figure 2. *Photos (A) and (B) show the sedimentation pond in September and May, and photos (C) and (D) show the appearance and location of the outlet point. Photo: Amund Dahle.*

2.2. Study species: Atlantic salmon and brown trout

2.2.1. Life history

The Atlantic salmon is found in ocean areas between Europe and North America (Hansen & Quinn, 1998), whereas the brown trout is native to Europe, North Africa and West Asia, but is now distributed all over the world by man (Klemetsen et al., 2003). Atlantic salmon and brown trout are present in sympatry in many rivers and their anadromous life cycles are highly similar (Figure 3; Heggberget et al., 1988). Both Atlantic salmon and brown trout spawn in running water mainly from the middle of autumn (October) to early winter (December) in Norway, with brown trout usually spawning slightly earlier (Heggberget, 1988; Heggberget et al., 1988; Lura & Sægrov, 1993). The variation in peak spawning time is highly dependent on altitude, latitude, temporal variation among years (weather), and local conditions; specifically, the lower the water temperature, the earlier the spawning and the longer the egg incubation period (Elliot, 1984; Ojanguren & Brana, 2003; Saltveit & Brabrand, 2013). Both species lay their eggs in suitable gravel (size and shape) at places with sufficient flow conditions to ensure that the eggs receive enough oxygen (Louhi et al., 2008). The eggs hatch into alevins during spring to early summer and after resorption of the yolk-sac emerge from the gravel protection to become a juvenile in the river called parr (Crisp, 1996; Klemetsen et al., 2003). After approximately 2–4 (1–8) years in the river, dependent on factors such as environmental conditions and growth of the fish, the parr of both anadromous Atlantic salmon and brown trout smoltify during the spring to early summer (Hutchings & Jones, 1998; L'Abée-Lund et al., 1989). Smoltification is a process whereby “behavioral, morphological, and physiological” changes in the parr prepare it for a life in the sea. Some of the changes include morphological transition from a dark brown suit with vertical bands (parr marks) to a silvery suit without parr marks and higher tolerance of saline water (McCormick, 2012, p. 199). Most Atlantic salmon and anadromous brown trout feed in the sea around 1–3 years before they mature and migrate to their natal river to spawn (Jones & Hutchings, 1998; Jonsson & L'Abée-Lund, 1993; L'Abée-Lund, 1991). The rate of repeat spawners (iteroparity) will varies both temporally and between different rivers, but a substantial part of the stock usually dies after spawning each year. According to Fleming (1998), brown trout are more iteroparous than Atlantic salmon.

Moreover, brown trout can use a wide range of aquatic habitats such as rivers and lakes and can even become anadromous and migrate to the coast where they might remain for most of their life (Jonsson, 1989; L'Abée-Lund et al., 1989). Atlantic salmon are characterized more as an anadromous and pelagic salmonid species (Marschall et al., 1998) although freshwater resident populations exist (Hutchings et al., 2019). Anadromous populations of Atlantic salmon and brown trout are often divided into subpopulations of freshwater residents (mainly males) and sea-running migrants (more females than males) in the same river (Jonsson & Jonsson, 1993). Thus, males either migrate to later become large mature “competitors” at spawning redds or stay in the rivers as mature male parr attempting to "sneak fertilize" between larger individuals during spawning (Fleming, 1996), although freshwater residents can move to sea anytime (Jonsson et al., 2017; Nevoux et al., 2019).

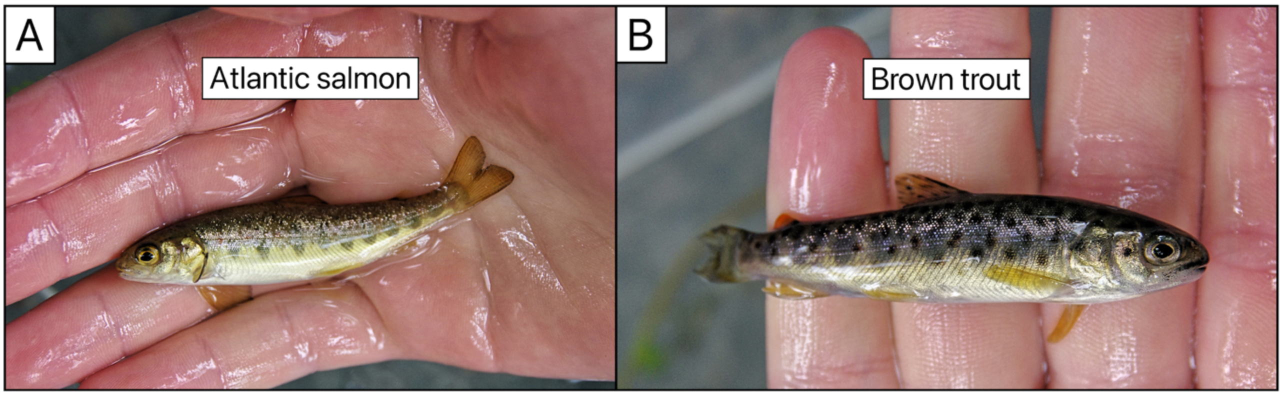

Figure 3. *0+ parr of Atlantic salmon (A) and brown trout (B) from Årungselva. Photo: Amund Dahle.*

2.2.2. Habitat preferences of juveniles

When juvenile Atlantic salmon and brown trout are sympatric in the same river, Atlantic salmon exhibit a narrower spatial niche distribution in relation to the available habitat compared with a river with Atlantic salmon alone because of the more competitive brown trout (Bremset & Heggenes, 2001; Harwood et al., 2001; Heggenes, 1991; Heggenes et al., 1999). In general, brown trout are expected to dominate over Atlantic salmon in narrower and smaller rivers than in larger and wider rivers (Armstrong et al., 2003; Nevoux et al., 2019). Although there is an overlap in habitat use between the species to some degree when they live in sympatry, the general pattern in rivers is that Atlantic salmon parr use shallow and faster-flowing habitats, whereas larger brown trout parr use slower-flowing and deeper pools and smaller brown trout use the shallowest parts. Larger individuals of both species will generally stick to deeper and coarser sites (Crisp, 1996; Heggenes et al., 1999; Heggenes & Saltveit, 1990; Morantz et al., 1987). Furthermore, they both prefer coarse and rocky substratum, with Atlantic salmon being more selective of coarser substrate, whereas brown trout can use finer and more varied substratum if there are areas to hide in nearby, such as undercut river banks (Bohlin, 1977; Bremset, 2000; Bremset & Heggenes, 2001; Gibson, 1993; Heggenes & Dokk, 2001; Heggenes et al., 2002; Hesthagen, 1988). Both Atlantic salmon and brown trout generally have a preference for riparian vegetation cover to some degree with variation in shaded and lighted habitats, and the height from vegetation to water surface is important.

Furthermore, such vegetation can increase hiding places and food supply (Dineen et al., 2007; Heggenes & Traaen, 1988; Moring et al., 1985; McCormick & Harrison, 2011). Because Atlantic salmon are more adapted to faster water velocities (e.g., because of their larger pectoral fins and lower body depth), they can be more competitive than brown trout in such conditions (Berg et al., 2014; Bremset & Heggenes, 2001; Riddell & Leggett, 1981). Changes in the use of different habitats can also be expected with changes in the environment, such as season, daylight, temperature, and waterflow (Armstrong et al., 2003; Heggenes, 1996; Heggenes et al., 1999).

2.3. Sampling and handling of the fish

Sampling in the form of electrofishing was conducted once during the field period at five different stations (Figure 1) in Årungselva. This one round consisted of three capture rounds (removals) at each of the five stations in the river during September 2020 (Appendices A and B) to provide estimates on the density of Atlantic salmon and brown trout in the river. The captures were completed in September because estimates would be safer due to the good catchability of 0+, since they would have grown large enough during summer. In addition, temperature, water clarity, and water flow were optimal during this period, which facilitated good catchability.

The sampling gear used to capture salmonids in Årungselva was an electrofishing apparatus of type GeOmega FA-4 35-70 Hz, pulsed-DC (Terik technology, Levanger, Norway). The electrofishing apparatus was composed of three major parts: a battery that supplied power, a transformer that controlled the current and pulse, and electrodes that transmitted the pulse into the water. The battery and transformer were carried in a backpack. Of the electrodes, the anode was at the end of a handheld rod with an iron ring at the end and the cathode was located in the water held by a hanging wire from the backpack. The transformer controlled the current from the battery to varying degrees of voltage and controlled the way the pulse was emitted from the electrodes. When the current moved in the "correct" direction, the fish were pulled toward the anode and repelled by the cathode. What happens when one fishes with electricity is that the tension in the body of the fish increases above a certain level, thus immobilizing them. When one performs electrofishing with direct current, the fish will first attempt to swim away from the anode through a fear response (negative electrotaxis). As the fish gets closer to the anode, it will be pulled toward the anode (positive electrotaxis) by constantly swimming faster toward it. Finally, the fish will become completely anesthetized and immobilized (galvanonarcosis; Bohlin et al., 1989).

Factors that may affect the reaction distance from the anode to the fish are the current line density, pulse type of the current, size of the fish, species, position of the fish relative to the anode, habitat, and whether the fish has been electrocuted before. The larger the fish, the more efficient it is to electrically fish for a particular species. An earlier study observed decreased catchability for fish that have been exposed to an electric shock, but there is more uncertainty linked to this (Bohlin et al., 1989). The actual fishing strategy was conducted by electrofishing slowly upstream at each station in a meandering line from one side to the other side of the river (Jones & Stockwell, 1995).

When the electrofishing was conducted, there were always two people working together: one controlled the electrofishing apparatus in addition to the net in the other hand, while the other person carried a catch container (black bucket) and a net (Bohlin et al., 1989). It was crucial that the water in the bucket was replaced regularly during the fishing so that oxygen and temperature levels remained optimal during the field work (Landman et al., 2005). To avoid oxygen problems with the fish in the buckets during the time required for electrofishing, PIT-tagging and registration of the fish, the fish were dropped into laundry baskets with sufficiently small holes (i.e., even the smallest fish could not swim through them) that were placed directly below the station being sampled (Figure 4). Small stones were placed in the baskets to ensure that they remained in the river. Three baskets were used to separate the fish from the three capture rounds. In addition, the baskets were black in color to keep the fish as relaxed as possible. After all the fish were caught within the station, they were anesthetized with benzocaine before being further analyzed and tagged (Figure 5). In this study, a product named Benzoak (ACD Pharmaceuticals AS, Leknes, Norway) was used, which is a ready mixed benzocaine mixture; 2–3 mL of Benzoak was used in a 10 L bucket of water (ACD Pharmaceuticals AS, 2017), with some modifications according to temperature.

Figure 4. *Laundry baskets placed below station 3. They were used as a temporary holding nets during the time required for electrofishing and PIT-tagging. Here, Sander Lomsdalen places salmonids in the laundry basket. Photo: Amund Dahle.*

Figure 5. *Registration and PIT-tagging of salmonids executed by me. Photo: Adrian Dahle.*

All Atlantic salmon and brown trout individuals in the samples were registered while individuals over 6 cm also were tagged with PIT-tags (passive integrated transponders) during the field work. Notably, those that were caught in the second and third removals received too much electricity, and therefore, they were not PIT-tagged. The fish first had their length measured and then the species was determined visually. To separate Atlantic salmon from brown trout, several traits were recognized as differences between the species. While Atlantic salmon often had a slight trace of olive, the brown trout were often more brown/black. Furthermore, the brown trout were much redder in the adipose fin and often had a white line in the lowermost rays in the anal fin. Atlantic salmon also had much clearer transverse parr marks on the body side, more streamlined bodies, and deeper forked tails. Finally, Atlantic salmon maxilla bone was smaller than in brown trout where the former reached to the middle of the eye and the latter at or beyond the posterior end of the eye. The length was measured from the snout end to the inner fork of the tail in mm precision (fork length) for all fish in capture round one at each station (except stations 1 and 2, where total length was measured), and fish in capture rounds two and three were measured from the snout end to the tail tip (total length). Furthermore, each fish was injected with an ethanol disinfected PIT-tag into the body cavity. A scalpel was used to make a ventral incision in the fish where the PIT-tag was placed. Fish having fork length >6 cm and <8 cm were injected with a 12-mm tag; those >8 cm and <12 cm with a 14-mm tag and >12 cm with a 23-mm tag (HDX PIT-tags, Oregon RFID, Portland, United States). After tagging, the injected tags were identified and noted with a handheld FDX/HDX reader (FDX/HDX datatracer reader, Oregon RFID, Portland, United States). This was displayed by the 12-digit numeric code unique to each tag.

2.4. PIT-telemetry

A mobile antenna was used to detect movements of PIT-tagged individuals between the sampling round in September and the recapture (detection) round in February, and between detection rounds in February and March (Appendix B; Figure 6). The equipment consisted of a single-antenna reader box (HDX single-antenna PIT-tag reader, Oregon RFID, Portland, United States) in a backpack, powered by an external lithium-ion battery (6.5 Ah 14.4 V), which was further connected to a handhold rod with a plastic ring at the end (50 cm diameter). It detected individuals with PIT-tags in the river in a range of approximately 30–50 cm from the detecting ring. The detection strategy was to walk upstream along Årungselva in a meandering line from the outlet point of the river by Bunnefjorden and approximately 50–60 m past the upper station (station 1).

Figure 6. *Scanning for PIT-tagged salmonids in Årungselva in February using a mobile antenna. Photo: Amund Dahle.*

The current from the mobile antenna created an electromagnetic field to detect the PIT-tags as they passed the PIT-antenna. The electromagnetic field provided energy that activated the copper coil in the PIT-tags when they passed the PIT-antenna. The copper transmitted a radio frequency signal back to the mobile antenna, and with this the antenna reader could capture the alphanumeric code for the particular PIT-tag. All data captured in the antenna reader were stored in a program where information about the PIT-tags were recorded. Additionally, a track-log was recorded simultaneously on a handheld GPS (Garmin Montana 680) as the detection started to later calibrate the detection time of PIT-tags with the track-log time on the GPS. To synchronize the time between the antenna reader and the GPS, a test PIT-tag was detected when each round started and ended (Roussel et al., 2000; Zydlewski et al., 2006). The efficiency of the antenna with respect to the detection of PIT-tags can be expected to have been limited by the conditions created by water flow and inaccessible areas of the river (Hodge et al., 2015). To capture and transfer the data from the PIT-tags from the antenna reader to the computer, the terminal program CoolTerm (Meier, 2021) was used. Two stationary PIT-antennas were also mounted close to the outlet point of the river (Figure 1) in spring of 2021 to obtain data on quantity, sizes, and timing of smolting individuals, but data from these antennas were not used in this study due to lack of relevance.

2.5. Fish density

Fish density was calculated at each station using the removal method of population size estimation (Seber & Cren, 1967). I used three-pass removals to estimate population size at each station. This method estimated the catchability at each station by using catch numbers from each round. With the use of the catch numbers per pass and catchability, a station population size can be estimated. By dividing the population size estimate per station on the stations area a density estimate can be calculated for each station. It was crucial that the same effort was exerted in the fishing in all removals to ensure that the probability of catching fish in the second and third rounds was the same as that in the first round (i.e., the same conditions and little intrapopulation variation in behavior). Furthermore, individuals exposed to electrofishing had to have the same probability of being captured (Seber & Cren, 1967; Zippin, 1958). In addition, there had to be "no recruitment, mortality, immigration or emigration between the times" of the fishing rounds (Seber & Cren, 1967, p. 633).

2.6. Water sampling

Water samples were taken above (station 2) and below (station 3) the outlet point of the Vassum sedimentation pond before and during tunnel washing. The water samples were sent for analysis to Eurofins in Moss, Norway. The following contents were measured: heavy metals (arsenic [As], cadmium [Cd], chromium [Cr], copper [Cu], lead [Pb], nickel [Ni] quicksilver [Hg], and zinc [Zn]) and polycyclic aromatic hydrocarbons (PAHs; acenaphthene, acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo[b]fluoranthene, benzo[ghi]perylene, benzo[k]fluoranthene, dibenz[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, naphthalene, phenanthrene, pyrene, and triphenylene). The samples of heavy metals and PAHs were collected in separate bottles; specifically, heavy metals were in plastic bottles and PAHs were in glass bottles (because PAHs react with plastic). The total content of the measured contaminants – both particle-bound and dissolved contaminants (digested water samples) – were measured.

2.7. Habitat mapping

The variation in environmental conditions between the stations was measured using the habitat variables of water depth, surface water velocity, substrate sizes, shelter availability (degree of cavities in the substrate), number of pieces of dead wood (woody debris and twigs), number of pools, benthic algae cover, moss cover and vegetation cover separated in shaded water, flood zone, and river edge (Table 1). The rationale of habitat mapping was to correct for habitat effects that could not be associated with the effects of being above/below (categoric variable) the Vassum outlet point. Because the habitat conditions were not the same above and below (Figure 7, Table 1) the outlet point, I needed to correct for or test whether the differences in response variables (e.g., survival) I found were as easily attributable to other environmental factors than those caused by discharges from the sedimentation pond.

The values obtained at each station for the different variables were entered into a google-form application created by my supervisor (Haugen, 2021). River width, water depth, surface water velocity, substrate size, shelter availability, moss cover, cover of benthic algae, vegetation shading water, vegetation cover – flood zone, and vegetation cover – river edge were measured at five transects at each station, whereas the number of pools (>2 m^2 still water) and pieces of dead wood (>10 cm diameter of woody debris and >1 length of twigs) were counted at each station. Then, mean values for each habitat variable at each station was found by dividing the total value from all transects from the specific station. Water depth was measured from the riverbank across the river to the other side at five spots: 10, 25, 50, 75, and 90 %. Surface water velocity was measured by observing how far (cm) a leaf on the water surface drifted in one second. Moss cover and cover of benthic algae at each transect was measured to have either 1–33, 34–66 or >66 % cover. The vegetation cover variables flood zone and river edge at each transect was measured to have either 1–25, 26–50, 51–75, 76–90, or >90 % cover, while vegetation shading water was set to %-value in degree of cover. The percentage distribution of substrates of different sizes was measured at each transect: 0–2 mm, 2–20 mm, 20–100 mm, 100–250 mm and, >250 mm. The cavities in the substrate were measured to consider access to hiding places for parr. This was measured with a 13-mm diameter plastic hose with marked lengths. We applied one random point on each of our transects to a frame measuring 50 × 50 cm, and measured the number of places at which we could move the tube into the cavity in the substrate as well as how deep into the substrate it could be guided. The marked lengths were divided into three categories: 2–5 cm, 5–10 cm, and >10 cm (Forseth &

Harby, 2013). Both larger substrates and deeper cavities were weighted more in the calculations of mean values at each station, allowing for more accurate station-specific values.

Table 1. *Values obtained for different habitat variables at each station. Mean value and standard deviation were calculated from five transects of each station for all variables, except for pools and pieces of dead wood, which were counted. Number of pools were counted as >2 m² of still water. Pieces of dead wood was measured as either woody debris with diameter >10 or twigs with length >1 m. Shelter availability was divided into three classes; (<5) low shelter, (5–10) moderate shelter, and (>10) high shelter (Forseth & Harby, 2013).*

Station	**1**	**2**	**3**	**4**	**5**
Area (m²)	135.36	199.7	232.63	279	158.34
Station length (m)	28.2	31.4	37.4	50	27.3
River width (m)	4.8 ± 0.6	6.36 ± 0.5	6.22 ± 0.87	5.58 ± 0.55	5.8 ± 2.13
Water depth (m)	0.36 ± 0.07	0.28 ± 0.04	0.40 ± 0.19	0.46 ± 0.11	0.29 ± 0.05
Surface water velocity (m/s)	0.36 ± 0.1	0.26 ± 0.02	0.18 ± 0.03	0.14 ± 0.02	0.56 ± 0.07
Substrate size (mm)	382.44 ± 77.75	138.88 ± 37.62	42.97 ± 35.82	44.56 ± 36.51	320.02 ± 139.1
Shelter availability	6.4 ± 6.02	1.6 ± 2.61	3.8 ± 3.9	4.6 ± 6.39	10.4 ± 7.23
Number of pools	0	2	5	4	3
Number of pieces of dead wood	3	10	50	11	1
Vegetation shading water (%)	36 ± 23.82	74 ± 31.5	55 ± 40	94 ± 8.94	58 ± 38.99
Vegetation cover – flood zone (%)	17.2 ± 11.63	27.4 ± 22.86	43 ± 11.18	48 ± 13.69	32.8 ± 11.63
Vegetation cover – river edge (%)	43 ± 11.18	32.8 ± 11.63	63 ± 0	58 ± 11.18	27.6 ± 14.24
Moss cover (%)	27.8 ± 26.39	16 ± 0	9.6 ± 8.76	4.1875 ± 7.88	55 ± 11.18
Cover of benthic algae (%)	16 ± 0	16 ± 0	22.8 ± 15.21	29.6 ± 18.62	12.8 ± 7.16

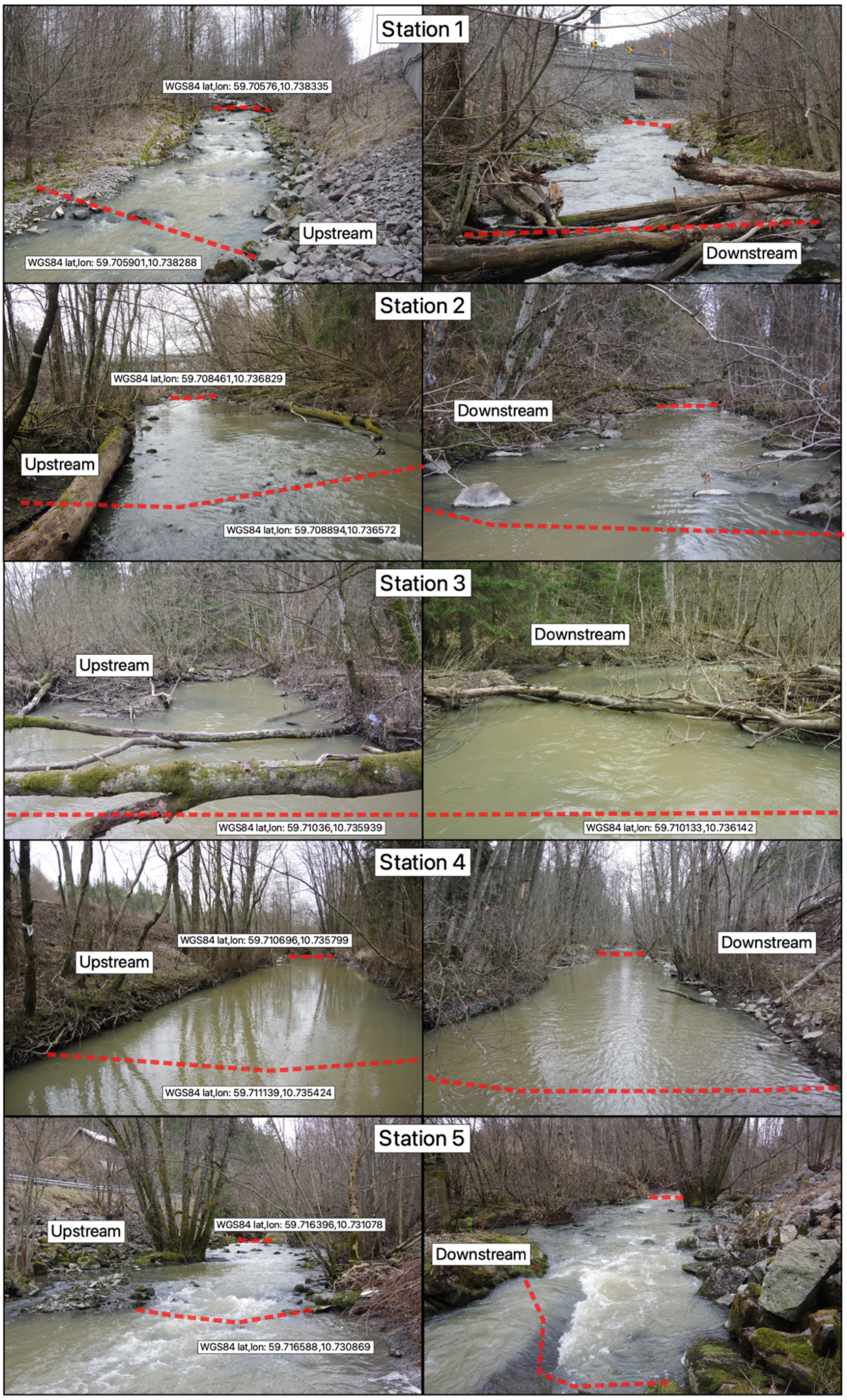

***Figure** 7. Photos of up- and downstream directions of each of the five sampling stations. Coordinates of the upper and lower boundaries of each station have also been added to the photos. Coordinates are listed in decimal degrees in geodetic datum WGS-84. Photo: Amund Dahle.*

2.8. Data processing and statistical analyses

2.8.1. Programs and software

The program QGIS version 3.10 (QGIS Development Team, 2019) was used when the maps were created. Layers for the maps were obtained from the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Mapping Authority (Kartverket).

All data illustrated in the figures were produced using the statistical computing software R (R Core Team, 2020) and RStudio (RStudio Team, 2020). RStudio was used to create meaningful plots by analyzing and handling the data. All the data were prepared in Microsoft Excel (Microsoft Corporation, 2021) before being used in RStudio in a csv-file. The packages AICcmodavg (Mazerolle, 2020), FSA (Ogle et al., 2021), ggplot2 (Wickham, 2016), ggrepel (Slowikowski, 2021), lme4 (Bates et al., 2015), and lubridate (Spinu, 2021) were used in RStudio. In addition, program MARK was used to estimate detection- and survival probability after preparing the capture history of individuals in Excel. A text file (.inp) was used in program MARK.

2.8.2. Quantitative analyses

There was fitted generalized linear models (GLM; McCullagh & Nelder, 1989) for survival and movement and generalized linear mixed models (GLMM; Bolker et al., 2008) for correlates of 0+ size variation in the statistical modelling. For all analyses, the alpha level (significance level) was set to 0.05. To test which variables (both categorical and continuous) had the most explanatory power regarding variation in correlates of 0+ size variation, survival and movements among individuals, model selection based on the Akaike information criterion (AIC) was used to find the model with most support from the data (Akaike, 1974). The model that attained the lowest AIC value was selected. This selected model attained most AIC-support in the data, meaning it had the most optimal balance between explained variation and model complexity (i.e., number of parameters). This was done by estimating AIC-values for candidate models that reflected different hypotheses on effects on a given response variable (e.g., 0+ size). All candidate models were compared to the one attaining the lowest AIC-score by estimating the difference in AIC-value (ΔAIC). Candidate models that got ΔAIC lower than two were assumed to have relevant empirical support in the data and were therefore also taken into account when assessing the candidate models (Burnham et al., 2011). AIC has the equation $AIC=-2\log(L)+2K$, whereas AICc has the equation $AICc=AIC+(2K(K+1))/(n-K-1)$.

AIC is used in large samples, whereas AICc is used in small samples (Symonds & Moussalli, 2011, p. 14). Log-likelihood ($\log(L)$) in the equation means how likely the model was based on our data, whereas K is the number of parameters in the model (Burnham et al., 2011). For all selected models, parameter estimates and their corresponding precision estimates (standard error) were reported along with the corresponding effect-test (ANOVA).

2.8.2.1. Species-, age-, and length structure and density

The length distributions were used for assigning individuals into age groups of 0+, 1+, and >1+ in Atlantic salmon and brown trout. These assignments were subjective assuming that 0+, 1+, and older individuals were grouped into distinct peaked distributions. The density of salmonids at each station using the removal method was estimated in R with a package called “FSA” (Simple Fisheries Stock Assessment Methods). The density estimates at each station were divided by the total area measured at the station (river length × average river width of the five transects in September). The variation in density between stations was also compared with variation in the measured habitat variables. To do this, the measurements were scaled to %-variation based on dividing the station-specific value by the total value of all stations for the specific variable. This made the trend between variables and stations more obvious. In addition, I compared my density results from 2020 with salmonid densities from an earlier study (Solberg, 2016).

2.8.2.2. Correlates of 0+ size variation

Since sampling of fish were only possible in September 2020 during the study period (due to extensive rain periods and high discharge levels), I did not obtain recapture-based individual growth data for estimation of between-station and movement pattern effects. I therefore analyzed the predictor variables (fixed effects from density dependent and density independent variables and stations as random effect) that correlated with Atlantic salmon 0+ lengths (response entity) instead.

2.8.2.3. Movement

To assess the variation in the proportion, distance, and direction (up- or downstream) of movement between salmonids at the stations, a plot was made to visualize the differences. The distances moved between PIT-tagging and the first detection (February) and between first detection and second detection (March) were used together with the time that had passed between them to estimate the movement velocity between individuals (meters moved per day). The recaptures of PIT-tagged individuals from the different stations were also plotted on maps in QGIS to visualize movements in space (Appendix C). In addition, an analysis of which predictor variables most efficiently explained the variation in movement distances up- and downstream was conducted.

2.8.2.4. Survival and detection probability

To estimate parr survival of Atlantic salmon and brown trout at various stations in Årungselva during the field study period, the catch-mark-recapture methodology was used. I used the Cormack–Jolly–Seber (CJS) model for estimating the recapture probability (***p***) and apparent survival probability (***φ***) of marked individuals between stations (Cormack, 1964; Jolly, 1965; Lebreton et al., 1992; Seber, 1965). The reason why this is apparent survival is because this model structure cannot separate individual losses that are due to emigration from those that are due to death (Pledger et al., 2003).

In this case, parr individuals were caught by electrofishing, PIT-tagged, and then released back into the river to later be recaptured. Since the first round was electrofishing (PIT-tagging) at five stations and the last two rounds were recapture (detection) from the mobile antenna from the whole river section from the river mouth to past the upper station (virtually the entire Årungselva), the marked individuals had the opportunity to be recaptured in the last two detection rounds. There were three encounter rounds for the PIT-tagged individuals, which fulfilled the minimum requirement that there must be at least two rounds for the recapture of marked individuals to find the probability of survival. With this, a CJS analysis could be conducted based on the three-digit binomial capture histories of each individual using the program MARK (Figures 8 and 9; White & Burnham, 1999). Each individual was assigned "1" for capture or "0" for not captured during that specific round. All individuals were captured in the first round due to PIT-tagging in that round. Furthermore, the detection probability ***p*** for all fish detected in the last time interval (February–March) was fixed to 1 as information was not available for this round (i.e., it was not possible to distinguish ***p*** from ***φ***). With this, estimated survival in the last period was the product of ***p*** and ***φ***. Model selection of the different candidate models fitted to explore effects on ***p*** and ***φ*** was conducted using AIC.

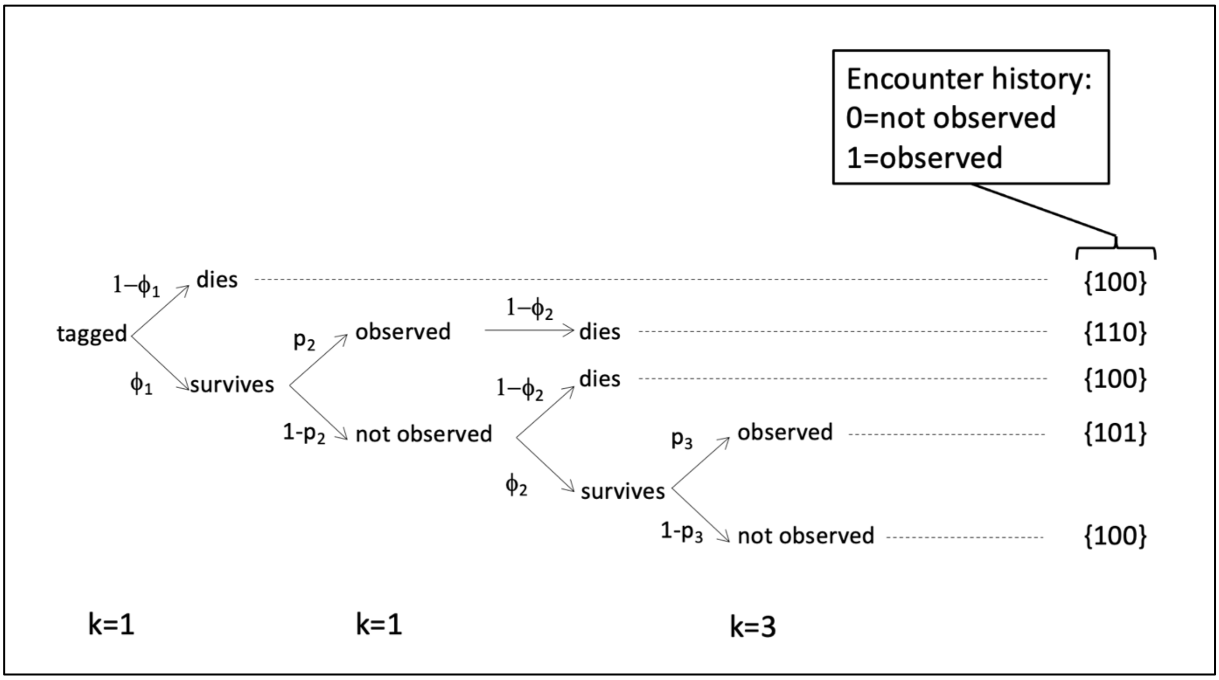

Figure 8. *Fate diagram with five possible detection histories of PIT-tagged parr in Årungselva with parameters based on the Cormack-Jolly-Seber model.* ***φ*** *is apparent survival and* ***p*** *is recapture probability.*

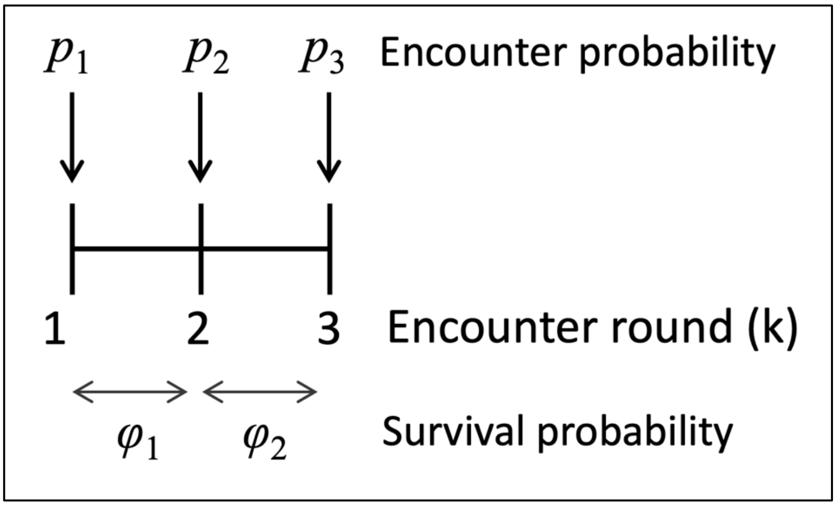

Figure 9. *Parametrization of the Cormack-Jolly-Seber model. All these parameters can be dependent on categorical variables (e.g., station) and both individual and environmental covariates (e.g., length).* ***p_1*** *cannot be estimated due to data not existing before this round, and* ***φ*** *and* ***p*** *from the last round cannot be estimated separately because this requires information about future recaptures to separate the recapture process from the survival process.*

3. Results

3.1. Species-, age-, and length structure

During fish sampling in September 2020, a total of 405 Atlantic salmon and 31 brown trout were caught (a total of 436 individuals; Appendix A). Atlantic salmon and brown trout were caught at all stations except station 4 where only Atlantic salmon were caught.

Atlantic salmon below and above 10 cm were set to 0+ and 1+ from stations 3–5, whereas Atlantic salmon below and above 11 cm were set to 0+ and 1+ from stations 1–2 (Figure 11). All brown trout under 11 cm were set to 0+, whereas all brown trout over 11 cm were set to >1+. Therefore, >1+ of Atlantic salmon and 1+ of brown trout were not caught based on this division (Figure 10).

Several individuals of assumed 0+ Atlantic salmon were longer than 9 and 10 cm at stations 1–2, whereas stations 3–4 had few individuals over 9 cm and none over 10 cm, and station 5 had none over 9 cm. The five shortest fish were caught at station 2 (5.5 and 5.9 cm), station 5 (5.52 cm), station 4 (5.8 cm), and station 3 (5.8 cm). The five longest 0+ Atlantic salmon were all caught at station 1 (10.9, 10.9, 10.8, 10.6, and 10.5 cm). The mean length (with standard deviation [SD]) for 0+ Atlantic salmon was calculated to be 8.33 ± 1.14 cm for station 1, 7.93 ± 1.06 cm for station 2, 7.51 ± 0.75 cm for station 3, 7.42 ± 1.26 cm for station 4 and 7.03 ± 0.69 cm for station 5.

Of the five shortest 1+ Atlantic salmon caught, four were at station 5 (10.52, 10.63, 10.95, and 11.5 cm), whereas one was at station 3 (11.48 cm). Of the 1+ Atlantic salmon, the four longest were caught at station 1 (17.4, 16.2, 15.9, and 15.8 cm) and the fifth longest at station 5 (15.5 cm). The mean length for 1+ Atlantic salmon was calculated to be 14.6 ± 1.12 cm for station 1, 12.72 ± 0.86 cm for station 2, 12.88 ± 0.98 cm for station 3, 13.82 ± 0.80 cm for station 4, and 12.58 ± 1.12 cm for station 5.

Of the 0+ brown trout, the five shortest were caught at station 3 (6.2, 6.5, and 6.5 cm) and station 5 (6.4 and 6.7 cm), whereas the longest were caught at station 1 (10.4 and 9.3 cm), station 2 (9.1 and 9.1 cm), and station 5 (8.6 cm). The mean length of all 0+ brown trout was 7.85 ± 1.05 cm. Six individuals of >1+ brown trout were caught, of which four were caught at station 3 (20.5, 23, 25.1, and 28.3 cm) and two were caught at station 5 (23.3 and 24.03 cm). The mean length for >1+ brown trout was 24.04 ± 2.58 cm.

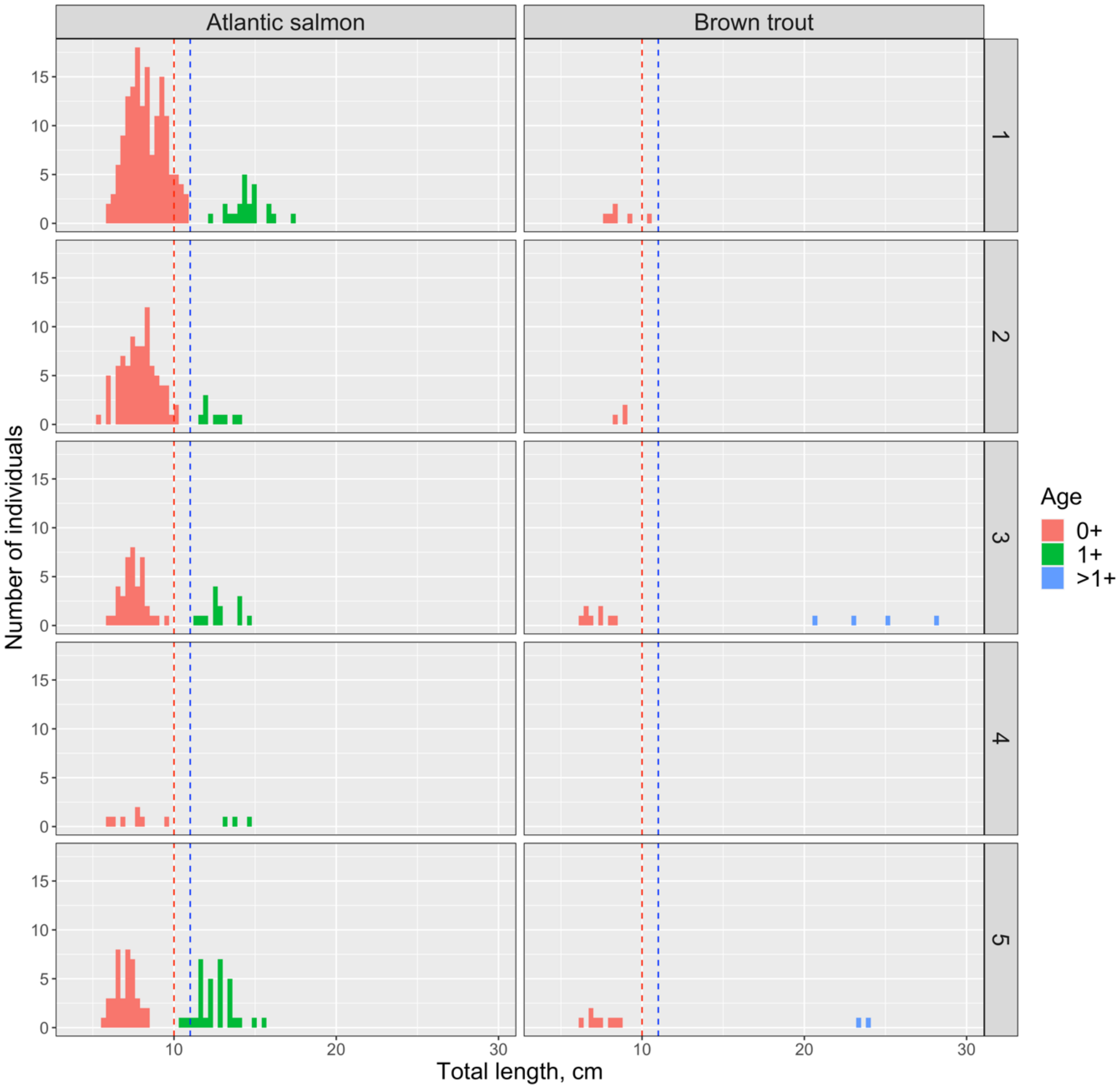

Figure 10. *Histogram of the total length distribution of age groups for Atlantic salmon and brown trout between the sampled stations 1–5. Atlantic salmon below and above 10 cm were set to 0+ and 1+ from stations 3–5, whereas Atlantic salmon below and above 11 cm were set to 0+ and 1+ from stations 1–2. All brown trout under 11 cm were set to 0+ and all brown trout over 11 cm were set to >1+.*

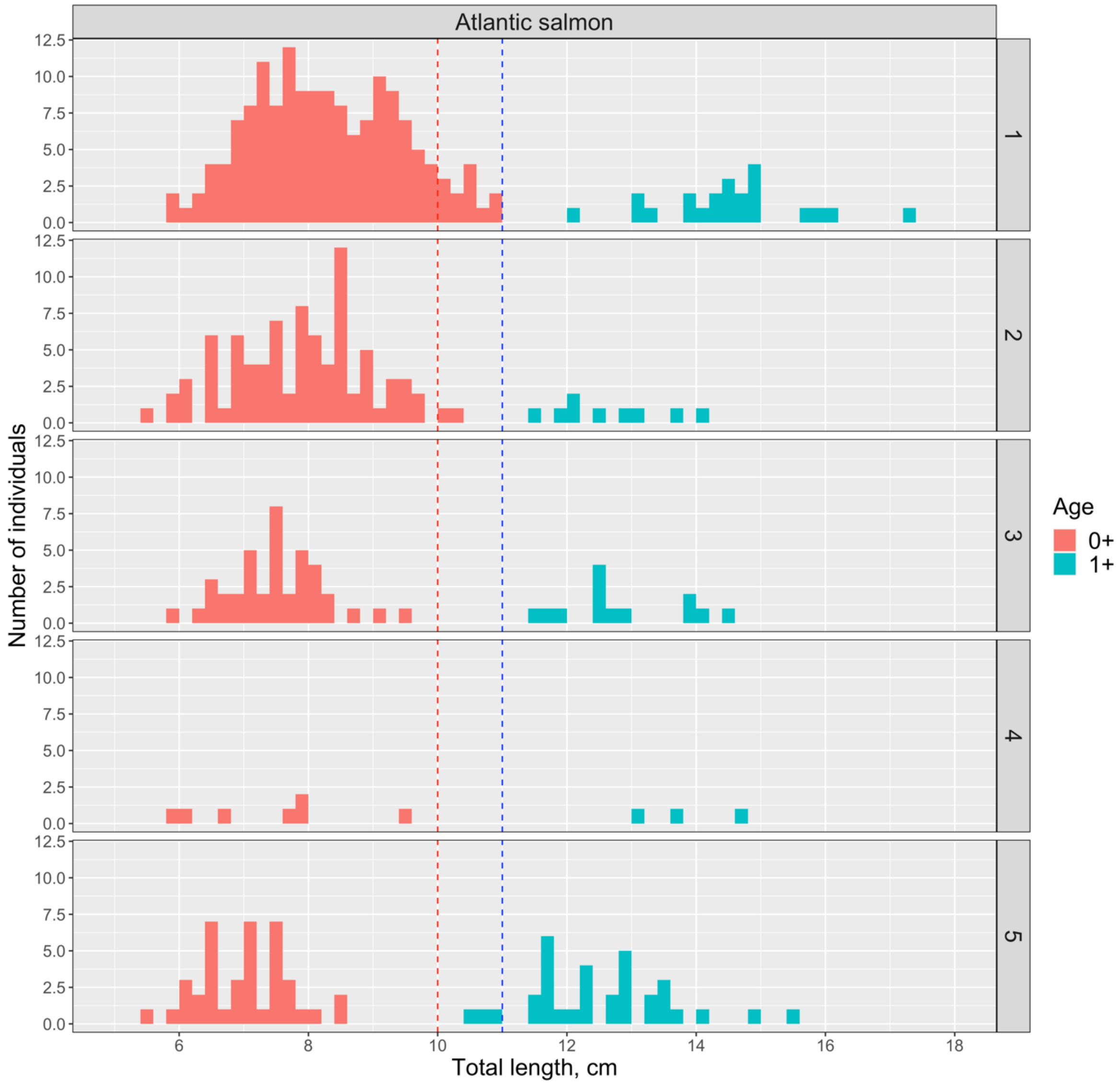

Figure 11. *Histogram of the length distribution of age groups for Atlantic salmon between the sampled stations 1–5. Atlantic salmon below and above 10 cm were set to 0+ and 1+ from stations 3–5, whereas Atlantic salmon below and above 11 cm were set to 0+ and 1+ from stations 1–2.*

3.2. Fish density

3.2.1. Salmonid densities in 2020

Higher estimated total densities of juvenile salmonids (both Atlantic salmon and brown trout) were found at stations above the outlet point (stations 1 and 2) than at stations below the outlet point (stations 3 and 4) except for the station furthest downstream (station 5), which had a higher density than all stations except station 1 (Table 2). The densities of 0+ and 1+ Atlantic salmon both exhibited a decreasing trend from stations 1 to 4 (Figure 12, Table 3). While the density of 0+ was highest at station 1, the density of 1+ was highest at station 5. The uncertainty of the estimates was greatest for 0+ at station 5 and 1+ at station 2. Since catches of brown trout were low for all stations in 2020, the density of brown trout was not estimated in this study (Table 4).

Table 2. *Total densities of salmonids between stations estimated with the use of catch data and Zippin*'s *method. Catchability p and standard error SE of the estimates were also estimated. C1, C2, and C3 are individuals captured in each capture round, whereas N is the total number of individuals captured in the specific station.*

Species	Station	Area (m²)	C1	C2	C3	N	SE(N)	p	SE(p)	Density (ind/100 m²)	SE (D)
Total	1	135.36	126	40	16	190	4.05	0.36	0.02	140.37	2.99
Total	2	199.70	50	32	14	105	5.21	0.26	0.03	52.58	2.61
Total	3	232.63	39	14	12	70	3.62	0.25	0.04	30.09	1.56
Total	4	279.00	6	2	2	11	2.08	0.35	0.16	3.94	0.75
Total	5	158.34	47	22	14	101	10.34	0.15	0.03	63.79	6.53

Table 3. *Density estimates of Atlantic salmon between stations and age groups estimated with the use of catch data and Zippin*'s *method. Catchability p and standard error SE of the estimates were also estimated. C1, C2, and C3 are individuals captured in each capture round, whereas N is the total number of individuals captured in the specific station.*

Species	Station	Area (m²)	Age	C1	C2	C3	N	SE(N)	p	SE(p)	Density (ind/100 m²)	SE (D)
A. salmon	1	135.36	0+	100	38	16	163	4.82	0.61	0.05	120.41	3.56
A. salmon	2	199.7	0+	46	27	11	96	7.31	0.5	0.08	48.07	3.66
A. salmon	3	232.63	0+	26	9	5	42	2.42	0.62	0.09	18.05	1.04
A. salmon	4	279	0+	4	2	1	7	0.87	0.64	0.22	2.50	0.31
A. salmon	5	158.34	0+	20	12	8	50	8.92	0.41	0.12	31.57	5.64
A. salmon	1	135.36	1+	21	1	0	22	0.22	0.96	0.04	16.25	0.16
A. salmon	2	199.7	1+	3	3	3	17	20.6	0.21	0.33	8.51	10.30
A. salmon	3	232.63	1+	9	3	1	13	0.68	0.72	0.14	5.58	0.29
A. salmon	4	279	1+	2	0	1	3	0.71	0.6	0.35	1.07	0.25
A. salmon	5	158.34	1+	23	6	4	34	1.65	0.66	0.09	21.47	1.04

Table 4. *Catches of brown trout between stations and age groups. C1, C2, and C3 are individuals captured in each capture round.*

Species	Station	Area (m²)	Age	C1	C2	C3
B. trout	1	135.36	0+	5	1	0
B. trout	2	199.70	0+	1	2	0
B. trout	3	232.63	0+	0	2	6
B. trout	4	279.00	0+	0	0	0
B. trout	5	158.34	0+	2	4	2
B. trout	1	135.36	>1+	0	0	0
B. trout	2	199.70	>1+	0	0	0
B. trout	3	232.63	>1+	4	0	0
B. trout	4	279.00	>1+	0	0	0
B. trout	5	158.34	>1+	2	0	0

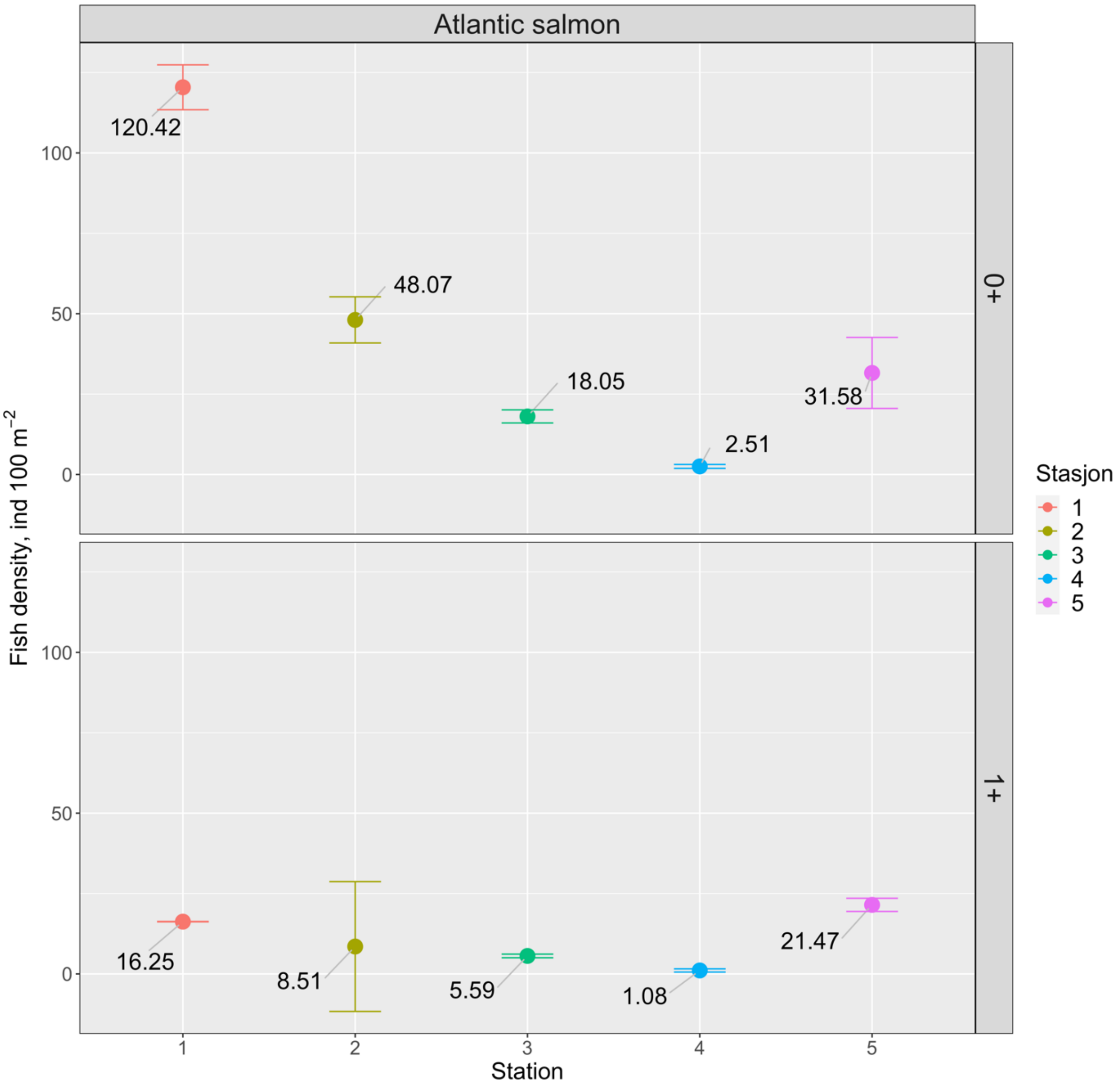

__Figure 12.__ Plot of estimated Atlantic salmon densities 100 m^{-2} divided into age groups for the sampled stations in Årungselva from September 2020. The vertical lines show the 95 % confidence intervals.

3.2.2. Salmonid densities and habitat variables

Compared with the different habitat variables measured at each station, the total densities of salmonids appeared to correlate positively with especially substrate size, followed by surface water velocity and moss cover. The other habitat variables appeared to be either uncorrelated or negatively correlated (Figure 13).

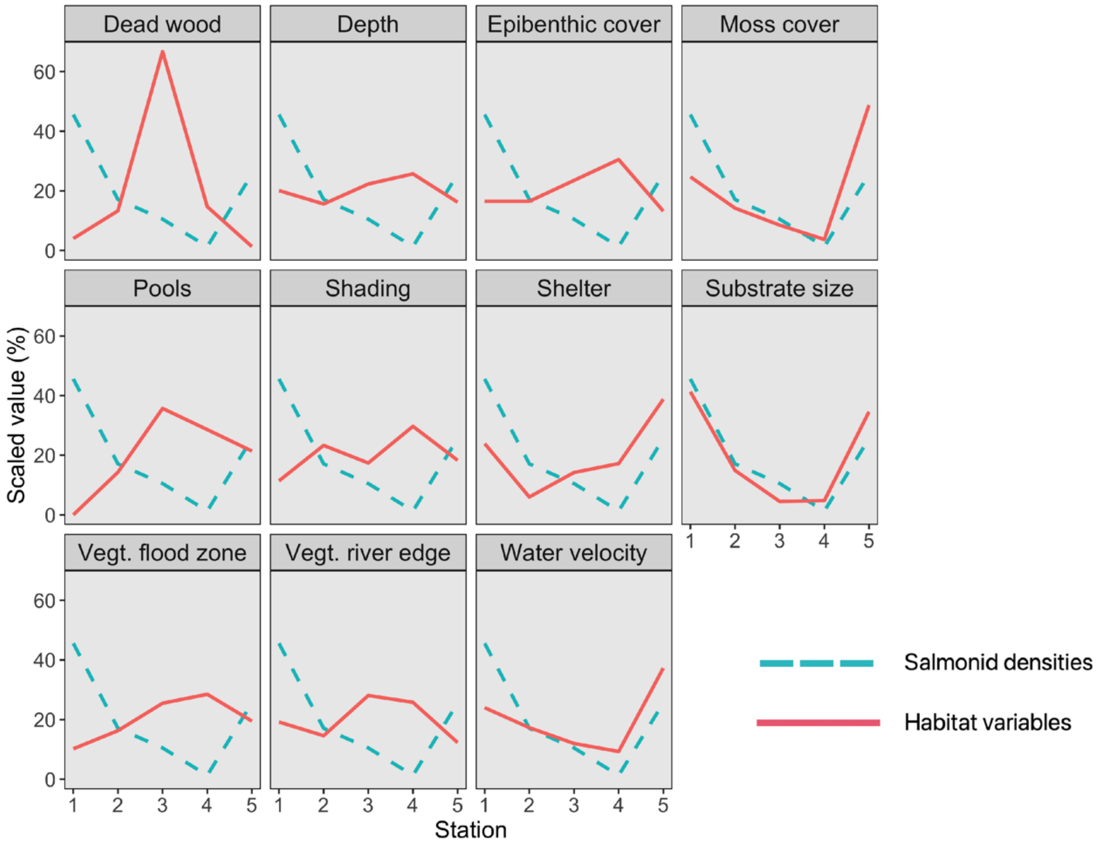

Figure 13. *Variation in total density of salmonids (blue dashed line) and habitat variables (red line). Full name of habitat variables from Table 1: dead wood = number of pieces of dead wood; depth = water depth; epibenthic cover = cover of benthic algae; moss cover; pools = number of pools; shading = vegetation shading of water; shelter = weighted shelter availability; substrate size = weighted substrate size; vegt. flood zone = vegetation cover – flood zone; vegt. river edge = vegetation cover – river edge; and water velocity = surface water velocity. Scaled value in % on the y-axis is the station-specific value divided by the total value of all stations for the habitat variable measured; the x-axis shows the sampling stations.*

3.2.3. Salmonid densities between 2015 and 2020

Compared with Solberg's (2016) densities at stations 1, 2, and 4 (corresponding to stations 1, 2, and 3 in Solberg's study) from 14.09.2015, the total densities of salmonids revealed that all these stations had higher densities in 2015 than in 2020 (Figure 14). There were also significantly higher densities of brown trout in 2015 than in 2020, with somewhat higher densities of brown trout (more 0+ than 1+) compared with Atlantic salmon at all stations (Figure 14). While in 2020 there were higher densities of Atlantic salmon 0+ compared with 1+ at stations 1 and 2, it was the opposite in 2015 (Figure 14).

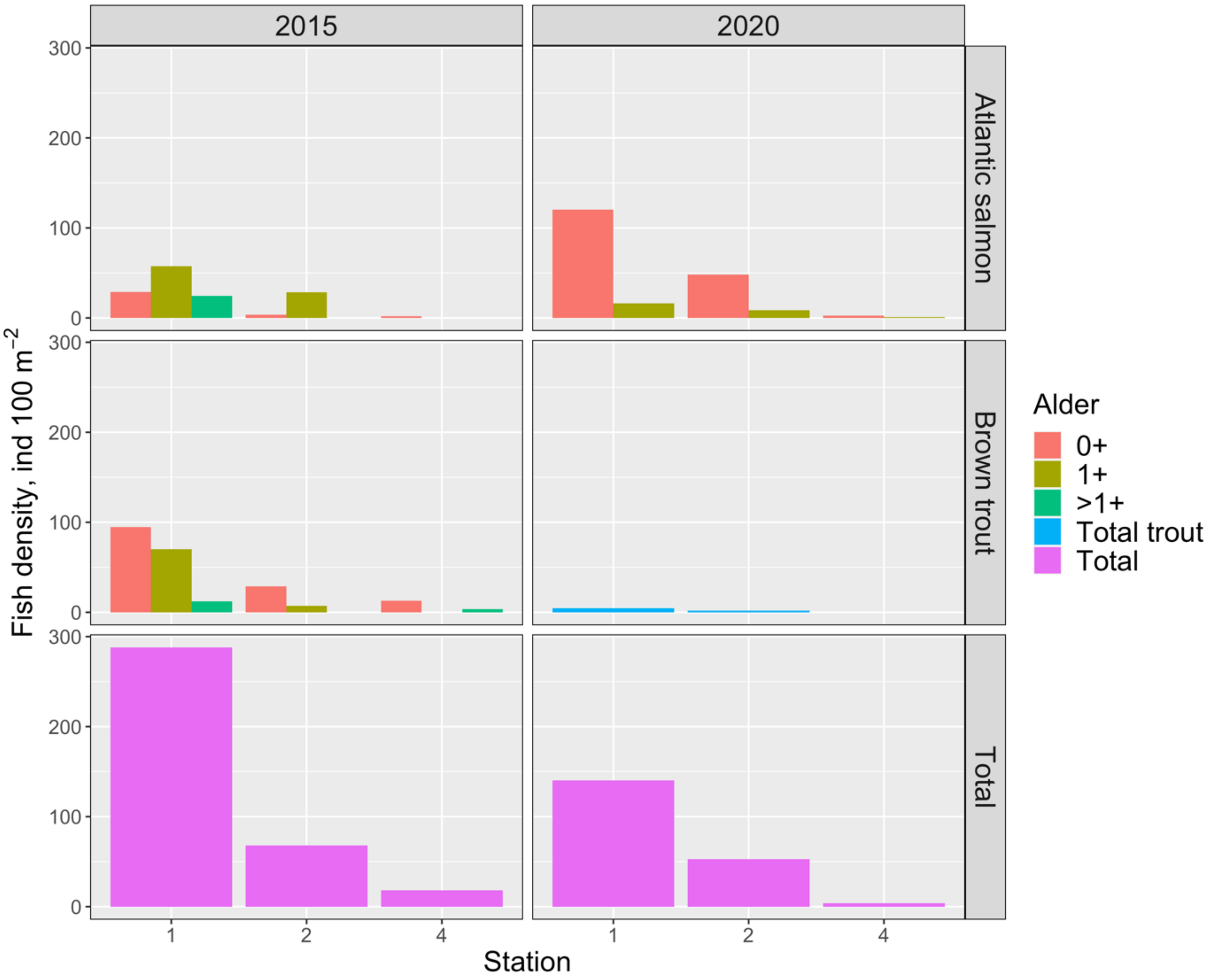

Figure 14. *Barplot of salmonid densities from stations 1, 2, and 4 in 2015 and 2020. The plot is divided into estimates of total- (both species and all age groups), Atlantic salmon- and brown trout densities in 2015 and 2020. Different catchabilities were used between 2015 and 2020 data. The 2015 data were retrieved from Solberg (2016). Standard errors are not included because they are not completely comparable between the two studies.*

3.3. Correlates of 0+ size variation

The most supported candidate model fitted to explain variation in total length of 0+ Atlantic salmon (cm, response variable) included the predictor variables: density of 0+ Atlantic salmon and shelter availability (Tables 5 and 6, Figure 15). This top model attained 10 % of the AIC-support in the data, the second most supported model got ΔAICc at 0.30 and the third most supported model got ΔAICc 1.87, both assumed to also have relevant empirical support in the data.

The selected model predicted that total 0+ length of Atlantic salmon to increase with lower shelter availability and increased density of 0+ Atlantic salmon (Figure 15). The third most supported model (Table 5) included the effect of being above/below the outlet point in addition to density of 0+ Atlantic salmon and displayed that being below the outlet point had a positive effect on 0+ length.

Table 5. *AIC model selection table for candidate models fitted to explain variation in 0+ Atlantic salmon total lengths in Årungselva 2020, with the upper models having better AIC_C scores according to corrected Akaike information criterion (AIC; Burnham & Anderson, 2001).*

Model[a]	K[b]	AICc[c]	ΔAICc[d]	AICc.Wt[e]	LL[f]
densN+shelter+(1|station)	5	1015.37	0	0.10	–502.60
densT+shelter+(1|station)	5	1015.67	0.30	0.09	–502.75
densN+treat2+(1|station)	6	1017.25	1.87	0.04	–502.50
densT+treat2+(1|station)	6	1017.26	1.88	0.04	–502.51
densO+treat2+(1|station)	6	1017.44	2.06	0.04	–502.60
densN*shelter+(1|station)	6	1017.44	2.07	0.04	–502.60
densO*vegt.flo.+(1|station)	6	1017.44	2.07	0.04	–502.60
densN+ subst+(1|station)	5	1017.52	2.15	0.03	–503.67
densT*shelter+(1|station)	6	1017.56	2.19	0.03	–502.66
densT+ subst+(1|station)	5	1017.68	2.30	0.03	–503.75
densN*moss+(1|station)	6	1017.71	2.34	0.03	–502.73
densN*velocity+(1|station)	6	1017.82	2.45	0.03	–502.79
densO+vegt.flo.+(1|station)	5	1017.83	2.45	0.03	–503.83
densT*moss+(1|station)	6	1017.90	2.53	0.03	–502.83

[a] *The fixed variables used in the 14 highest AIC-ranked models were as follows: density of 0+ Atlantic salmon (densN), density of 1+ Atlantic salmon (densO), total density of Atlantic salmon and brown trout (densT), shelter availability (shelter), above, just below or far below outlet point (treat2), vegetation cover flood zone (vegt.flo.), substrate size (subst), moss cover (moss), and surface water velocity (velocity). Station was used as random intercept effect in all candidate models (1|station).*

[b] *Number of estimated parameters.*

[c] *AIC_C score (lower value means better fitted model).*

[d] *AIC_C score difference between the model with lowest AIC_C-value and the model being compared.*

[e] *AIC_C weight is the relative AICc-support the model attained compared to the other candidate models.*

[f] *Log-likelihood. This value describes model probability based on data.*

Table 6. *Parameter estimates and associated ANOVA test statistics for the model with the most support for predicting the length of 0+ individuals of Atlantic salmon between different 0+ Atlantic salmon densities and shelter availabilities (shelter availability; Table 5).*

	Parameter estimates				**ANOVA Effect test**		
Fixed effects:				**Analysis of variance table:**			
Parameter[a]	Estimate	SE[b]	t-value	Effect	npar[c]	SS[d]	F-value
Intercept	7.586	0.136	55.879	0+ density	1	57.562	55.631
0+ density	0.010	0.001	8.181	Shelter availability	1	15.599	15.075
Shelter availability	–0.078	0.020	–3.883				

Random effects:		
Groups[a]	Variance	Std.Dev.[e]
Station	0	0
Residual	1.035	1.017

[a] *Parameters used in the most supported model include the fixed effects 0+ density of Atlantic salmon and shelter availability (shelter availability) and stations as random effects.*

[b] *Standard error (standard deviation of the sampling distribution).*

[c] *Number of model parameters.*

[d] *Sum of squares (total variation between the group means and the overall mean).*

[e] *Standard deviation.*

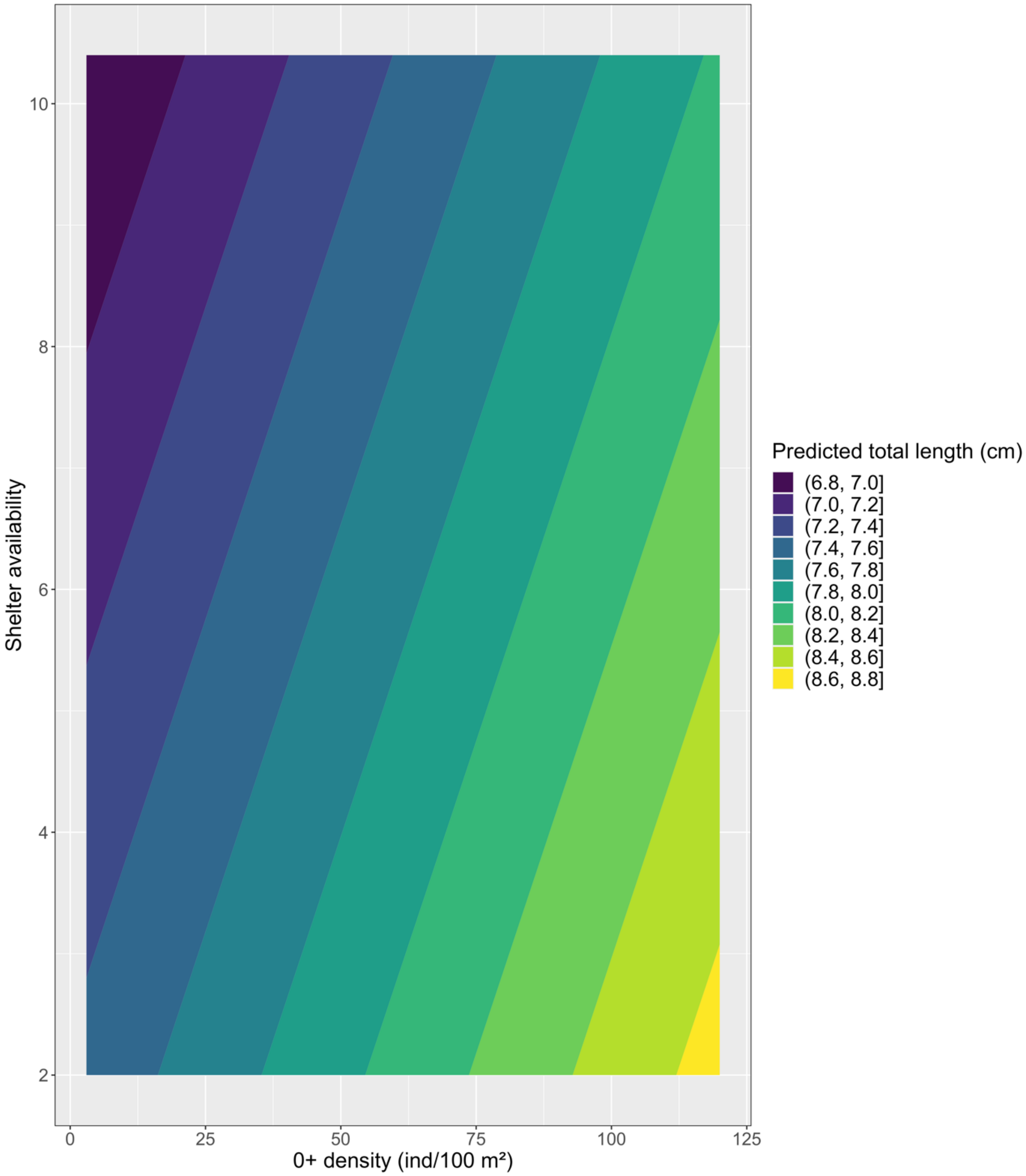

Figure 15. *Predicted total lengths (cm) of 0+ Atlantic salmon estimated from the density of 0+ (ind/100 m^2) Atlantic salmon and shelter availability (weighted shelter availability).*

3.4. Apparent survival (*φ*) and recapture probability (*p*)

The most supported candidate CJS model was an interaction model which included the predictor variables: the effect of being above/below the outlet point; length (i.e., standardized total length [cm]); and time (i.e., recaptured between September and February or February and March) for apparent survival probability (***φ***) and recapture probability (***p***), a function of time*length (Tables 7 and 8). This top model attained 86 % of the AIC-support in the data and the second most supported model got ΔAICc at 5.17, rendering the top model clearly most supported.

Although above (upper) and below (lower) individuals from both periods (Sep–Feb and Feb–Mar) did not exhibit a significant difference in length-specific monthly survival (overlapping confidence intervals), both periods supported higher length-specific survival for individuals above the outlet point compared with below the outlet point (Figure 17, Table 8). While monthly survival probability decreased with increasing length in the first period (Sep–Feb) for both above and below individuals, increased monthly survival with increasing length was found for both above and below individuals in the second period (Feb–Mar). When individuals reached 15 cm in length in the second period, the predicted monthly survival was 100 % for above individuals and approximately 78 % for below individuals; 100 % monthly survival was not achieved for any of the below individuals in this period. Recapture probability (***p***) in the best fitting model included the predictors of standardized total lengths and time interval from Sep–Feb for all individuals (both above and below the out point). Predicted recapture probabilities were predicted to increase with length of the fish with about 65 % recapture probability at 6 cm and 100 % recapture probability of individuals with lengths of approximately 28 cm (Figure 16).

Table 7. *Model selection table for candidate models fitted to explain variation in monthly survival probability for salmonids in Årungselva, with the upper models having better* AIC_C *scores according to corrected Akaike information criterion (AIC; Burnham & Anderson, 2001).*

Model[a]	AICc[b]	ΔAICc[c]	AICc.Wt[d]	K[e]	LL[f]
{φ(upLow*stL*t)p(t*stL)}	621.718	0	0.85873	10	601.158
{**φ**(upLow*stL*t)p(t)}	626.893	5.175	0.06457	9	608.437
{**φ**(upLow*ageL*t)p(t*stL)}	627.511	5.793	0.04741	10	606.952
{**φ**(upLow*t)p(t)}	628.524	6.806	0.02857	5	618.373
{**φ**(upLow*stL*t)p(.)}	635.920	14.201	0.00071	9	617.463
{**φ**(upLow*ageL)p(t*stL)}	646.747	25.029	0	6	634.536
{**φ**(upLow*stL*t)p(t)}	648.314	26.595	0	5	638.163

[a] *The variables used in prediction of variation in survival and recapture probability in the seven highest AIC-ranked models were: down- or upstream of the outlet point (upLow), standardized lengths (stL), age-adjusted length (ageL), time interval Sep–Feb or Feb–Mar (t), and same recapture probabilities in both time intervals (.).*

[b] *AIC_C score (lower value means better fitted model).*

[c] *AIC_C score difference between the model with lowest AIC_C-value and the model being compared.*

[d] *AIC_C weight is the relative AICc-support the model attained compared to the other candidate models.*

[e] *Number of estimated parameters.*

[f] *Log-likelihood. This value describes model probability based on data.*

Table 8. *Beta estimates (logit scale) for the most supported CJS model (Table 8).* ***Φ*** *= phi = monthly apparent survival probability,* ***p*** *= recapture probability. Recapture probabilities from the last round (Feb–Mar) were fixed to 1.*

Parameter	Term (Section[a])(Time-interval[b])	Estimate	SE[c]	LCL[d]	UCL[e]
φ	intercept (upper)(Sep–Feb)	2.860	0.181	2.503	3.216
φ	length (upper)(Sep–Feb)	–0.245	0.222	–0.682	0.191
φ	intercept (upper)(Feb–Mar)	2.303	0.499	1.324	3.282
φ	length (upper)(Feb–Mar)	1.985	0.868	0.282	3.687
φ	intercept (lower)(Sep–Feb)	2.782	0.268	2.256	3.309
φ	length (lower)(Sep–Feb)	–0.265	0.139	–0.539	0.008
φ	intercept (lower)(Feb–Mar)	1.145	0.339	0.480	1.810
φ	length (lower)(Feb–Mar)	0.055	0.272	–0.478	0.589
p	intercept (all)(Sep–Feb)	1.437	0.226	0.993	1.881
p	length (all)(Sep–Feb)	0.780	0.340	0.112	1.447

[a] *Section "upper" refer to stations above the outlet point (stations 1 and 2), whereas section "lower" refers to stations below the outlet point (stations 3–5).*

[b] *Time-interval is months between recapture rounds.*

[c] *Standard error (standard deviation of the sampling distribution).*

[d] *Lower confidence interval.*

[e] *Upper confidence interval.*

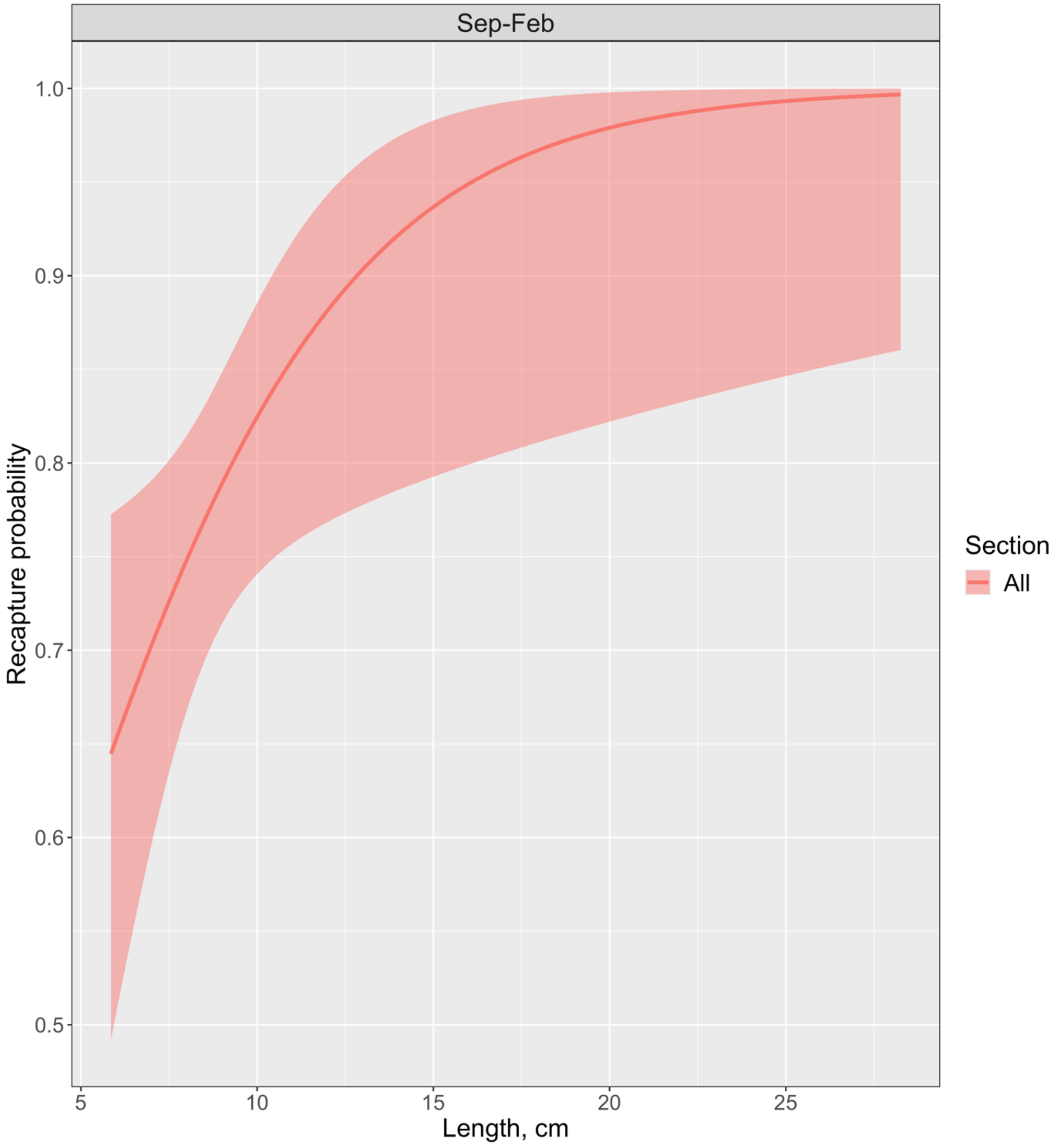

Figure 16. *Predicted recapture probability (**p**) as a function of length of the fish in the time interval from September to February for all individuals (both above and below the outlet point) in the best fitting model. Shaded areas show the 95 % confidence intervals.*

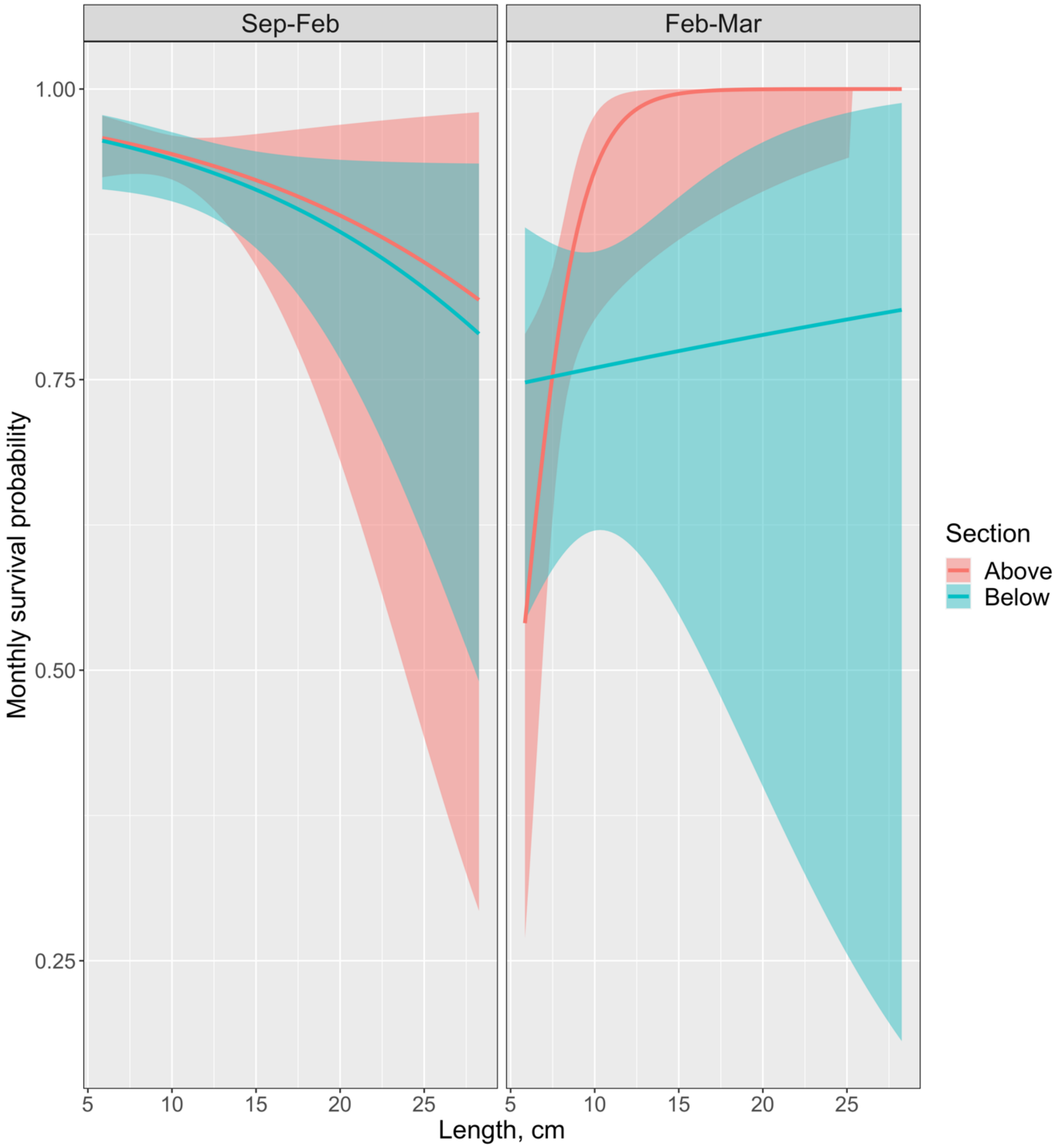

Figure 17. *Predicted monthly survival probability (φ) as function of length of the fish and tagging-and-release stations during Sep-Feb and Feb-Mar periods. Upper (above the outlet point) individuals had higher length-specific survival than lower (below the outlet point) individuals. Shaded areas show the 95 % confidence intervals. Predictions were made from the selected CJS model reported in Tables 9 and 10.*

3.5. Movement

During the scan with the mobile antenna, 177 individuals of the 255 tagged individuals were detected (recaptured) in February and 178 individuals in March 2021. A total of 183 individuals were detected once, 122 detected twice and 4 detected three times (Appendix A). Moreover, 17 PIT-tagged fish were also detected from Solberg’s (2016) study in Årungselva, where 17 were detected once, 13 were twice, and three were three times (Appendix A). Those that were detected three times were detected an extra time because the river was scanned in section-by-section over several days in each round, where the scan started where it left off on the previous section. In addition, seven PIT-tags that were not found in neither my nor Solberg’s study were detected during the scan, where seven were detected once and four were detected twice. Individuals tagged in stations 1 and 2 moved furthest downstream between PIT-tagging and first detection round, and between first and second detection round (Figure 18). Individuals from station 3 moved furthest upstream between PIT-tagging and first detection round, and between first and second detection round.

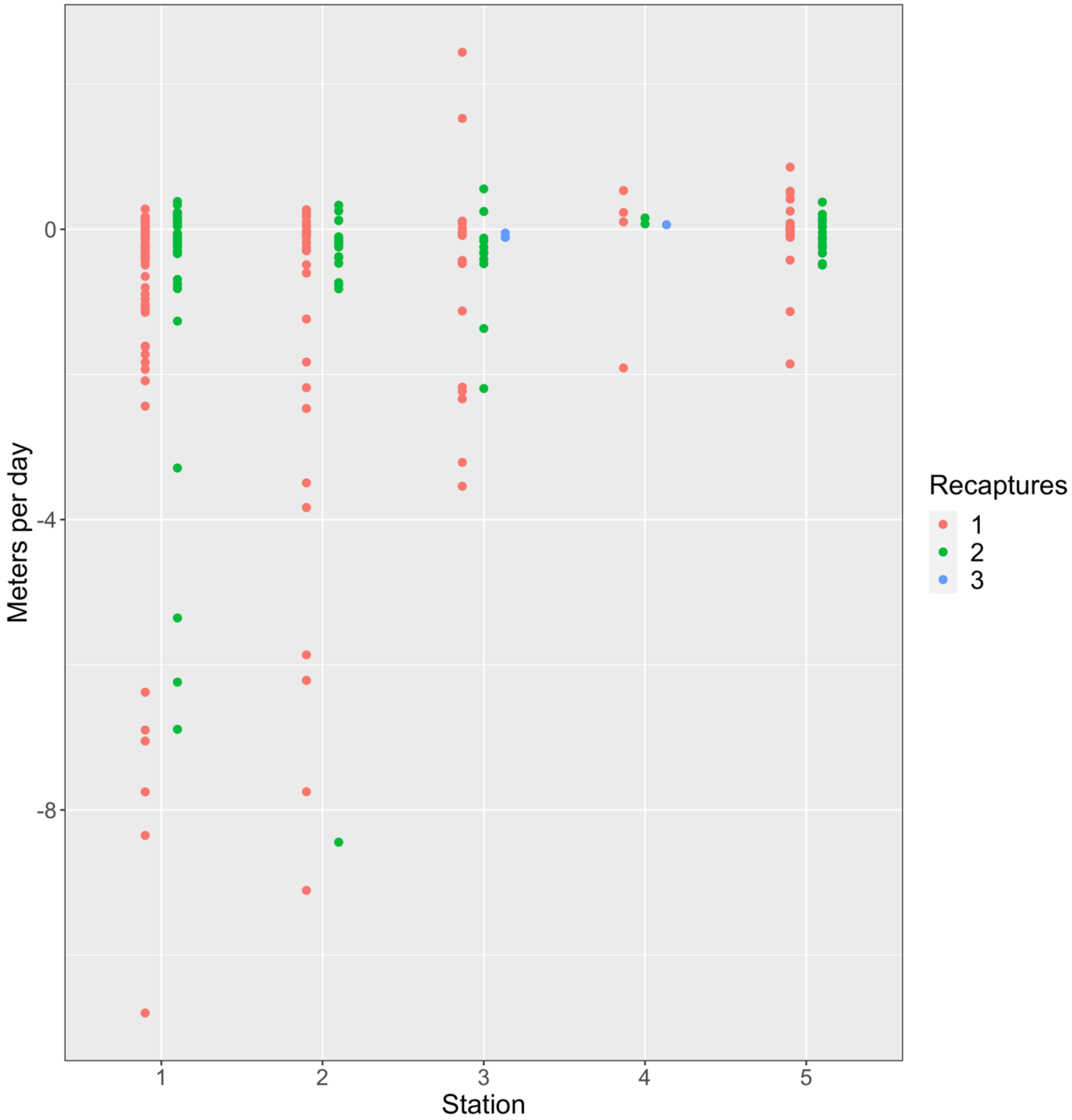

Figure 18. *Movement rates (meters per day) of individuals of juvenile Atlantic salmon (mainly) between stations. Red dots show velocities between PIT-tagging and first detection round, green dots between first and second detection round, and blue dots between second and third detection round. 0 = no movement; <0 = downstream movement; >0 = upstream movement.*

The most supported candidate model fitted to explain variation in individual movement rates (meters per day, response variable) included the predictor variables: effect of being above/below the outlet point (above, below, and far below the outlet point), movement direction (down- and upstream), and growth differences relative to mean total length in age group (Figure 19, Tables 9 and 10). The top model attained 20 % of the AIC-support in the data and the second-most supported model got ΔAICc at 0.65, assumed to also have relevant empirical support in the data.

The model exhibited a trend of higher degree of downward movement for faster-growing individuals within the age groups. Upward-moving individuals were found to consist of slower-growing individuals within the age groups, although this was not as prominent. The difference in both downstream and upstream movement between individuals located above and below the outlet point were non-significant. Regardless, individuals from the stations just below the outlet point (Figure 19) exhibited the highest tendency of movement both down- and upstream.

Table 9. *Model selection table for candidate models fitted to explain variation in meters moved per day for salmonids in Årungselva, with the upper models having better AIC_C scores according to corrected Akaike information criterion (AIC; Burnham & Anderson, 2001).*

Model[a]	K[b]	AICc[c]	ΔAICc[d]	AICc.Wt[e]	LL[f]
treat2+Up_down*deltaTL (used)	7	1068.61	0	0.20	−527.12
Age1*Up_down*deltaTL	9	1069.26	0.65	0.14	−525.33
treat2*Up_down	7	1070.17	1.56	0.09	−527.90
treat2+densN+Up_down*deltaTL	8	1070.41	1.80	0.08	−526.96
Age1*Up_down	5	1071.26	2.65	0.05	−530.53
Age1*densN*Up_down*deltaTL	17	1071.66	3.05	0.04	−517.76
Age1*treat2+Up_down*deltaTL	10	1071.70	3.09	0.04	−525.48
treat2+Up_down	5	1071.89	3.28	0.04	−530.84
Age1+Up_down	4	1072.27	3.66	0.03	−532.07
treat2*densN+Up_down*deltaTL	9	1072.49	3.87	0.03	−526.94
treat2+densO+Up_down*deltaTL	9	1072.49	3.87	0.03	−526.94
Age1+dens+Up_down*deltaTL	7	1072.49	3.88	0.03	−529.06
dens+Up_down*deltaTL	6	1072.55	3.94	0.03	−530.13
Age1+treat2+Up_down	6	1072.63	4.02	0.03	−530.17

[a] *The models estimated the relative contributions of age groups 0+ and >0+ (Age1); up- or downstream movement (Up_down); age-adjusted length-difference in relation to the mean length (deltaTL); stations above, just below or far below the outlet point (treat2); total density of Atlantic salmon and brown trout (dens); Atlantic salmon 0+ density (densN); and Atlantic salmon 1+ density (densO).*

[b] *Number of estimated parameters.*

[c] *AIC_C score (a lower value means a better fitted model).*

[d] *AIC_C score difference between the model with the lowest AIC_C value and the model being compared.*

[e] *AIC_C weight is the relative AICc-support the model attained compared to the other candidate models.*

[f] *Log-likelihood. This value describes the model probability based on data.*

Table 10. *Parameter estimates and associated ANOVA test statistics for the model with the most support for estimating meters moved per day for individuals above and below the outlet point with different age-adjusted sizes (Table 7).*

Parameter estimates

Fixed effects:

Parameter[a]	Estimate	SE[b]
(Intercept)	–1.1994	0.1104
treat2Impact	0.1018	0.2389
treat2Down	–0.5498	0.2509
Up_downUp	–0.8999	0.1706
deltaTL	0.1889	0.0991
Up_downUp:deltaTL	–0.3594	0.1323

ANOVA effect test

Analysis of variance table:

Effect[a]	Df[c]	SS[d]	F-value	p-value
treat2	2	17.29	4.5658	0.011
Up_down	1	59.79	31.5763	0
deltaTL	1	0.04	0.0191	0.89
Up_down:deltaTL	1	13.97	7.3786	0.007

[a] *Parameters used in the most fitted model included up- or downstream movement (Up_down); age-adjusted length difference in relation to the mean length (deltaTL); and stations above, just below, or far below the outlet point (treat2).*

[b] *Standard error (standard deviation of the sampling distribution).*

[c] *Degrees of freedom.*

[d] *Sum of squares (total variation between the group means and the overall mean).*

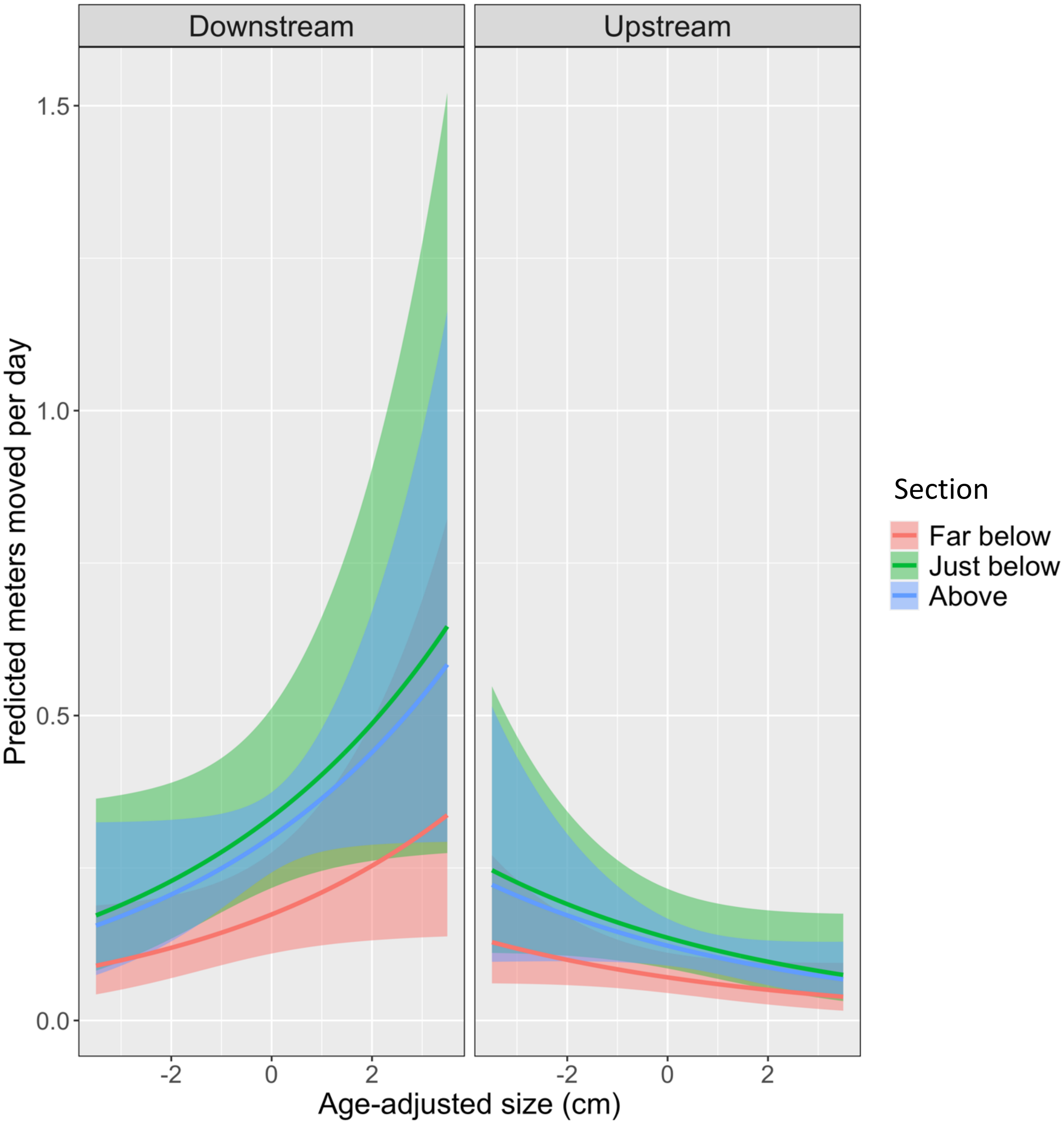

Figure 19. *Predicted meters moved per day (y-axis) between individuals above the outlet point, just below the outlet point, and far below the outlet point. Individuals consisted of Atlantic salmon and brown trout with different age-adjusted size (cm; x-axis). Age-adjusted size is the length difference from individual total length minus the mean length of the specific age group. Shaded areas show the 95 % confidence intervals.*

3.6. Water samples

The water samples were taken on the following dates: 08.04.2021, 12.04.2021, 13.04.2021, and 02.06.2021. The Smiehagen and Vassum tunnels received a full wash on the night of 13.04.2021, whereas the Nordby tunnel received a full wash on the two nights of 01.06.2021 and 02.06.2021. Overflow of the sedimentation pond was documented through discharges of water from the outlet point into the river during both full washings.

The heavy metal content in the water samples varied both above (station 2) and below (station 3) the outlet point and between sampling dates (Figure 20). On 08.04.2021, all heavy metals exhibited higher values below than above the outlet point, except for cadmium. On 12.04.2021, arsenic, chromium, copper, nickel, and zinc exhibited higher values above the outlet point, while cadmium, and lead exhibited higher values below it. On 13.04.2021, lead, and zinc exhibited higher values above the outlet point, whereas arsenic exhibited higher values below it, and cadmium, chromium, copper, and nickel exhibited approximately same value. On 02.06.2021, copper, chromium, lead, and zinc exhibited higher values below the outlet point, whereas arsenic and nickel values were higher above it. Cadmium was the same above and below the outlet point. Values obtained from 02.06.2021 were remarkably lower than all other samples. All the PAHs that were measured had values <0.010 μg/L; thus, PAHs were not detected in the samples.

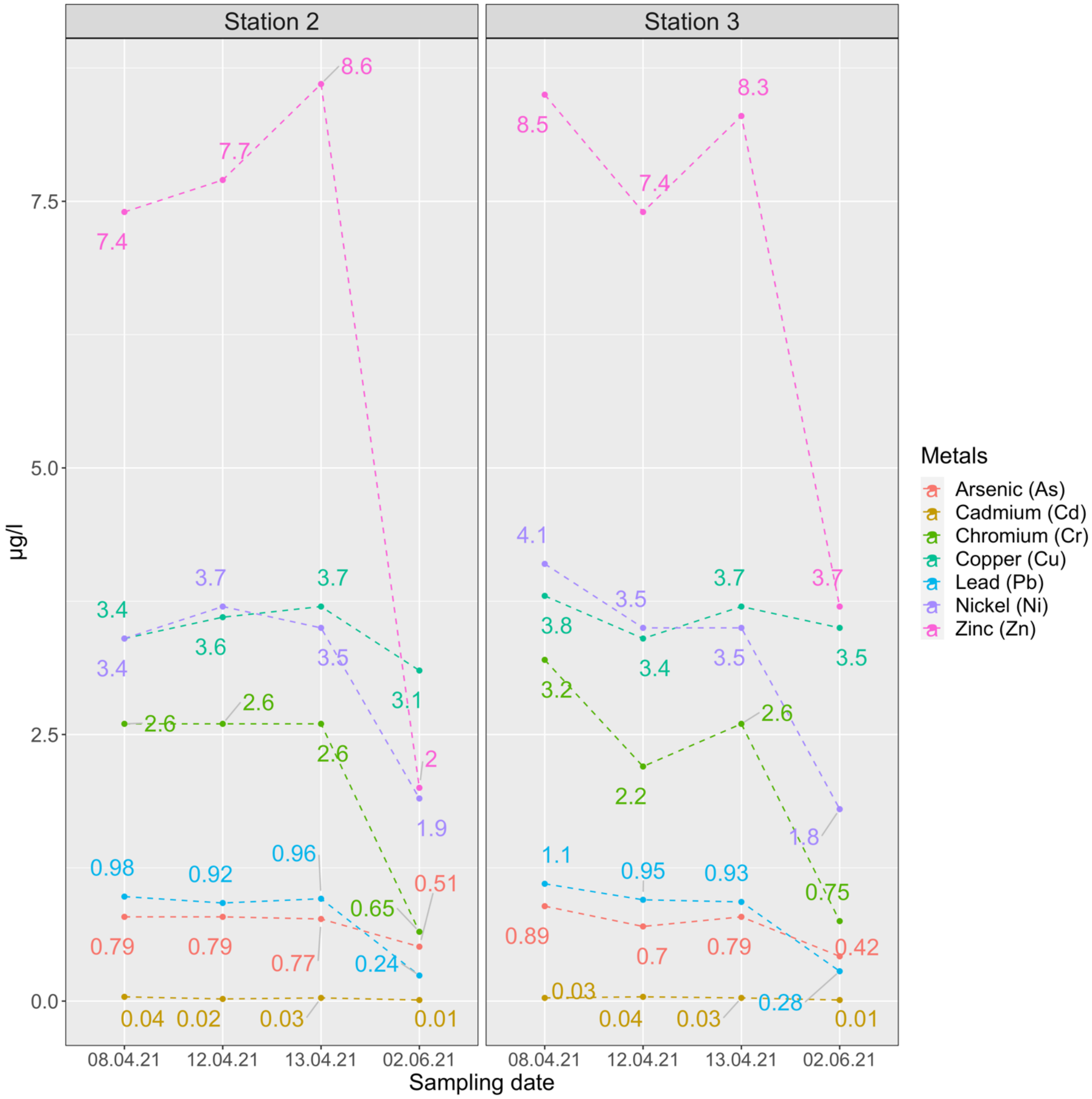

Figure 20. *Concentrations (µg/l) plotted for the heavy metals arsenic, cadmium, chromium, copper, lead, nickel, and zinc above (station 2) and below (station 3) the outlet point at four different sampling dates.*

4. Discussion

In this study, lower monthly survival was found for salmonids below the outlet point of Vassum sedimentation pond in Årungselva than salmonids above it. A higher degree of displacement was found for salmonids just below the outlet point than above it and further downstream. Lower densities were found below the outlet point except for the lowermost station, which had high densities. Length of 0+ Atlantic salmon was found to correlate positively with density of 0+ Atlantic salmon and correlate negatively with increasing shelter availability. There were only marginal differences between concentrations of various heavy metals above and below the outlet point, even during full-scale washings of the tunnels.

4.1. Did sections below the sedimentation pond exhibit higher concentrations of contaminants than sections above it during tunnel washing?

The water samples taken in this study did not exhibit a remarkable increase in concentrations of contaminants in samples taken directly below (station 3) the outlet point during two full washings of the Smiehagen and Vassum tunnels (13.04.2021; simultaneously), and Nordby tunnel (02.06.2021), compared with samples taken above (station 2) the outlet point and samples taken below it before washing. In addition, all the PAHs measured were below the detection level (<0.010 μg/L). These results were found despite discharges being observed from the outlet point when the tunnels were washed. The only remarkable differences between the above and below samples that could be attributed to discharges from the outlet point were higher detected concentrations of arsenic, chromium, copper, lead, nickel, and zinc in the below samples on 08.04.2021, and higher levels for copper, chromium, lead, and zinc in below samples on 02.06.2021. Values obtained from metals in water samples from 02.06.2021 were generally much lower than all other samples. Noteworthily, the river had substantial lower turbidity than all the other samplings on that date. Emphasis should be placed on the concentration of nickel at station 3 on 08.04.2021 which exhibited total concentration values that could cause chronic effects on aquatic biota with long-term exposure based on the guidelines of the Water Framework Directive. The levels of chromium and lead (08.04.2021) were close to those that can impose chronic effects with longtime exposure (Directive group of Water Framework Directive Norway, 2018). Emphasis should also be placed on the large difference between the zinc concentrations (<2 µg/L at station 2 and 3.7 µg/L at station 3) 02.06.2021, although both levels were low. Furthermore, none of the metals in this study exceeded the concentrations of the class limit 2 "Some sensitive species may be affected, but no effects on fish" from the paper of Lydersen et al. (2002), which were mainly based on salmonids.

Meland et al. (2010b) found that the concentration of both metals and PAHs increased in the outlet point (measured in the manhole between the pond and the outlet point) of the Vassum sedimentation pond during a full wash of the Nordby tunnel, and that many of these contaminants gained high ranks according to environmental quality standards from different countries. Of the metals measured, 38% of the metals were related to particles and colloids, whereas 50% were related to low molecular mass. Noteworthily, they found that nickel was mostly associated with the low molecular mass fraction, whereas chromium and lead were more associated with particles and colloids. Furthermore, Solberg (2016) found, of several anion and cation metals measured, higher concentrations of chloride, sulfate, and uranium in water samples below the outlet point than above it, although no information exist from this study on timing of tunnel washings.

On a general basis, the bioavailability and toxicity of metals varies with dissolved organic matter, dissolved oxygen, hardness, pH, salinity, temperature, and turbidity of the water (Lydersen et al., 2002). Solberg (2016) also measured some physical variables such as conductivity, oxygen saturation, temperature, and turbidity. For example, turbidity tended to increase in winter but decrease in summer. This is in accordance with personal observations. As international guidelines on concentration levels of contaminants are usually based on total concentration (i.e., both dissolved and particulate), caution must be taken when interpreting water samples. Simpler forms of metals, such as "free ions and weak complexes," are known to be more bioavailable and toxic than forms that are related to "stronger complexes and particulate matter." If only a small part of the total concentration of a metal is in a bioavailable form, the water sample can possibly be overprotective in interpretations, whereas the opposite can be true if a larger proportion is in the bioavailable form (Markich et al., 2001, p. 109). In this study, the relative reduction in arsenic, chromium, lead, nickel, and zinc in both above and below samples on 02.06.2021 is possibly due to reduced turbidity of the water compared to the other samplings (Nasrabadi et al., 2016).

Due to the highly polluted water samples documented from Meland et al. (2010b) in the outlet point during a tunnel wash in the Nordby tunnel, the water samples in this study indicated that potential discharges of contaminants from the outlet point was either highly diluted when it entered the river sections just below the outlet point or that the sedimentation pond mostly function as intended (or a combination of both processes). Rosing Eide from the NPRA (2021) expressed that it is the supply of new water that displaces the finished purified water so that the purified water flows out of the sedimentation pond first. Accordingly, the capacity of the pond to function properly is dependent on the amount of water entering the pond within a certain time. Åstebøl et al. (2012) stated that a minimum of three days must pass to ensure sufficient sedimentation before new runoff water enters the pond. Additionally, to ensure sufficient degradation of detergents used in the washing process, a minimum of two weeks must pass (Åstebøl & Hvitved-Jacobsen, 2014). It is unknown why samples below the outlet point were higher on 08.04.2021, but it could be due to discharges from the outlet point immediately before water samples were taken, as no discharges from the outlet point were observed during sampling. Importantly, photos of the sedimentation pond from 08.04.2021 reveals that the pond was "more than filled" as the water level was above the point which releases water from the pond. Strikingly, earlier observations have documented that wash water have "flowed through" the pond despite the pond had more enough volume to store wash water (Åstebøl et al., 2012). In addition, it is worth mentioning that the sedimentation pond was emptied of sludge no later than early 2019 (Gundersen, NPRA, 2021).

The water samples taken in this study demonstrated that concentrations of contaminants below the outlet point were the same or marginally higher than above it for some metals, although some metals exhibited higher values above the outlet point, even during tunnel washing. This indicates that wash water which is released from the Vassum sedimentation pond and into Årungselva is either appreciably purified in the pond under "normal conditions" or diluted "sufficiently" downstream (or both).

4.2. Densities of juvenile salmonids above and below the sedimentation pond

Higher densities of juvenile salmonids were found at the stations above the outlet point (stations 1 and 2) than at the stations below the outlet point (3 and 4), except for the lowermost station (station 5), which had higher densities than all other stations except station 1. In addition, there were found higher densities of Atlantic salmon than brown trout at all stations in 2020, and brown trout was almost absent. In 2015, Solberg (2016) also revealed higher densities of salmonids for stations above the outlet point compared with those below it, with a decreasing trend from stations 1 to 4 in Solberg's study (stations 1, 2, and 4 in the present study overlapped with Solberg's stations 1, 2, and 3). In contrast with findings from 2020, Solberg (2016) found higher densities of brown trout than Atlantic salmon in 2015, although the proportion of both species were more evenly distributed. Meland et al. (2010b) compared densities of brown trout with data from the years before and after 2000 (i.e., before and after the establishment of the sedimentation pond) in two stations, one in the lower part of the river close to the fjord, and one above the outlet point of the sedimentation pond. He could not find any remarkable differences in density between years in these stations as "no significant change in number of captured 0+ per sampling was observed between the sites before and after year 2000" (Meland et al., 2010b, p. 4115).

The downward trend in salmonid densities found from stations 1 to 4 and the great variation in salmonid densities from stations above compared to below the outlet point, which were found both in 2015 and 2020, indicate some sort of strong mechanisms distributing juvenile salmonids in Årungselva between years. Salmonid densities in rivers are expected to vary with their preferable habitat conditions (Armstrong et al., 2003; Crisp, 1996; Heggenes et al., 1999) and densities will usually fluctuate with variation in different environmental factors (habitat variables). Of the measured habitat variables in this study, substrate size seemed to be most connected to densities of salmonids and exhibited strong positive correlation. Several studies (e.g., Cunjak, 1988; Dolinsek et al., 2007; Gries & Juanes, 1998; Heggenes & Saltveit, 1990; Heggenes & Borgstrøm, 1991; Johnson, 2008; Venter et al., 2008) have demonstrated that coarse substrate is an important habitat variable for determining the distribution of juvenile individuals of Atlantic salmon. Complex habitats with coarser substrates will probably lead to higher densities as this facilitates smaller territories with greater access to shelter availability from conspecifics and predators, increasing visual isolation from competitors, shorter paths to food access, and better current conditions (Venter et al., 2008). The riverbed in stations just below the outlet point consisted mainly of fine-grained substrate, which most probably are more avoided by Atlantic salmon than the stations above and far below the outlet point which was remarkably coarser. It was expected that coarser substrate was increasing shelter availability, and that shelter availability was strongly connected to salmonid densities, but this was not as obvious as variation in substrate size, even though shelter availability were highest for the stations with highest salmonid densities. Earlier studies have found that increased access to (Foldvik et al., 2017) and higher distribution of (Finstad et al., 2009) shelter increased densities of Atlantic salmon.

There also appeared to be an evident positive association between the average surface water velocity and the density of juvenile salmonids in Årungselva. Crisp (1996) found that Atlantic salmon preferred water velocities between 50 and 60 cm/s^{-1}, whereas Heggenes et al. (1999) found that Atlantic salmon preferred average water velocities between 30 and 50 cm/s^{-1} and avoided lower and higher water velocities. This seems to be true in relation to salmonid densities in Årungselva, where the highest average surface water velocities was measured at stations with the highest salmonid densities, with 56 cm s^{-1} at station 5, followed by station 1 with 36 cm s^{-1}.

Considering the water depth measurements, it appears that salmonids avoid deeper sections of the river as stations 3 and 4 had the lowest densities and the deepest average water depth. Hedger et al. (2005) found that water depth was the second most important habitat variable after substrate distribution and found a decrease in density for Atlantic salmon parr with increasing water depth. Even though Atlantic salmon can use a wide range of water depths (Bremset & Berg, 1997; Bremset & Berg, 1999; Heggenes et al., 2002), Atlantic salmon usually occupy shallower sections of rivers than brown trout (Armstrong et al., 2003; Heggenes et al., 1999).

Overall, it appeared that densities of salmonids in 2020, which consisted mainly of Atlantic salmon, followed the gradient in the habitat variables substrate size, surface water velocity, and water depth, which is known from earlier studies to be important variables in distributing salmonids in rivers (Armstrong et al., 2003; Crisp, 1996; Heggenes et al., 1999). The stations with highest salmonid densities were shallower, had coarser substrate, and higher surface water velocities. Stations 3 and 4, which had the lowest densities, had probably the poorest habitat for salmonids in Årungselva, which had the lowest substrate sizes, was the deepest, and slowest flowing stations. The other habitat variables measured in this study are considered less important in distributing salmonids in Årungselva, although dead wood (Floyd et al., 2009; Lehane et al., 2002) and vegetation cover (McCormick & Harrison, 2011) are considered important in distributing salmonids in rivers. Furthermore, the relative importance of the different habitat variables is expected to vary temporally as altering conditions, for example drought, can cause more salmonids to occupy habitats with deeper water.

4.3. Was a higher proportion of Atlantic salmon relative to brown trout in 2020 in line with distributions of these species from previous years?

The higher proportion of Atlantic salmon relative to brown trout in 2020 contrasted with the trend of catches from earlier years from the course titled Management of Freshwater Fish (NATF340) at the Norwegian University of Life Sciences (NMBU), with a dominance of brown trout over Atlantic salmon (Figure 21). This is also in contrast to results obtained by Borgstrøm & Heggenes (1988), Meland et al. (2010b), and Solberg (2016) who have found higher densities of brown trout than Atlantic salmon in the river. The reason for this distribution in earlier years is most likely that the river as a habitat is more preferable for brown trout (Armstrong et al., 2003), and that brown trout is more competitive than Atlantic salmon in Årungselva (Bremset & Heggenes, 2001; Harwood et al., 2001). Therefore, there are annual differences in the ratio between Atlantic salmon and brown trout, possibly due to variation in the spawning ratio and timing of peak spawning between the species each year (Heggberget et al., 1988). Redds spawned by brown trout could be superimposed by Atlantic salmon later in autumn, or larger individuals of one species could suppress the other species during spawning. Based on my results and the data from Årungselva between the years, it seemed that 2019 and 2020 were unusually bad years for brown trout. The reason for this is unknown, but it could be due to long-lasting effects from the extremely warm summer of 2018, as Atlantic salmon have higher tolerance to higher temperatures than brown trout (Elliott & Elliott, 2010). Another explanation could be changes in conditions in the river in the past years making it less preferable for brown trout compared with earlier years. Moreover, brown trout might be more sensitive to the release of contaminants from the outlet point. It appears that Atlantic salmon spawn more in the upstream sections of the river than brown trout (Haugen, 2021). Interestingly, based on personal communication with Gundersen (2021) and Torgersen (2021) from the NPRA, a shift occurred to a new detergent used for washing the tunnels approximately 3–5 years ago (i.e., from TK-601, Teknisk Kjemisk Produksjon AS, Mjøndalen, Norway, to PG-IV1-X1-1000, PURIFY AS, Stavanger, Norway). Perhaps the search for a more effective detergent could have led to a detergent being used that is more toxic to salmonids in Årungselva; moreover, perhaps the washing of the tunnels in spring to early summer during a low flow in the river could have a great impact on the sensitive newly hatched embryos and fries below the outlet point (Luckenbach et al., 2001, 2003), which probably consist of mainly brown trout. The detergent could be more severe itself, or possibly increase the mobility of heavy metals, as documented for TK-601 by Aasum (2013) from the NMBU, who found increased mobility of heavy metals with detergents in the washing water from the Nordby tunnel. On the other hand, the density of brown trout being so low above the outlet point is strange because it argues against the reduced densities of brown trout only being caused by emissions from tunnel washing.

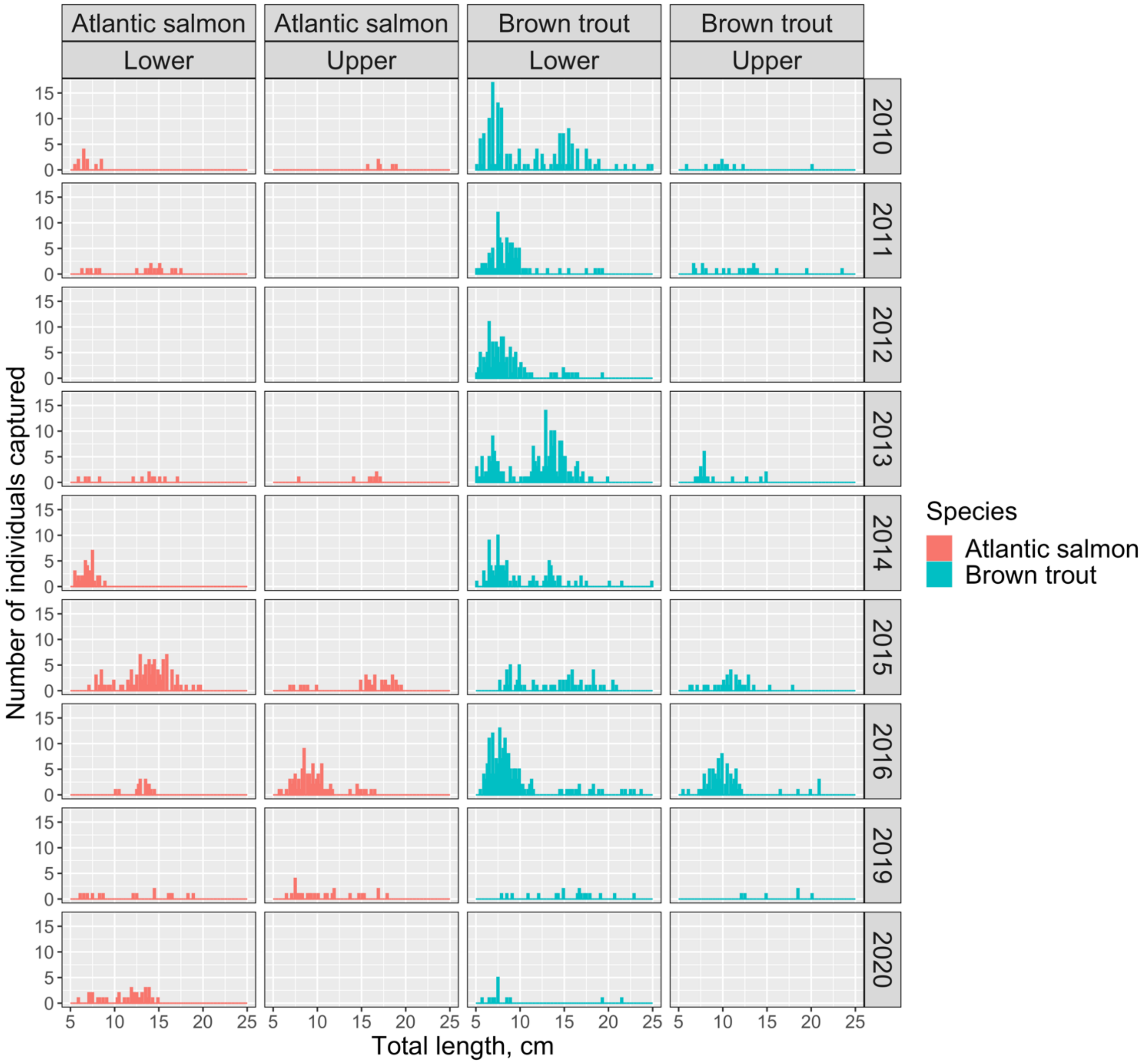

Figure 21. *Relative catches of Atlantic salmon and brown trout between the years from the course NATF340 at NMBU. Fishing effort is not correlated for, but the distribution of length and species can be observed. The upper section of the river was not sampled in 2012, 2014, or 2020. Furthermore, there were no catches of Atlantic salmon in the upper section in 2011 or in the lower section in 2012.*

4.4. Did variation in 0+ size of Atlantic salmon correlate with being above or below the sedimentation pond?

The variation in total length of 0+ individuals of Atlantic salmon was best explained by a candidate model that included shelter availability and the density of 0+ Atlantic salmon. This model explained that the predicted total length of 0+ increased with lower shelter availability and increased with higher density of 0+ Atlantic salmon. This was somewhat unexpected as increasing shelter availability is known to increase the habitat quality of Atlantic salmon (Finstad et al., 2009; Millidine et al., 2006; Valdimarsson & Metcalfe, 1998) whereas increased density of 0+ Atlantic salmon is known to limit growth within the cohort and population (e.g., Bohlin et al., 2002; Imre et al., 2005; Reid et al., 2011; Ward et al., 2009).

Millidine et al. (2006) found that the standard metabolic rate in Atlantic salmon juveniles increased with a lack of shelter. They suggested this relationship could decrease the growth rate for individuals with poor shelter availability. Another implication of the results is that increasing shelter availability means that larger holes and coarser substrate are more present, which can lead to less acceptable habitat for 0+ individuals relative to 1+ and older individuals. If shelter availability corresponds to the distribution of different substrate sizes, the growth of 0+ individuals possibly increase with shelter availability up to certain level, and then ceases before decreasing with increased shelter availability (coarser substrate). With this, the reduced size of 0+ could be due to stress linked to poorer shelter quality and competition with older conspecifics, although shelter availability was measured as being high. Other studies have reported that smaller parr prefer less coarse substrate than larger parr (Gibson, 1993; Heggenes et al., 1999) which makes sense in this context.

Imre et al. (2005) found that average lengths of 0+ Atlantic salmon were lowest at higher densities. They also suggested that the effects of density on growth were highest at lower densities, which was explained by exploitative competition. Mortality and movement seemed to be more important on higher densities due to direct competition between individuals. This pattern is also found by others (Jenkins et al., 1999). Higher competition for resources such as food and territory are likely a critical factor decreasing the average size in dense sections.

Moreover, the positive effect of 0+ density on 0+ size could be explained by the combination of the effect of greater habitat quality for 0+ Atlantic salmon, which makes space for more individuals, and individuals that move from this good habitat are smaller subordinates suppressed by more dominant, larger individuals (Jenkins et al., 1999). This would possibly be more evident if huge variations in habitat quality were found within the river. With this, smaller individuals may have to settle for less suitable habitats downstream and thus attain a lower growth rate. Superior feeding opportunities have been found to be more crucial than density on variation in the growth of juvenile Atlantic salmon (Ward et al., 2009). Variation in environmental conditions between rivers is likely an important factor explaining these differing results. It is possible that nutrient-rich rivers can retain high growth in sections with high densities although most individuals have small feeding territories. This means that density-independent processes in the form of habitat quality could potentially be more critical than density-dependent processes for explaining variation in growth (Gibson et al., 2008).

The 0+ length of Atlantic salmon did correlate negatively with increasing shelter availability and positively with increasing density of 0+ Atlantic salmon in this study. This is most likely an indication for variability in habitat quality, as good habitats for 0+ salmonids can hold higher growth and densities than poorer available habitats for 0+ individuals. Moreover, variation in 0+ length of Atlantic salmon was not found to correlate with being above or below the outlet point.

4.5. Did salmonids below the sedimentation pond experience lower survival?

Monthly survival probability for salmonids in this study was found to be lower for individuals below the outlet point compared with individuals above it. Solberg (2016) also found lower monthly survival probability from individuals sampled below the outlet point compared with individuals from above it. Coghlan & Ringler (2005) also found decreased survival of Atlantic salmon in the downstream direction of a river. They stated that reduced survival in the downstream direction of the river was due to increasing anthropogenic perturbations in the catchment in downstream sections (nonpoint pollution), which led to a higher degree of water pollution in these sections compared with sections higher up in the river basin.

In addition, it was found that survival probability was length-specific, with lower survival for larger individuals both above and below the outlet point between September and February, but higher survival for larger individuals between February and March. Solberg (2016) also found that monthly survival probability was higher for larger individuals. The differences in length-specific monthly survival between above and below individuals was also most remarkable between February and March. The higher monthly survival probability observed for larger individuals between February and March agrees with the "bigger is better" hypothesis (Sogard, 1997). This hypothesis explains that juvenile individuals in a cohort of teleost fish with better growth or larger size gain a higher survival probability due to reduced vulnerability to predators and their higher potential to deal with starvation and environmental extremes. Smaller individuals generally have a higher metabolic rate and smaller energy reserves (lipid content; Berg & Bremset, 1998). Thus, higher survival of larger individuals under challenging conditions is not always as clear (Carlson et al., 2008). With this, winter survival in general might be lower for smaller individuals compared with larger individuals during this harsh period of the year (Metcalfe & Thorpe, 1992).

In this study, the advantage of being larger appeared to be more pronounced in individuals above the outlet point compared with individuals below the outlet point. While individuals larger than 15 cm from stations above the outlet point achieved 100 % monthly survival, no individuals below the outlet point achieved 100 % survival between February and March. This could be because those individuals below the outlet point are exposed to additional stresses upon the limiting effects that winter conditions exert on them. Lemly (1996) mentioned an important condition called winter stress syndrome, which refers to an increase in the use of energy reserves caused by additional stressors such as contaminants in the otherwise demanding cold period of the year. In the case of Årungselva, if individuals below the outlet point are exposed to discharges of contaminants occasionally during winter, it could be that increased metabolism due to detoxification processes could increase the overall mortality of individuals due to the depletion of energy reserves. Stressors that are tolerated in summer can become lethal in winter, and reduced food intake in winter can restrict the compensation probabilities due to increased metabolic costs (Lemly, 1996). With this, the effect of additional stresses on smaller individuals will likely be most obvious in the last part of the winter as energy reserves possibly is at its lowest. This is in line with that "bigger is better" is more pronounced between February and March than between September and February.

In the time between September and February, larger individuals exhibited decreasing monthly survival compared with smaller ones both above and below the outlet point. This is not in line with the “bigger is better” hypothesis mentioned earlier (Sogard, 1997). There is some uncertainty linked to this result, but it could be that a proportion of larger individuals are moving out of the system and into Bunnefjorden, as estimates in this study could not differentiate between deaths or emigrations. This is supported by this study’s results on movements as larger individuals tended to move further downstream and that more far-reaching movements were made during the period between sampling in September and recapture in February compared with recapture between February and March. Although most parr smoltify and migrate to sea during spring to early summer, they can literally move to sea anytime of the year (Jonsson & Jonsson, 2014; Jonsson et al., 2017; Winter et al., 2016). It could be that larger individuals are moving downstream in search of a better habitat and end in the estuary outside the river mouth of Årungselva. The residence of parr in an estuarine environment has been found by other researchers (Cunjak et al., 1989; Pinder et al., 2007). Notably, in the study of Jonsson et al. (2017), 55% of the individuals that were 20 cm or longer moved to sea between July and September.

With this, salmonids below the sedimentation pond in this study did experience lower survival than above it. It appears that salmonids below the outlet point are exposed to an additional stress factor compared to salmonids above the outlet point, which could be due to discharges of untreated tunnel wash water from the Vassum sedimentation pond.

4.6. Did salmonids below the sedimentation pond move more than salmonids above the sedimentation pond?

Most recaptured individuals (detected on the mobile antenna) in this study were detected “inside” or close to the station where they were PIT-tagged in the period from September to March. Nevertheless, there were moving individuals, mostly downstream, from stations both below and above the outlet point, with a tendency of more individuals moving as with increasing number of PIT-tagged individuals from the specific station (Appendix C, Figure 18). Individuals PIT-tagged from stations below the outlet point (stations 3–5) were the only ones that presented some degree of upstream movements (Appendix C, Figure 18).

The high proportion of recaptured individuals within the station agrees with the “restricted movement paradigm,” which claims that salmonids inhabiting rivers are mainly sedentary (Gowan et al., 1994). This paradigm is consistent with movement studies of juvenile Atlantic salmon in rivers both in summer (Hesthagen, 1988; Juanes et al., 2000; Roy et al., 2013;

Steingrímsson & Grant, 2003) and winter (Enders et al., 2008; Linnansaari & Cunjac, 2013; Stickler et al., 2008), which have found high degrees of site fidelity with most individuals staying within a few meters during longer periods. These studies also reported some degree of movement, at least of some few individuals, mostly downstream. This is in accordance with my study with downstream movements observed for individuals at each station (Appendix C, Figure 18). Studies have also found a larger proportion of juvenile Atlantic salmon to be more mobile, to move between different sections of the river, and to use larger home ranges (e.g., Brunsdon et al., 2017; Cunjak & Randall, 1993; Økland et al., 2004). Most of the more far-reaching movements were made in the period between sampling in September and recapture in February. Earlier studies have also found a proportion of the juvenile Atlantic salmon stock to move longer distances in autumn (Hesthagen, 1988; Ibbotson et al., 2013; Pinder et al., 2007) and winter (Cunjak & Randall, 1993).

This study also tested for different predictor variables that could explain the variation in movement between individuals. The best candidate model demonstrated that faster growing individuals exhibited a higher tendency to move further downstream, while slower growing individuals exhibited a higher tendency to move further upstream, whereas the former one was most pronounced. Other studies have found movement to vary with changes in density-independent factors such as discharge and light (Boavida et al., 2016; Roy et al., 2013), ice formation (Linnansaari et al., 2009; Whalen et al., 1999), pollution of contaminants (Atchison et al., 1987), and temperature (Dugdale, 2016), as well as density-dependent factors such as shelter availability (Finstad et al., 2009; Teichert et al., 2017), growth (Steingrímsson & Grant, 1999), territory, and food availability (Milner et al., 2003; Steingrímsson & Grant, 2003; Symons, 1971). A common pattern to expect in terms of the movement of juvenile salmonids in rivers is that those who grow the poorest in high-density areas are more likely to move to other available territories of the river due to competition with faster-growing and dominant individuals (Armstrong, 1997; Einum et al., 2012; Elliott, 1993; Steingrímsson & Grant, 1999). Since faster-growing individuals seemed to move further downstream in this study, processes other than competition are possibly responsible for this pattern. It could be that the increasing movement of larger individuals is motivated by the search for a better habitat in terms of a more suitable temporal flow and/or temperature conditions, feeding opportunities, over-wintering habitat, shelter availability, and/or territory size (McCormick et al., 1998). It could also be that larger parr inhabiting areas close to the spawning habitat are suppressed by larger migratory spawners during the spawning period in autumn (Jonsson &

Jonsson, 2014). Such movements of faster-growing individuals downstream might also be linked to the behavior of presmolts (Jonsson & Jonsson, 2014; McCormick et al., 1998; Pinder et al., 2007; Youngson et al., 1994). Previous studies have found that stocks of Atlantic salmon with good conditions in the juvenile stage (e.g., suitable temperatures and abundant food supply) grow quickly and can already smoltify after one year (1+). Such populations of 0+ in the autumn often evolve to a bimodal group, which is divided into a subgroup that reduces growth (lower modal group) and one that continues to grow throughout the autumn and winter (upper modal group). The upper modal group is often those that migrate out as smolts the following spring, whereas the lower modal group wait one or two additional years (Kristinsson et al., 1985; Metcalfe et al., 1988). Interestingly, Heggenes & Borgstrøm (1988) found that faster-growing individuals of brown trout in Årungselva smoltified as 1+ which indicates that 0+ individuals in autumn evolve to an upper and lower modal group. The higher degree of downstream movement of individuals with larger age-specific lengths between September and first detection round in February could be somewhat linked to this bimodality in smolting of 0+ individuals.

Furthermore, the best candidate model which explained variation in movement also exhibited a higher degree of movement for salmonids just below the outlet point than above it and further downstream. These results can be interpreted as it being more unfavorable to be in these river sections, as individuals above and far below the outlet point moved less despite higher densities in these sections. There are few studies that have investigated in avoidance behavior in fish to responses to contaminants in the field, while several laboratory studies have tested for different concentrations of various contaminants on avoidance behavior (Tierney, 2016). Two field studies mentioned in the review paper of Atchison et al. (1987) found that adult migrating Atlantic salmon avoided sections polluted with higher concentrations of copper and zinc. Furthermore, a study by Thorstad et al. (2005) found that in a sample of 32 radio-tagged adult migrating Atlantic salmon that had attained the resident phase during spawning-migration, 50 % exhibited an avoidance response after the release of wastewater from a decommissioned wood pulp industry and into a river; 19 % moved upstream and 31 % moved downstream, although the wastewater was concluded to be nontoxic. Earlier laboratory studies have generally reported low threshold concentrations of avoidance from different metals in salmonids: 1 μg/L Cu, 0.01 μg/L Zn (rainbow trout; Svecevičius, 1999), 6.4 μg/L Cu, 23.9 μg/L Ni (rainbow trout; Giattina et al., 1982), 5.6 μg/L

Zn (rainbow trout; Sprague, 1968), 2.3 µg/L Cu, 53 µg/L Zn, mixture of 0.42 µg/L Cu and 6.1 µg/L Zn (Atlantic salmon; Sprague, 1964), and mixture of 1.2 µg/L Cu, 0.11 µg/L Cd, 0.32 µg/L Pb, and 5.0 Zn (rainbow trout; Hansen et al., 1999).

According to a washing plan from the NPRA, three nights of full washings and six nights of half washings were completed in the period between 01.10.2020 and 15.02.2021 (Appendix B). It could be possible that individuals just below the outlet point are moving away from contaminated water due to avoidance behavior. Noteworthily, the two individuals that moved furthest upstream were PIT-tagged at station 3, the station closest to the outlet point of the stations below it. It is difficult to relate discharges from tunnel wash water from the outlet point to potential avoidance behavior in salmonids just below the outlet point tunnel by interpreting the water samples from this study. Nevertheless, small increases in concentrations of particular contaminants in Årungselva caused by discharges from the outlet point could possibly be enough to cause avoidance behavior as; releases happens irregularly (i.e., acclimation to higher concentrations not possible); 50 % of the metals from discharges from the outlet point are linked to the low molecular mass (Meland et al., 2010b); and threshold of avoidance to metals is much lower in mixture of different metals than of a single metal (Hansen et al., 1999; Sprague, 1964; Tierney, 2016). As bioavailability of metals will vary with several conditions (e.g., dissolved organic matter, turbidity, and temperature), threshold concentrations of avoidance behavior will differ between study systems. Furthermore, careful interpretation must be employed as only small differences in movement were found between individuals from above, just below, and far below stations in this study.

Compared with Solberg's (2016) results, which did not reveal any individual moving between sections above and below the outlet point, this study revealed that a proportion of the individuals located both above and below the outlet point sections were moving both down- and upstream, and past the outlet point from both above and below individuals. Nevertheless, Solberg used two stationary antennas immediately below the outlet point, which were in proximity to each other, to determine the direction and timing of potential movements of PIT-tagged individuals. It is possible that those stationary antennas did not catch the movements of passing individuals as well as the mobile antenna used in the present study. Furthermore, although Solberg conducted six sampling rounds and PIT-tagged 253 individuals during his study, no individuals were recaptured outside of their tagging station.

Overall, the higher degree of movement found for salmonids just below the sedimentation pond indicates that it is more unfavorable to be in these areas, which may be due to avoidance behavior against contaminants from the outlet point.

4.7. Is there any connection between density, survival, and movement of salmonids above and below the sedimentation pond?

Although the habitat quality just below the outlet point is found to be poor in terms of salmonids, with Atlantic salmon generally preferring coarser substrate than brown trout (Armstrong et al., 2003; Heggenes et al., 1999), the low densities found in these sections could be due to lower survival and higher degree of movement found in this section. The lower survival and higher degree of movement found below the outlet point could also be due to poor habitat quality per se, with individuals from these sections possibly suffer from lower food supply and little access to territories. Other explanations may be additional stressors in this river section, such as discharges from the outlet point. As densities were higher at station 3 which were closer to the outlet point than station 4 indicates that other factors than discharges from the outlet point is responsible for differences in density between those stations, as concentration of contaminants are expected to be diluted downstream. The lower survival found for individuals below the outlet point could also be a result of displacement of smaller subordinates from dense sections above the outlet point which have to settle for poorer areas below the outlet point. As such smaller individuals are considered to have higher metabolic rate and lower energy reserves, lower survival can be experienced by those individuals.

4.8. Other potential factors influencing density, survival, and movement of salmonids in Årungselva

In Årungselva, pike (*Esox lucius*) are present, at least temporally, in some pools and the slower-flowing parts of the river (Haugen, 2021; personal observations, 2021). This means probably that juvenile salmonids will avoid slower-flowing areas to a greater extent and that survival is lower in these sections than if pike had not been in the system (Greenberg, 1992), as pike are an important predator of juvenile salmonids where they are found (Jepsen et al., 1998). Heggenes & Borgstrøm (1988) also found that mink (*Neovison vison*) is an important predator of juvenile salmonids in Årungselva. They discussed that high water flow and good access to coarse substrate and high shelter availability were limiting the proportion of parr that the mink managed to take. It is reasonable to think that juvenile salmonids in Årungselva will mostly seek faster-flowing water and coarser habitat above and further downstream of the outlet point. Furthermore, at station 3, as many as four brown trout between 20 and 30 cm were caught. Since station 3 was the station with the second lowest density of 0+ and 1+ Atlantic salmon, competition or territorial claims from larger and aggressive brown trout may be a contributing factor to relatively lower density, survival, and higher degree of movement at this station. In addition, station 1 had smaller waterfalls close to the upper limit; the upper limit of station 2 was right next to where the river crosses the road; and station 5 had rapids close to the upper limit. It is possible that such characteristics could function as partial barriers to upstream movements at these stations.

4.9. Shortcomings

After the sampling and PIT-tagging of fish in September 2020, which were conducted under “perfect” sampling conditions with a low flow, the right temperature, and high clarity of water, the river increased in water flow and turbidity immediately after the sampling was conducted at the end of September with increased precipitation (Appendix D). After this, the river remained inaccessible during longer periods in the autumn and winter as the water flow remained high and exhibited high turbidity. Even though two detection rounds with the mobile antenna were completed, the conditions could possibly be more optimal during these rounds. The water flow should be as low as possible for a higher recapture probability (O´Donnell et al., 2010). Although the water level was low enough in February, the probability of detection may also have been reduced due to the increasing proportion of ice on the riverbank and across the river in some sections. Furthermore, it appeared to be harder to detect PIT-tagged individuals in the slower flowing sections just below the outlet point as these sections were deeper and wider. It could be that reduced survival probability in below sections is partly due to inability to detect all PIT-tagged individuals in these sections, compared to other sections of Årungselva.

Another weakness of detections of PIT-tags is whether the fish are alive. As Årungselva had a high degree of turbidity in winter, it was impossible to see if the fish were dead or alive. Even though attempts were made to scare the fish to see if they were moving with the use of antenna, most individuals remained sedentary. The fish were most probably sheltering between stones. Noteworthily, Gries & Letcher (2002) tagged 3037 individuals of 0+ Atlantic salmon that were kept in a flow-through tank for 9 months and found that tag retention was 99.8% and survival was 94.3%.

Since larger PIT-tags have a longer range, it is expected that detection probability would be higher for larger individuals. This fits well with the results as higher recapture probabilities for larger individuals were found in this study (Figure 16). Another weakness is whether it is the fish that have moved or whether it is a potential predator that has moved the PIT-tag. Furthermore, even movement was detected for many individuals, the true motivation for such movement is uncertain.

Moreover, the variation in weighted shelter availabilities between stations in this study could also be more accurate since cavities were measured only randomly at one point on each of the transects within 50 × 50 cm. Several fixed points should have been measured on each transect instead, since this would catch more of the overall variation in shelter availability. In addition, cavities between logs in the water should have been included to provide a more accurate overall picture of the hiding conditions. The method used was originally adapted to rivers in West Norway (Harby & Forseth, 2013; Haugen, 2021).

Even though water samples were taken at two different full washings of the tunnels, it could be that concentrations of contaminants were not evenly distributed in the river when they got released from the sedimentation pond. Furthermore, since the water is released in a slow flowing part of the river, it could be that it takes time before the pulse with the highest concentration of contaminants to reach the downstream sampling site. Even though water samples in this study could not reveal any larges differences between water samples taken above and below the outlet point, these samples are only a snapshot of the water quality during washing events, and concentrations could possibly be higher before and after samplings. In addition, detergents from the washing process were not measured in this study, and, since detergents need more than two weeks to be sufficiently degraded, it could be that concentrations of detergents were relatively high compared to concentrations found for metals in this study.

As this is a field study on a population- and community of fish (Munkittrick & McCarty, 1995; Suter II et al., 2005), general limitations are accepted for data obtained in such studies

(Baker, 1991). Patterns observed from the field cannot be completely associated with an exact cause since many factors could be responsible. Nevertheless, surveys in the field can at least reveal how severe potential releases of contaminants could affect fish populations/ communities in impacted sections compared to reference sites (Baker, 1991).

4.10. Further research and recommendations

If the current sedimentation pond is still to be used to remove contaminants from runoff water from tunnel washing as well as from roads from precipitation and snowmelt, further studies on salmonids in the river are strongly recommended, especially because Meland et al. (2010b) found high loadings of several contaminants in the outlet point. Moreover, the degree to which the water discharged into Årungselva is purified seems to be dependent on environmental conditions such as precipitation intensity before and after the tunnels are washed (Åstebøl et al., 2012). Furthermore, attention should also be paid to other specific circumstances such as periods with snowmelt, low flow, and high-intensity precipitation when the detention pond is covered with ice. Vollertsen et al. (2009) found that a wet detention pond close to a highway generally removed pollutants effectively through the year, except during two snowmelt events (February and March).

In general, field studies in Årungselva should continue in the years to come to catch following trends in species- and length structures, density, growth, survival, and movements between the sections above and below the outlet point. This is especially true for species structure, as Atlantic salmon densities were completely dominant in 2020, in contrast to earlier years. If a similar study in Årungselva is conducted in the future, it should establish more sampling stations and use as many stationary antennas as possible to obtain results on the timing of movements to link effects on salmonids from tunnel washings. Furthermore, studies of macroinvertebrate diversity between the above and below sections should be conducted, which could possibly indicate indirect effects from tunnel washings on salmonids through reduced feeding possibilities in sections below the outlet point. In the course NATF340 at NMBU in years to come, three rounds of overfishing (Zippin's method) should be performed at the stations used to catch density differences between the years. Furthermore, biomarker responses should be investigated from individuals above and below the outlet point shortly after full washings of the tunnels, which is earlier recommended (Dybwad, 2015; Skarsjø, 2015). A logging-system in the outlet point could be useful to catch when overflows are released into the river. Focus should also be placed on taking water samples during and after tunnel washings, during high-intensity precipitation, and snowmelt periods, which can be detected by the potential logging system in the outlet point.

The goal would be to obtain a holistic view of how runoff from tunnel washings can affect salmonids in Årungselva (Connon et al., 2012). As other field studies on salmonids conducted in Årungselva (Meland et al., 2010b; Solberg, 2016) have also indicated poorer conditions for salmonids below the outlet point, and since discharges from the outlet point were documented as being highly polluted under specific circumstances (Meland et al., 2010b), additional or other "safer" measures for removing contaminants from water entering the river should be considered (Rambøll et al., 2016; Åstebøl et al., 2012). Rambøll (2016) recommended that the existing sedimentation pond should be at least 2 m deeper in both ponds, and that the uppermost pre sedimentation pond should be expanded from 50 m^2 to 75 m^2.

5. Conclusion

This study documented lower survival of salmonids located below the outlet point of Vassum sedimentation pond which flows into Årungselva. Furthermore, a higher degree of movement, both down- and upstream, from salmonids located just below the outlet point was found compared with individuals located above and far below the outlet point. This was despite the fact there were lower densities just below than above and far below the outlet point. However, this study was unable to find evidence of reduced 0+ sizes of salmonids below the outlet point compared with above it, but these results did not have individual control on relocation histories of the fish. Water samples collected in this study indicated that the sedimentation pond works adequately to remove contaminants from tunnel washing "under normal conditions" as only few metals showed marginally higher values below the outlet point compared to sections above it. Although lower survival and higher degree of movement was found for salmonids below the outlet point, this study cannot blame discharges from the Vassum sedimentation pond to this pattern. This is mainly because habitat conditions for salmonids just below the outlet point is remarkable poorer than above it and further downstream. The hypothesis that salmonids below the outlet point experience poorer conditions in term of lower survival and higher degree of movement is supported, but that this is due to increased concentrations of contaminants from discharges from the Vassum sedimentation pond during tunnel washings is not supported. Thus, this study supports previous studies (Meland et al., 2010b; Solberg, 2016) that salmonids below the outlet point experience poorer conditions than salmonids above it.

Nevertheless, it could be that other kinds of overflow episodes are more important, e.g., high-intensity precipitation and snowmelt events at the same time as tunnel washings. A logging-system in the outlet point could be useful to catch when overflows are released into the river. Furthermore, it is recommended to take more water samples during upcoming tunnel washings and to study selected biomarkers in salmonids above and below the outlet point right after tunnel washings. There should also be set up stationary antennas next to all stations below the outlet point in studies where PIT-tagging is used to relate timing of movement to discharges from the Vassum sedimentation pond.

6. References

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7. Appendices

Appendix A: Capture-data from electrofishing and recapture-data from detections.

Table A-1. *Capture data from electrofishing.*

Species	Station	Date	Capture round	PIT-id	Size limit age	Total length (cm)	Age
Atlantic salmon	1	2020-09-21	1	939000002224604	11	10.2	0+
Atlantic salmon	1	2020-09-21	1	900226001154725	11	7.1	0+
Atlantic salmon	1	2020-09-21	1	900226001154776	11	6.5	0+
Atlantic salmon	1	2020-09-21	1	900226001154726	11	7.5	0+
Atlantic salmon	1	2020-09-21	1	900226001154702	11	7.5	0+
Atlantic salmon	1	2020-09-21	1	900226001154763	11	7	0+
Atlantic salmon	1	2020-09-21	1	939000002224583	11	9.7	0+
Atlantic salmon	1	2020-09-21	1	900226001154773	11	7.5	0+
Atlantic salmon	1	2020-09-21	1	900226001154759	11	7.5	0+
Atlantic salmon	1	2020-09-21	1	900228000642861	11	17.4	1+
Atlantic salmon	1	2020-09-21	1	900228000642869	11	16.2	1+
Atlantic salmon	1	2020-09-21	1	939000002224742	11	8.5	0+
Atlantic salmon	1	2020-09-21	1	939000002224533	11	9	0+
Atlantic salmon	1	2020-09-21	1	900226001154781	11	6.8	0+
Atlantic salmon	1	2020-09-21	1	939000002224664	11	9.2	0+
Atlantic salmon	1	2020-09-21	1	939000002224662	11	8.2	0+
Atlantic salmon	1	2020-09-21	1	939000002224658	11	9.5	0+
Atlantic salmon	1	2020-09-21	1	939000002224518	11	9.1	0+
Atlantic salmon	1	2020-09-21	1	939000002224545	11	7.7	0+
Atlantic salmon	1	2020-09-21	1	939000002224539	11	9.1	0+
Atlantic salmon	1	2020-09-21	1	900226001154760	11	7.9	0+
Atlantic salmon	1	2020-09-21	1	939000002224729	11	7	0+
Atlantic salmon	1	2020-09-21	1	900226001154705	11	7.5	0+
Atlantic salmon	1	2020-09-21	1	939000002224612	11	9.5	0+
Atlantic salmon	1	2020-09-21	1	900226001154749	11	7	0+
Atlantic salmon	1	2020-09-21	1	900226001155481	11	7.9	0+
Atlantic salmon	1	2020-09-21	1	939000002224519	11	8.2	0+
Atlantic salmon	1	2020-09-21	1	939000002224720	11	8.5	0+
Atlantic salmon	1	2020-09-21	1	900226001155485	11	7.4	0+
Atlantic salmon	1	2020-09-21	1	900228000642883	11	13.9	1+
Atlantic salmon	1	2020-09-21	1	939000002224556	11	9.7	0+
Atlantic salmon	1	2020-09-21	1	939000002224677	11	9.4	0+
Atlantic salmon	1	2020-09-21	1	900226001154711	11	7.2	0+
Atlantic salmon	1	2020-09-21	1	900226001154770	11	7.7	0+
Atlantic salmon	1	2020-09-21	1	900226001154751	11	7.8	0+

Atlantic salmon	1	2020-09-21	1	900228000642874	11	15.8	1+
Atlantic salmon	1	2020-09-21	1	900228000642863	11	14.8	1+
Atlantic salmon	1	2020-09-21	1	939000002224700	11	12.2	1+
Atlantic salmon	1	2020-09-21	1	900228000642866	11	13.2	1+
Atlantic salmon	1	2020-09-21	1	900228000642873	11	14.2	1+
Atlantic salmon	1	2020-09-21	1	900228000531268	11	14.4	1+
Atlantic salmon	1	2020-09-21	1	900228000531270	11	15	1+
Atlantic salmon	1	2020-09-21	1	900228000531272	11	14.5	1+
Atlantic salmon	1	2020-09-21	1	939000002224646	11	10.2	0+
Atlantic salmon	1	2020-09-21	1	900226001154724	11	7.7	0+
Atlantic salmon	1	2020-09-21	1	900228000531267	11	15	1+
Atlantic salmon	1	2020-09-21	1	939000002224596	11	9.5	0+
Atlantic salmon	1	2020-09-21	1	939000002224622	11	9.3	0+
Atlantic salmon	1	2020-09-21	1	900226001154719	11	7.3	0+
Atlantic salmon	1	2020-09-21	1	939000002224522	11	8.1	0+
Atlantic salmon	1	2020-09-21	1	900226001154793	11	7.8	0+
Atlantic salmon	1	2020-09-21	1	900228000531266	11	13.2	1+
Atlantic salmon	1	2020-09-21	1	900228000531275	11	14.4	1+
Atlantic salmon	1	2020-09-21	1	939000002224691	11	10.5	0+
Atlantic salmon	1	2020-09-21	1	939000002224619	11	8.7	0+
Atlantic salmon	1	2020-09-21	1	939000002224727	11	9.2	0+
Atlantic salmon	1	2020-09-21	1	900226001154744	11	7.7	0+
Atlantic salmon	1	2020-09-21	1	939000002224610	11	8.3	0+
Atlantic salmon	1	2020-09-21	1	939000002224565	11	9.6	0+
Atlantic salmon	1	2020-09-21	1	939000002224592	11	9.6	0+
Atlantic salmon	1	2020-09-21	1	939000002224734	11	9.7	0+
Atlantic salmon	1	2020-09-21	1	939000002224672	11	8.4	0+
Atlantic salmon	1	2020-09-21	1	939000002224597	11	8.8	0+
Atlantic salmon	1	2020-09-21	1		11	5.9	0+
Atlantic salmon	1	2020-09-21	1	900226001154797	11	7.8	0+
Atlantic salmon	1	2020-09-21	1	939000002224631	11	9.3	0+
Atlantic salmon	1	2020-09-21	1	939000002224502	11	8.9	0+
Atlantic salmon	1	2020-09-21	1	900226001154786	11	7.9	0+
Atlantic salmon	1	2020-09-21	1	900226001154715	11	7.5	0+
Atlantic salmon	1	2020-09-21	1	939000002224567	11	8.5	0+
Atlantic salmon	1	2020-09-21	1	939000002224635	11	8.1	0+
Atlantic salmon	1	2020-09-21	1	900226001155403	11	7.6	0+
Atlantic salmon	1	2020-09-21	1	939000002224728	11	9.4	0+
Atlantic salmon	1	2020-09-21	1	900226001154784	11	6.5	0+
Atlantic salmon	1	2020-09-21	1		11	6	0+
Atlantic salmon	1	2020-09-21	1	900226001154730	11	6.5	0+
Atlantic salmon	1	2020-09-21	1	939000002224671	11	9.3	0+
Atlantic salmon	1	2020-09-21	1	939000002224515	11	9.1	0+
Atlantic salmon	1	2020-09-21	1	900226001154737	11	7.2	0+
Atlantic salmon	1	2020-09-21	1	939000002224506	11	8.6	0+
Atlantic salmon	1	2020-09-21	1	900228000531269	11	15.9	1+

Atlantic salmon	1	2020-09-21	1	900228000531273	11	14.5	1+
Atlantic salmon	1	2020-09-21	1	939000002224656	11	7	0+
Atlantic salmon	1	2020-09-21	1	900226001155493	11	7.4	0+
Atlantic salmon	1	2020-09-21	1	939000002224688	11	8.4	0+
Atlantic salmon	1	2020-09-21	1	900226001155456	11	8	0+
Atlantic salmon	1	2020-09-21	1	900226001155435	11	7.4	0+
Atlantic salmon	1	2020-09-21	1	900226001154785	11	7	0+
Atlantic salmon	1	2020-09-21	1	900226001154747	11	8	0+
Atlantic salmon	1	2020-09-21	1	900226001154756	11	7.8	0+
Atlantic salmon	1	2020-09-21	1	900226001154713	11	7.2	0+
Atlantic salmon	1	2020-09-21	1	939000002224749	11	8.5	0+
Atlantic salmon	1	2020-09-21	1	900226001154767	11	9.7	0+
Atlantic salmon	1	2020-09-21	1	939000002224704	11	8.5	0+
Atlantic salmon	1	2020-09-21	1	900228000531274	11	15	1+
Atlantic salmon	1	2020-09-21	1	900228000531277	11	14.7	1+
Atlantic salmon	1	2020-09-21	1	900228000531271	11	14.5	1+
Atlantic salmon	1	2020-09-21	1	900228000531279	11	13.4	1+
Atlantic salmon	1	2020-09-21	1	939000002224594	11	8.3	0+
Atlantic salmon	1	2020-09-21	1	900226001154762	11	7.9	0+
Atlantic salmon	1	2020-09-21	1	939000002224576	11	8.5	0+
Atlantic salmon	1	2020-09-21	1	939000002224692	11	10	0+
Atlantic salmon	1	2020-09-21	1	900226001154774	11	8.5	0+
Atlantic salmon	1	2020-09-21	2		11	8.7	0+
Atlantic salmon	1	2020-09-21	1	939000002224676	11	10.5	0+
Atlantic salmon	1	2020-09-21	1	939000002224563	11	8.9	0+
Atlantic salmon	1	2020-09-21	1	900226001154783	11	7.1	0+
Atlantic salmon	1	2020-09-21	1	939000002224693	11	8.7	0+
Atlantic salmon	1	2020-09-21	2		11	10.3	0+
Atlantic salmon	1	2020-09-21	1	900226001154777	11	6.7	0+
Atlantic salmon	1	2020-09-21	1	939000002224707	11	10.3	0+
Atlantic salmon	1	2020-09-21	1	900226001154787	11	7.7	0+
Atlantic salmon	1	2020-09-21	1	900226001154712	11	7	0+
Atlantic salmon	1	2020-09-21	1	939000002224528	11	8.4	0+
Atlantic salmon	1	2020-09-21	1	939000002224531	11	9.2	0+
Atlantic salmon	1	2020-09-21	2		11	10.5	0+
Atlantic salmon	1	2020-09-21	1	900226001154772	11	7.9	0+
Atlantic salmon	1	2020-09-21	1	900228000531276	11	14.9	1+
Atlantic salmon	1	2020-09-21	1	939000002224611	11	9.5	0+
Atlantic salmon	1	2020-09-21	2		11	7.4	0+
Atlantic salmon	1	2020-09-21	1	939000002224586	11	10.2	0+
Atlantic salmon	1	2020-09-21	2		11	10.9	0+
Atlantic salmon	1	2020-09-21	1	939000002224544	11	8.1	0+
Atlantic salmon	1	2020-09-21	1	900226001154799	11	7.3	0+
Atlantic salmon	1	2020-09-21	1	939000002224599	11	10	0+
Atlantic salmon	1	2020-09-21	1	939000002224590	11	9.2	0+
Atlantic salmon	1	2020-09-21	2		11	14	1+

Atlantic salmon	1	2020-09-21	3		11	8.9	0+
Atlantic salmon	1	2020-09-21	2		11	8.4	0+
Atlantic salmon	1	2020-09-21	2		11	8.3	0+
Atlantic salmon	1	2020-09-21	2		11	7.3	0+
Atlantic salmon	1	2020-09-21	2		11	6.2	0+
Atlantic salmon	1	2020-09-21	2		11	7.4	0+
Atlantic salmon	1	2020-09-21	2		11	9	0+
Atlantic salmon	1	2020-09-21	2		11	6.7	0+
Atlantic salmon	1	2020-09-21	2		11	6.3	0+
Atlantic salmon	1	2020-09-21	2		11	6.5	0+
Atlantic salmon	1	2020-09-21	2		11	7.9	0+
Atlantic salmon	1	2020-09-21	2		11	8	0+
Atlantic salmon	1	2020-09-21	2		11	9.3	0+
Atlantic salmon	1	2020-09-21	2		11	8.8	0+
Atlantic salmon	1	2020-09-21	2		11	9.9	0+
Atlantic salmon	1	2020-09-21	2		11	6.9	0+
Atlantic salmon	1	2020-09-21	2		11	9.1	0+
Atlantic salmon	1	2020-09-21	2		11	7.7	0+
Atlantic salmon	1	2020-09-21	2		11	8.1	0+
Atlantic salmon	1	2020-09-21	2		11	9.3	0+
Atlantic salmon	1	2020-09-21	2		11	10.9	0+
Atlantic salmon	1	2020-09-21	3		11	7.4	0+
Atlantic salmon	1	2020-09-21	2		11	9.5	0+
Atlantic salmon	1	2020-09-21	2		11	7.2	0+
Atlantic salmon	1	2020-09-21	2		11	7.3	0+
Atlantic salmon	1	2020-09-21	2		11	9.2	0+
Atlantic salmon	1	2020-09-21	2		11	8.9	0+
Atlantic salmon	1	2020-09-21	2		11	7.7	0+
Atlantic salmon	1	2020-09-21	3		11	8.7	0+
Atlantic salmon	1	2020-09-21	3		11	7.5	0+
Atlantic salmon	1	2020-09-21	2		11	7.3	0+
Atlantic salmon	1	2020-09-21	2		11	6.8	0+
Atlantic salmon	1	2020-09-21	3		11	8.9	0+
Atlantic salmon	1	2020-09-21	2		11	9.3	0+
Atlantic salmon	1	2020-09-21	2		11	6.3	0+
Atlantic salmon	1	2020-09-21	2		11	10.6	0+
Atlantic salmon	1	2020-09-21	2		11	9.2	0+
Atlantic salmon	1	2020-09-21	2		11	9.3	0+
Atlantic salmon	1	2020-09-21	3		11	8.2	0+
Atlantic salmon	1	2020-09-21	3		11	9.8	0+
Atlantic salmon	1	2020-09-21	3		11	7.8	0+
Atlantic salmon	1	2020-09-21	3		11	8.1	0+
Atlantic salmon	1	2020-09-21	3		11	8.2	0+
Atlantic salmon	1	2020-09-21	3		11	8.4	0+
Atlantic salmon	1	2020-09-21	3		11	7.2	0+
Atlantic salmon	1	2020-09-21	3		11	7.1	0+

Atlantic salmon	1	2020-09-21	3		11	10.8	0+
Atlantic salmon	1	2020-09-21	3		11	8.4	0+
Atlantic salmon	1	2020-09-21	3		11	9.9	0+
Atlantic salmon	2	2020-09-21	1	900226001154738	11	7.8	0+
Atlantic salmon	2	2020-09-21	1		11	9.4	0+
Atlantic salmon	2	2020-09-21	1	939000002224587	11	9	0+
Atlantic salmon	2	2020-09-21	1	900226001154754	11	7.6	0+
Atlantic salmon	2	2020-09-21	1	900226001154716	11	7.2	0+
Atlantic salmon	2	2020-09-21	1	900226001154734	11	7.4	0+
Atlantic salmon	2	2020-09-21	1	939000002224633	11	9.6	0+
Atlantic salmon	2	2020-09-21	1	900226001154794	11	7	0+
Atlantic salmon	2	2020-09-21	1	900226001154750	11	6.5	0+
Atlantic salmon	2	2020-09-21	1	939000002224618	11	9	0+
Atlantic salmon	2	2020-09-21	1	900226001154758	11	6.1	0+
Atlantic salmon	2	2020-09-21	1	900226001154718	11	7.3	0+
Atlantic salmon	2	2020-09-21	1	939000002224532	11	9.7	0+
Atlantic salmon	2	2020-09-21	1	900226001154708	11	7.9	0+
Atlantic salmon	2	2020-09-21	1	900226001154746	11	6.5	0+
Atlantic salmon	2	2020-09-21	1	900226001154714	11	5.9	0+
Atlantic salmon	2	2020-09-21	1	900226001154771	11	7.9	0+
Atlantic salmon	2	2020-09-21	1	939000002224678	11	9.8	0+
Atlantic salmon	2	2020-09-21	1	939000002224628	11	12.1	1+
Atlantic salmon	2	2020-09-21	2		11	8.6	0+
Atlantic salmon	2	2020-09-21	1	900226001154780	11	7.2	0+
Atlantic salmon	2	2020-09-21	1	939000002224738	11	8.7	0+
Atlantic salmon	2	2020-09-21	1	939000002224713	11	8.5	0+
Atlantic salmon	2	2020-09-21	1	900226001154701	11	7.2	0+
Atlantic salmon	2	2020-09-21	1	939000002224598	11	13.8	1+
Atlantic salmon	2	2020-09-21	1	900226001154748	11	8.6	0+
Atlantic salmon	2	2020-09-21	1	900226001154752	11	6.5	0+
Atlantic salmon	2	2020-09-21	1	900226001154796	11	8.1	0+
Atlantic salmon	2	2020-09-21	1	900226001154798	11	7.6	0+
Atlantic salmon	2	2020-09-21	1	939000002224623	11	9	0+
Atlantic salmon	2	2020-09-21	1	939000002224731	11	9.2	0+
Atlantic salmon	2	2020-09-21	1	900226001154790	11	6.8	0+
Atlantic salmon	2	2020-09-21	1	900226001154709	11	6.9	0+
Atlantic salmon	2	2020-09-21	1	900226001154733	11	6.1	0+
Atlantic salmon	2	2020-09-21	1	900226001154704	11	10.1	0+
Atlantic salmon	2	2020-09-21	1	900226001154753	11	7.9	0+
Atlantic salmon	2	2020-09-21	1	900226001154720	11	8.5	0+
Atlantic salmon	2	2020-09-21	1	939000002224709	11	8.6	0+
Atlantic salmon	2	2020-09-21	1	900226001154741	11	6.5	0+
Atlantic salmon	2	2020-09-21	1	900226001154739	11	9	0+
Atlantic salmon	2	2020-09-21	1	900226001154782	11	8.1	0+
Atlantic salmon	2	2020-09-21	1	900226001155452	11	7.1	0+
Atlantic salmon	2	2020-09-21	1	900226001154334	11	8.5	0+

Atlantic salmon	2	2020-09-21	1	939000002224697	11	8.7	0+
Atlantic salmon	2	2020-09-21	1	900226001154743	11	7.6	0+
Atlantic salmon	2	2020-09-21	1	900226001154757	11	10.3	0+
Atlantic salmon	2	2020-09-21	1	900226001154727	11	7.9	0+
Atlantic salmon	2	2020-09-21	1	900226001154775	11	7.5	0+
Atlantic salmon	2	2020-09-21	1	939000002224566	11	8.5	0+
Atlantic salmon	2	2020-09-21	1	900228000642867	11	13.2	1+
Atlantic salmon	2	2020-09-21	2		11	9.4	0+
Atlantic salmon	2	2020-09-21	2		11	6.6	0+
Atlantic salmon	2	2020-09-21	2		11	7	0+
Atlantic salmon	2	2020-09-21	2		11	8.5	0+
Atlantic salmon	2	2020-09-21	2		11	8.3	0+
Atlantic salmon	2	2020-09-21	2		11	12.1	1+
Atlantic salmon	2	2020-09-21	2		11	7	0+
Atlantic salmon	2	2020-09-21	2		11	8.5	0+
Atlantic salmon	2	2020-09-21	2		11	8	0+
Atlantic salmon	2	2020-09-21	3		11	9.5	0+
Atlantic salmon	2	2020-09-21	2		11	8.4	0+
Atlantic salmon	2	2020-09-21	2		11	7.5	0+
Atlantic salmon	2	2020-09-21	2		11	11.6	1+
Atlantic salmon	2	2020-09-21	2		11	5.9	0+
Atlantic salmon	2	2020-09-21	2		11	8	0+
Atlantic salmon	2	2020-09-21	2		11	7	0+
Atlantic salmon	2	2020-09-21	2		11	8.1	0+
Atlantic salmon	2	2020-09-21	2		11	8.3	0+
Atlantic salmon	2	2020-09-21	2		11	14.1	1+
Atlantic salmon	2	2020-09-21	2		11	7.7	0+
Atlantic salmon	2	2020-09-21	2		11	8.1	0+
Atlantic salmon	2	2020-09-21	2		11	6.1	0+
Atlantic salmon	2	2020-09-21	3		11	9.3	0+
Atlantic salmon	2	2020-09-21	2		11	8.1	0+
Atlantic salmon	2	2020-09-21	2		11	7.6	0+
Atlantic salmon	2	2020-09-21	2		11	8.2	0+
Atlantic salmon	2	2020-09-21	2		11	7.9	0+
Atlantic salmon	2	2020-09-21	2		11	9.6	0+
Atlantic salmon	2	2020-09-21	2		11	7.4	0+
Atlantic salmon	2	2020-09-21	2		11	7	0+
Atlantic salmon	2	2020-09-21	3		11	8.6	0+
Atlantic salmon	2	2020-09-21	2		11	6.5	0+
Atlantic salmon	2	2020-09-21	3		11	7.5	0+
Atlantic salmon	2	2020-09-21	3		11	13	1+
Atlantic salmon	2	2020-09-21	3		11	8.5	0+
Atlantic salmon	2	2020-09-21	3		11	9	0+
Atlantic salmon	2	2020-09-21	3		11	8.3	0+
Atlantic salmon	2	2020-09-21	3		11	12.6	1+
Atlantic salmon	2	2020-09-21	3		11	5.5	0+

Atlantic salmon	2	2020-09-21	3		11	7.9	0+
Atlantic salmon	2	2020-09-21	3		11	12	1+
Atlantic salmon	2	2020-09-21	3		11	8.5	0+
Atlantic salmon	2	2020-09-21	3		11	7.3	0+
Atlantic salmon	3	2020-09-13	1		10	14.56	1+
Atlantic salmon	3	2020-09-13	1		10	7.01	0+
Atlantic salmon	3	2020-09-13	1		10	13.9	1+
Atlantic salmon	3	2020-09-13	1		10	7.5	0+
Atlantic salmon	3	2020-09-13	1		10	7.4	0+
Atlantic salmon	3	2020-09-13	2		10	7	0+
Atlantic salmon	3	2020-09-13	2		10	6.5	0+
Atlantic salmon	3	2020-09-13	2		10	7.8	0+
Atlantic salmon	3	2020-09-13	2		10	7.8	0+
Atlantic salmon	3	2020-09-13	1	939000002224071	10	11.79	1+
Atlantic salmon	3	2020-09-13	1	900226001155484	10	7.5	0+
Atlantic salmon	3	2020-09-13	1	900226001155421	10	6.69	0+
Atlantic salmon	3	2020-09-13	1	939000002224995	10	12.4	1+
Atlantic salmon	3	2020-09-13	1	939000002224003	10	12.4	1+
Atlantic salmon	3	2020-09-13	1	939000002224206	10	12.4	1+
Atlantic salmon	3	2020-09-13	1	900226001154645	10	6.79	0+
Atlantic salmon	3	2020-09-13	1	939000002224145	10	7.5	0+
Atlantic salmon	3	2020-09-13	1	939000002224055	10	11.47	1+
Atlantic salmon	3	2020-09-13	1	900226001154679	10	7.4	0+
Atlantic salmon	3	2020-09-13	1	939000002224108	10	12.86	1+
Atlantic salmon	3	2020-09-13	1	939000002224077	10	12.5	1+
Atlantic salmon	3	2020-09-13	1	939000002224620	10	9.03	0+
Atlantic salmon	3	2020-09-13	1	900226001155497	10	7.22	0+
Atlantic salmon	3	2020-09-13	1	900226001154605	10	7.4	0+
Atlantic salmon	3	2020-09-13	1	900226001155457	10	6.9	0+
Atlantic salmon	3	2020-09-13	1	900226001155433	10	7.4	0+
Atlantic salmon	3	2020-09-13	1	900226001154647	10	7.01	0+
Atlantic salmon	3	2020-09-13	1	939000002224084	10	8.39	0+
Atlantic salmon	3	2020-09-13	1	900226001154644	10	6.37	0+
Atlantic salmon	3	2020-09-13	1	939000002224120	10	8.07	0+
Atlantic salmon	3	2020-09-13	1	939000002224176	10	8.18	0+
Atlantic salmon	3	2020-09-13	1	900226001155437	10	5.83	0+
Atlantic salmon	3	2020-09-13	1	900226001155474	10	6.58	0+
Atlantic salmon	3	2020-09-13	1	939000002224199	10	8.07	0+
Atlantic salmon	3	2020-09-13	1	900226001155400	10	7.01	0+
Atlantic salmon	3	2020-09-13	1	900226001155438	10	6.47	0+
Atlantic salmon	3	2020-09-13	1	900226001155402	10	7.01	0+
Atlantic salmon	3	2020-09-13	1	939000002224202	10	7.86	0+
Atlantic salmon	3	2020-09-13	1	900226001155441	10	7.01	0+
Atlantic salmon	3	2020-09-13	2		10	12.8	1+
Atlantic salmon	3	2020-09-13	2		10	8	0+
Atlantic salmon	3	2020-09-13	2		10	14	1+

Atlantic salmon	3	2020-09-13	2		10	14.2	1+
Atlantic salmon	3	2020-09-13	2		10	8	0+
Atlantic salmon	3	2020-09-13	2		10	8.4	0+
Atlantic salmon	3	2020-09-13	3		10	8	0+
Atlantic salmon	3	2020-09-13	3		10	12	1+
Atlantic salmon	3	2020-09-13	3		10	7.5	0+
Atlantic salmon	3	2020-09-13	2		10	8.1	0+
Atlantic salmon	3	2020-09-13	3		10	7.3	0+
Atlantic salmon	3	2020-09-13	2		10	7.9	0+
Atlantic salmon	3	2020-09-13	3		10	8.7	0+
Atlantic salmon	3	2020-09-13	3		10	9.5	0+
Atlantic salmon	4	2020-09-11	1	900226001154363	10	7.75	0+
Atlantic salmon	4	2020-09-11	1	939000002224638	10	13.07	1+
Atlantic salmon	4	2020-09-11	1	900228000642851	10	14.67	1+
Atlantic salmon	4	2020-09-11	1	900226001154320	10	6.79	0+
Atlantic salmon	4	2020-09-11	1	900226001154341	10	5.8	0+
Atlantic salmon	4	2020-09-11	1	900226001154351	10	6.158	0+
Atlantic salmon	4	2020-09-11	2		10	9.5	0+
Atlantic salmon	4	2020-09-11	2		10	7.9	0+
Atlantic salmon	4	2020-09-11	3		10	8	0+
Atlantic salmon	4	2020-09-11	3		10	13.7	1+
Atlantic salmon	5	2020-09-09	1	939000002224188	10	11.79	1+
Atlantic salmon	5	2020-09-09	1	939000002224125	10	11.58	1+
Atlantic salmon	5	2020-09-09	1	939000002224013	10	13.39	1+
Atlantic salmon	5	2020-09-09	1	939000002224244	10	12.3	1+
Atlantic salmon	5	2020-09-09	1	939000002224040	10	12.86	1+
Atlantic salmon	5	2020-09-09	1	939000002224212	10	11.9	1+
Atlantic salmon	5	2020-09-09	1	939000002224140	10	11.79	1+
Atlantic salmon	5	2020-09-09	1	900228000642853	10	14.99	1+
Atlantic salmon	5	2020-09-09	1	900226001154678	10	7.01	0+
Atlantic salmon	5	2020-09-09	1	939000002224121	10	7.648	0+
Atlantic salmon	5	2020-09-09	1	939000002224220	10	11.69	1+
Atlantic salmon	5	2020-09-09	1	900228000642854	10	14.03	1+
Atlantic salmon	5	2020-09-09	1		10	6.47	0+
Atlantic salmon	5	2020-09-09	1	900228000642848	10	13.5	1+
Atlantic salmon	5	2020-09-09	1	939000002224072	10	11.79	1+
Atlantic salmon	5	2020-09-09	1	939000002224038	10	10.9	1+
Atlantic salmon	5	2020-09-09	1	939000002224147	10	12.33	1+
Atlantic salmon	5	2020-09-09	1	939000002224075	10	12.33	1+
Atlantic salmon	5	2020-09-09	1	939000002224043	10	12.96	1+
Atlantic salmon	5	2020-09-09	1		10	6.47	0+
Atlantic salmon	5	2020-09-09	1	900226001154661	10	7.5	0+
Atlantic salmon	5	2020-09-09	1	900226001154697	10	6.58	0+
Atlantic salmon	5	2020-09-09	1	939000002224153	10	10.6	1+
Atlantic salmon	5	2020-09-09	1	900228000642855	10	12.756	1+
Atlantic salmon	5	2020-09-09	1	900226001154650	10	7.1	0+

Atlantic salmon	5	2020-09-09	1	900226001154651	10	6.9	0+
Atlantic salmon	5	2020-09-09	1	900226001154665	10	7.01	0+
Atlantic salmon	5	2020-09-09	1	900226001154673	10	7.01	0+
Atlantic salmon	5	2020-09-09	1	939000002224009	10	12.86	1+
Atlantic salmon	5	2020-09-09	1	900226001154670	10	6.05	0+
Atlantic salmon	5	2020-09-09	1	900226001154653	10	6.265	0+
Atlantic salmon	5	2020-09-09	1	900226001154662	10	6.3	0+
Atlantic salmon	5	2020-09-09	1	900226001154649	10	6.47	0+
Atlantic salmon	5	2020-09-09	1	900226001154639	10	6.47	0+
Atlantic salmon	5	2020-09-09	1	900226001154655	10	7.01	0+
Atlantic salmon	5	2020-09-09	1	900228000642845	10	15.5	1+
Atlantic salmon	5	2020-09-09	1	900226001154622	10	6.158	0+
Atlantic salmon	5	2020-09-09	2		10	13.8	1+
Atlantic salmon	5	2020-09-09	2		10	13	1+
Atlantic salmon	5	2020-09-09	2		10	8.5	0+
Atlantic salmon	5	2020-09-09	2		10	8.5	0+
Atlantic salmon	5	2020-09-09	2		10	7.5	0+
Atlantic salmon	5	2020-09-09	2		10	13.4	1+
Atlantic salmon	5	2020-09-09	2		10	7.5	0+
Atlantic salmon	5	2020-09-09	2		10	13	1+
Atlantic salmon	5	2020-09-09	1	939000002224048	10	11.79	1+
Atlantic salmon	5	2020-09-09	2		10	7.1	0+
Atlantic salmon	5	2020-09-09	2		10	8	0+
Atlantic salmon	5	2020-09-09	2		10	13.5	1+
Atlantic salmon	5	2020-09-09	2		10	11.8	1+
Atlantic salmon	5	2020-09-09	2		10	8.1	0+
Atlantic salmon	5	2020-09-09	2		10	7	0+
Atlantic salmon	5	2020-09-09	1	939000002224161	10	12.2	1+
Atlantic salmon	5	2020-09-09	2		10	7.7	0+
Atlantic salmon	5	2020-09-09	2		10	7.1	0+
Atlantic salmon	5	2020-09-09	1	939000002224167	10	10.5	1+
Atlantic salmon	5	2020-09-09	2		10	7.5	0+
Atlantic salmon	5	2020-09-09	2		10	6.7	0+
Atlantic salmon	5	2020-09-09	1		10	5.9	0+
Atlantic salmon	5	2020-09-09	3		10	7.8	0+
Atlantic salmon	5	2020-09-09	3		10	6.6	0+
Atlantic salmon	5	2020-09-09	3		10	12.8	1+
Atlantic salmon	5	2020-09-09	3		10	11.5	1+
Atlantic salmon	5	2020-09-09	1		10	5.5	0+
Atlantic salmon	5	2020-09-09	3		10	6.1	0+
Atlantic salmon	5	2020-09-09	3		10	7.5	0+
Atlantic salmon	5	2020-09-09	3		10	13.5	1+
Atlantic salmon	5	2020-09-09	3		10	7	0+
Atlantic salmon	5	2020-09-09	3		10	12.2	1+
Atlantic salmon	5	2020-09-09	3		10	7.3	0+
Atlantic salmon	5	2020-09-09	1	900226001154641	10	6.58	0+

Atlantic salmon	5	2020-09-09	3		10	7.5	0+
Atlantic salmon	5	2020-09-09	3		10	7.5	0+
Brown trout	1	2020-09-21	1	900226001154706	11	8	0+
Brown trout	1	2020-09-21	1	939000002224645	11	9.3	0+
Brown trout	1	2020-09-21	1	939000002224548	11	10.4	0+
Brown trout	1	2020-09-21	1		11	8.5	0+
Brown trout	1	2020-09-21	2		11	8.4	0+
Brown trout	1	2020-09-21	1	900226001154731	11	7.7	0+
Brown trout	2	2020-09-21	2		11	9.1	0+
Brown trout	2	2020-09-21	1	939000002224630	11	8.5	0+
Brown trout	2	2020-09-21	2		11	9.1	0+
Brown trout	3	2020-09-13	1	900228000642857	11	25.1	>1+
Brown trout	3	2020-09-13	2		11	7.5	0+
Brown trout	3	2020-09-13	2		11	7.4	0+
Brown trout	3	2020-09-13	1	900228000642856	11	28.2	>1+
Brown trout	3	2020-09-13	3		11	8.5	0+
Brown trout	3	2020-09-13	1	900228000642846	11	20.5	>1+
Brown trout	3	2020-09-13	3		11	6.5	0+
Brown trout	3	2020-09-13	1	900228000642847	11	22.9	>1+
Brown trout	3	2020-09-13	3		11	8	0+
Brown trout	3	2020-09-13	3		11	7	0+
Brown trout	3	2020-09-13	3		11	6.5	0+
Brown trout	3	2020-09-13	3		11	6.2	0+
Brown trout	5	2020-09-09	1	900228000642859	11	24.03	>1+
Brown trout	5	2020-09-09	3		11	8.1	0+
Brown trout	5	2020-09-09	2		11	6.9	0+
Brown trout	5	2020-09-09	3		11	8.6	0+
Brown trout	5	2020-09-09	1	900228000642850	11	23.29	>1+
Brown trout	5	2020-09-09	1	900226001154623	11	7.01	0+
Brown trout	5	2020-09-09	2		11	6.4	0+
Brown trout	5	2020-09-09	2		11	7.5	0+
Brown trout	5	2020-09-09	2		11	8.4	0+
Brown trout	5	2020-09-09	1	900226001154626	11	6.79	0+

Table A-2. *Recapture-data from detections. Tagging station 0 are PIT-tags which are unknown or from Solberg*'s *(2016) study.*

Date	PIT-id-short	Lattitude	Longitude	Recapture number	Tagging station
07.02.2021	40713	59.7109707	10.7356164	1	0
08.02.2021	40713	59.7110156	10.7356235	2	0
10.03.2021	40713	59.7109873	10.735619	3	0
08.02.2021	40720	59.7089951	10.7365076	1	0
10.03.2021	40720	59.7089999	10.7366505	2	0
04.02.2021	40770	59.7172566	10.7301302	1	0
08.03.2021	40770	59.7171371	10.7302067	2	0
07.02.2021	40789	59.7129581	10.7340129	1	0
08.02.2021	500677	59.7065047	10.7385172	1	0
10.03.2021	500677	59.7065296	10.7384801	2	0
21.09.2020	531266	59.705868	10.73831	1	1
08.02.2021	531266	59.7063131	10.7383686	2	1
10.03.2021	531266	59.7063416	10.738349	3	1
21.09.2020	531267	59.705868	10.73831	1	1
21.09.2020	531268	59.705868	10.73831	1	1
21.09.2020	531269	59.705868	10.73831	1	1
08.02.2021	531269	59.7056737	10.7383763	2	1
10.03.2021	531269	59.7056908	10.7383897	3	1
21.09.2020	531270	59.705868	10.73831	1	1
21.09.2020	531271	59.705868	10.73831	1	1
21.09.2020	531272	59.705868	10.73831	1	1
08.02.2021	531272	59.705849	10.7382567	2	1
10.03.2021	531272	59.7058394	10.7383162	3	1
21.09.2020	531273	59.705868	10.73831	1	1
21.09.2020	531274	59.705868	10.73831	1	1
08.02.2021	531274	59.7056558	10.738382	2	1
10.03.2021	531274	59.7056908	10.7383897	3	1
21.09.2020	531275	59.705868	10.73831	1	1
08.02.2021	531275	59.7059784	10.7383308	2	1
10.03.2021	531275	59.7059644	10.7383564	3	1
21.09.2020	531276	59.705868	10.73831	1	1
10.03.2021	531276	59.7056386	10.7384204	2	1
21.09.2020	531277	59.705868	10.73831	1	1
21.09.2020	531279	59.705868	10.73831	1	1
08.02.2021	531279	59.7058915	10.7382629	2	1
10.03.2021	531279	59.7058412	10.7383166	3	1
09.09.2020	642845	59.716415	10.731068	1	5
07.02.2021	642845	59.7168819	10.7306699	2	5
09.03.2021	642845	59.7169411	10.730667	3	5
13.09.2020	642846	59.710209	10.735906	1	3

13.09.2020	642847	59.710209	10.735906	1	3
08.02.2021	642847	59.7102555	10.7358355	2	3
10.03.2021	642847	59.7101953	10.7358897	3	3
09.09.2020	642848	59.716415	10.731068	1	5
09.09.2020	642850	59.716415	10.731068	1	5
07.02.2021	642850	59.7152597	10.7319105	2	5
11.09.2020	642851	59.71089	10.735638	1	4
09.09.2020	642853	59.716415	10.731068	1	5
07.02.2021	642853	59.7163625	10.7311693	2	5
09.03.2021	642853	59.71636	10.7311832	3	5
09.09.2020	642854	59.716415	10.731068	1	5
09.09.2020	642855	59.716415	10.731068	1	5
07.02.2021	642855	59.7163625	10.7311693	2	5
09.03.2021	642855	59.7163545	10.7311432	3	5
13.09.2020	642856	59.710209	10.735906	1	3
13.09.2020	642857	59.710209	10.735906	1	3
08.02.2021	642857	59.710144	10.7361608	2	3
10.03.2021	642857	59.7101739	10.7360971	3	3
09.09.2020	642859	59.716415	10.731068	1	5
21.09.2020	642861	59.705868	10.73831	1	1
08.02.2021	642861	59.7058145	10.7383591	2	1
10.03.2021	642861	59.705805	10.7383479	3	1
21.09.2020	642863	59.705868	10.73831	1	1
08.02.2021	642863	59.7058623	10.7382684	2	1
10.03.2021	642863	59.7058307	10.7383755	3	1
21.09.2020	642866	59.705868	10.73831	1	1
21.09.2020	642867	59.708509	10.736808	1	2
08.02.2021	642867	59.7086301	10.7366963	2	2
10.03.2021	642867	59.7086955	10.7366902	3	2
21.09.2020	642869	59.705868	10.73831	1	1
08.02.2021	642869	59.7056558	10.738382	2	1
10.03.2021	642869	59.7056682	10.7383997	3	1
21.09.2020	642873	59.705868	10.73831	1	1
08.02.2021	642873	59.7057246	10.7383838	2	1
10.03.2021	642873	59.705761	10.7383514	3	1
21.09.2020	642874	59.705868	10.73831	1	1
08.02.2021	642874	59.70566	10.7383861	2	1
10.03.2021	642874	59.7056682	10.7383997	3	1
21.09.2020	642883	59.705868	10.73831	1	1
08.02.2021	642883	59.7058682	10.7383188	2	1
10.03.2021	642883	59.7058363	10.7383089	3	1
10.03.2021	719302	59.7091844	10.7365104	1	0
08.02.2021	719323	59.7093823	10.7364936	1	0

10.03.2021	719323	59.709451	10.7365089	2	0
07.02.2021	719337	59.7130414	10.7338317	1	0
09.03.2021	719337	59.7130304	10.7337443	2	0
07.02.2021	719340	59.7110011	10.7355698	1	0
08.02.2021	719340	59.7110156	10.7356235	2	0
10.03.2021	719340	59.7109897	10.7355406	3	0
08.02.2021	719361	59.7101687	10.7359634	1	0
10.03.2021	719361	59.7101811	10.7358654	2	0
08.02.2021	719371	59.7100232	10.7363099	1	0
10.03.2021	719371	59.7100496	10.7362779	2	0
08.02.2021	719376	59.7095958	10.7363937	1	0
08.02.2021	719393	59.7102476	10.7358832	1	0
10.03.2021	719393	59.7102241	10.7357257	2	0
07.02.2021	719396	59.7110084	10.7355406	1	0
08.02.2021	719396	59.7110471	10.7356003	2	0
10.03.2021	719396	59.7110587	10.7355588	3	0
08.02.2021	719403	59.7082572	10.7368477	1	0
10.03.2021	719403	59.7082383	10.7369388	2	0
08.02.2021	719410	59.7080345	10.7370316	1	0
10.03.2021	719416	59.712137	10.7367591	1	0
04.02.2021	719428	59.7180787	10.7292847	1	0
08.03.2021	719428	59.7178693	10.7291935	2	0
08.02.2021	719435	59.7065131	10.7384959	1	0
10.03.2021	719435	59.7066016	10.7384252	2	0
09.03.2021	719471	59.7167347	10.7308483	1	0
08.02.2021	719480	59.7059784	10.7383308	1	0
10.03.2021	719480	59.705975	10.7383297	2	0
10.03.2021	719488	59.7085564	10.7368406	1	0
04.02.2021	719494	59.7175229	10.7295276	1	0
08.03.2021	719494	59.7174378	10.7296911	2	0
11.09.2020	1154320	59.71089	10.735638	1	4
21.09.2020	1154334	59.708509	10.736808	1	2
10.03.2021	1154334	59.708254	10.7369445	2	2
11.09.2020	1154341	59.71089	10.735638	1	4
08.02.2021	1154341	59.7101871	10.7359631	2	4
10.03.2021	1154341	59.7101824	10.7359248	3	4
11.09.2020	1154351	59.71089	10.735638	1	4
07.02.2021	1154351	59.7106188	10.7359395	2	4
10.03.2021	1154351	59.710641	10.7358657	3	4
11.09.2020	1154363	59.71089	10.735638	1	4
07.02.2021	1154363	59.713265	10.7337126	2	4
13.09.2020	1154605	59.710209	10.735906	1	3
10.03.2021	1154605	59.7101884	10.7361171	2	3

09.09.2020	1154622	59.716415	10.731068	1	5
07.02.2021	1154622	59.7157209	10.7315642	2	5
09.03.2021	1154622	59.715751	10.7315109	3	5
09.09.2020	1154623	59.716415	10.731068	1	5
09.09.2020	1154626	59.716415	10.731068	1	5
07.02.2021	1154626	59.7163096	10.7312591	2	5
09.09.2020	1154639	59.716415	10.731068	1	5
09.03.2021	1154639	59.716228	10.7312204	2	5
09.09.2020	1154641	59.716415	10.731068	1	5
07.02.2021	1154641	59.7163359	10.7312066	2	5
09.03.2021	1154641	59.71636	10.7311832	3	5
13.09.2020	1154644	59.710209	10.735906	1	3
10.03.2021	1154644	59.7101235	10.7363093	2	3
13.09.2020	1154645	59.710209	10.735906	1	3
07.02.2021	1154645	59.7107671	10.7357548	2	3
10.03.2021	1154645	59.7106628	10.7359125	3	3
13.09.2020	1154647	59.710209	10.735906	1	3
07.02.2021	1154647	59.7129581	10.7340129	2	3
09.09.2020	1154649	59.716415	10.731068	1	5
09.09.2020	1154650	59.716415	10.731068	1	5
07.02.2021	1154650	59.7164415	10.7309153	2	5
09.09.2020	1154651	59.716415	10.731068	1	5
07.02.2021	1154651	59.7162792	10.7312562	2	5
09.03.2021	1154651	59.7163671	10.7312276	3	5
09.09.2020	1154653	59.716415	10.731068	1	5
09.03.2021	1154653	59.7164245	10.7309911	2	5
09.09.2020	1154655	59.716415	10.731068	1	5
08.03.2021	1154655	59.7190935	10.7286743	2	5
09.09.2020	1154661	59.716415	10.731068	1	5
07.02.2021	1154661	59.7156893	10.7316369	2	5
09.03.2021	1154661	59.7156135	10.7317707	3	5
09.09.2020	1154662	59.716415	10.731068	1	5
09.09.2020	1154665	59.716415	10.731068	1	5
09.03.2021	1154665	59.7157169	10.7315821	2	5
09.09.2020	1154670	59.716415	10.731068	1	5
09.09.2020	1154673	59.716415	10.731068	1	5
09.03.2021	1154673	59.7163261	10.7312175	2	5
09.09.2020	1154678	59.716415	10.731068	1	5
07.02.2021	1154678	59.7164724	10.7310425	2	5
09.03.2021	1154678	59.7165377	10.7310746	3	5
13.09.2020	1154679	59.710209	10.735906	1	3
10.03.2021	1154679	59.7102076	10.7361066	2	3
09.09.2020	1154697	59.716415	10.731068	1	5

21.09.2020	1154701	59.708509	10.736808	1	2
08.02.2021	1154701	59.7088323	10.7366861	2	2
10.03.2021	1154701	59.7088483	10.7367744	3	2
21.09.2020	1154702	59.705868	10.73831	1	1
08.02.2021	1154702	59.7062336	10.7383292	2	1
21.09.2020	1154704	59.708509	10.736808	1	2
08.03.2021	1154704	59.7194536	10.7284665	2	2
21.09.2020	1154705	59.705868	10.73831	1	1
08.02.2021	1154705	59.7066721	10.7386366	2	1
10.03.2021	1154705	59.7067238	10.7385576	3	1
21.09.2020	1154706	59.705868	10.73831	1	1
21.09.2020	1154708	59.708509	10.736808	1	2
08.02.2021	1154708	59.7085845	10.7368151	2	2
10.03.2021	1154708	59.7085349	10.7368748	3	2
21.09.2020	1154709	59.708509	10.736808	1	2
08.02.2021	1154709	59.7092478	10.7364428	2	2
10.03.2021	1154709	59.7092653	10.736528	3	2
21.09.2020	1154711	59.705868	10.73831	1	1
08.02.2021	1154711	59.7057784	10.7383689	2	1
10.03.2021	1154711	59.7057786	10.7383436	3	1
21.09.2020	1154712	59.705868	10.73831	1	1
08.02.2021	1154712	59.705979	10.7383044	2	1
21.09.2020	1154713	59.705868	10.73831	1	1
10.03.2021	1154713	59.705975	10.7383297	2	1
21.09.2020	1154714	59.708509	10.736808	1	2
21.09.2020	1154715	59.705868	10.73831	1	1
21.09.2020	1154716	59.708509	10.736808	1	2
08.02.2021	1154716	59.708261	10.7368306	2	2
10.03.2021	1154716	59.7082329	10.7369539	3	2
21.09.2020	1154718	59.708509	10.736808	1	2
10.03.2021	1154718	59.7103376	10.7358324	2	2
21.09.2020	1154719	59.705868	10.73831	1	1
10.03.2021	1154719	59.708254	10.7369445	2	1
21.09.2020	1154720	59.708509	10.736808	1	2
08.02.2021	1154720	59.7085375	10.7367617	2	2
10.03.2021	1154720	59.7085195	10.7368289	3	2
21.09.2020	1154724	59.705868	10.73831	1	1
08.02.2021	1154724	59.706389	10.7384567	2	1
10.03.2021	1154724	59.7064433	10.7383969	3	1
21.09.2020	1154725	59.705868	10.73831	1	1
08.02.2021	1154725	59.7082157	10.736996	2	1
21.09.2020	1154726	59.705868	10.73831	1	1
08.02.2021	1154726	59.7061404	10.7385611	2	1

21.09.2020	1154727	59.708509	10.736808	1	2
08.02.2021	1154727	59.7086249	10.7367657	2	2
10.03.2021	1154727	59.7085426	10.736895	3	2
21.09.2020	1154730	59.705868	10.73831	1	1
08.02.2021	1154730	59.7072791	10.7385091	2	1
10.03.2021	1154730	59.7072446	10.7383701	3	1
21.09.2020	1154731	59.705868	10.73831	1	1
08.02.2021	1154731	59.7059498	10.7382707	2	1
10.03.2021	1154731	59.7061069	10.7384667	3	1
21.09.2020	1154733	59.708509	10.736808	1	2
21.09.2020	1154734	59.708509	10.736808	1	2
21.09.2020	1154737	59.705868	10.73831	1	1
07.02.2021	1154737	59.7142396	10.732706	2	1
09.03.2021	1154737	59.7142723	10.7328031	3	1
21.09.2020	1154738	59.708509	10.736808	1	2
21.09.2020	1154739	59.708509	10.736808	1	2
07.02.2021	1154739	59.7107468	10.7358043	2	2
10.03.2021	1154739	59.7107789	10.7357785	3	2
21.09.2020	1154741	59.708509	10.736808	1	2
08.02.2021	1154741	59.7085375	10.7367617	2	2
10.03.2021	1154741	59.7085761	10.7368249	3	2
21.09.2020	1154743	59.708509	10.736808	1	2
07.02.2021	1154743	59.7114936	10.7351791	2	2
10.03.2021	1154743	59.7117043	10.735124	3	2
21.09.2020	1154744	59.705868	10.73831	1	1
08.02.2021	1154744	59.7060117	10.738296	2	1
21.09.2020	1154746	59.708509	10.736808	1	2
08.02.2021	1154746	59.7084282	10.7368653	2	2
21.09.2020	1154747	59.705868	10.73831	1	1
08.02.2021	1154747	59.7058804	10.7382961	2	1
10.03.2021	1154747	59.705858	10.7383069	3	1
21.09.2020	1154748	59.708509	10.736808	1	2
10.03.2021	1154748	59.7081899	10.7370313	2	2
21.09.2020	1154749	59.705868	10.73831	1	1
21.09.2020	1154750	59.708509	10.736808	1	2
21.09.2020	1154751	59.705868	10.73831	1	1
21.09.2020	1154752	59.708509	10.736808	1	2
08.02.2021	1154752	59.7083805	10.7368812	2	2
10.03.2021	1154752	59.7083689	10.7369435	3	2
21.09.2020	1154753	59.708509	10.736808	1	2
21.09.2020	1154754	59.708509	10.736808	1	2
08.02.2021	1154754	59.7088586	10.7365472	2	2
10.03.2021	1154754	59.7088465	10.7366144	3	2

21.09.2020	1154756	59.705868	10.73831	1	1
21.09.2020	1154757	59.708509	10.736808	1	2
21.09.2020	1154758	59.708509	10.736808	1	2
08.02.2021	1154758	59.7090866	10.7363765	2	2
10.03.2021	1154758	59.7090775	10.7364283	3	2
21.09.2020	1154759	59.705868	10.73831	1	1
08.02.2021	1154759	59.7058335	10.7383288	2	1
10.03.2021	1154759	59.70582	10.7383352	3	1
21.09.2020	1154760	59.705868	10.73831	1	1
08.02.2021	1154760	59.708408	10.7369051	2	1
21.09.2020	1154762	59.705868	10.73831	1	1
21.09.2020	1154763	59.705868	10.73831	1	1
08.02.2021	1154763	59.7060102	10.7382962	2	1
10.03.2021	1154763	59.7059894	10.738323	3	1
21.09.2020	1154767	59.705868	10.73831	1	1
08.02.2021	1154767	59.7057697	10.7383808	2	1
10.03.2021	1154767	59.7057809	10.7383561	3	1
21.09.2020	1154770	59.705868	10.73831	1	1
08.02.2021	1154770	59.707176	10.7383709	2	1
10.03.2021	1154770	59.7071497	10.7383965	3	1
21.09.2020	1154771	59.708509	10.736808	1	2
21.09.2020	1154772	59.705868	10.73831	1	1
08.02.2021	1154772	59.708091	10.7370129	2	1
10.03.2021	1154772	59.7080992	10.737104	3	1
21.09.2020	1154773	59.705868	10.73831	1	1
10.03.2021	1154773	59.7060309	10.7384017	2	1
21.09.2020	1154774	59.705868	10.73831	1	1
08.02.2021	1154774	59.7056965	10.7383867	2	1
10.03.2021	1154774	59.7057982	10.7383552	3	1
21.09.2020	1154775	59.708509	10.736808	1	2
08.02.2021	1154775	59.7085639	10.7368744	2	2
21.09.2020	1154776	59.705868	10.73831	1	1
21.09.2020	1154777	59.705868	10.73831	1	1
08.02.2021	1154777	59.7061313	10.7384224	2	1
10.03.2021	1154777	59.7061598	10.7384472	3	1
21.09.2020	1154780	59.708509	10.736808	1	2
07.02.2021	1154780	59.7130546	10.7337199	2	2
09.03.2021	1154780	59.7151748	10.7320399	3	2
21.09.2020	1154781	59.705868	10.73831	1	1
08.02.2021	1154781	59.7058987	10.738265	2	1
10.03.2021	1154781	59.7058438	10.7383127	3	1
21.09.2020	1154782	59.708509	10.736808	1	2
08.02.2021	1154782	59.7087126	10.7366593	2	2

10.03.2021	1154782	59.7086655	10.7366776	3	2
21.09.2020	1154783	59.705868	10.73831	1	1
08.02.2021	1154783	59.7069942	10.7384455	2	1
10.03.2021	1154783	59.7072009	10.7384531	3	1
21.09.2020	1154784	59.705868	10.73831	1	1
08.02.2021	1154784	59.7062336	10.7383292	2	1
10.03.2021	1154784	59.7062642	10.7383584	3	1
21.09.2020	1154785	59.705868	10.73831	1	1
08.02.2021	1154785	59.7061565	10.7383942	2	1
10.03.2021	1154785	59.7070388	10.7384818	3	1
21.09.2020	1154786	59.705868	10.73831	1	1
10.03.2021	1154786	59.7058274	10.7383477	2	1
21.09.2020	1154787	59.705868	10.73831	1	1
08.02.2021	1154787	59.7062373	10.7384093	2	1
21.09.2020	1154790	59.708509	10.736808	1	2
21.09.2020	1154793	59.705868	10.73831	1	1
21.09.2020	1154794	59.708509	10.736808	1	2
08.02.2021	1154794	59.7085638	10.7368425	2	2
10.03.2021	1154794	59.7085007	10.7368916	3	2
21.09.2020	1154796	59.708509	10.736808	1	2
08.02.2021	1154796	59.7087473	10.7366674	2	2
10.03.2021	1154796	59.7087906	10.7366524	3	2
21.09.2020	1154797	59.705868	10.73831	1	1
21.09.2020	1154798	59.708509	10.736808	1	2
08.02.2021	1154798	59.7086229	10.7367033	2	2
10.03.2021	1154798	59.7085426	10.736895	3	2
21.09.2020	1154799	59.705868	10.73831	1	1
07.02.2021	1154799	59.7141295	10.7332492	2	1
13.09.2020	1155400	59.710209	10.735906	1	3
08.02.2021	1155400	59.7102084	10.7359084	2	3
10.03.2021	1155400	59.7101231	10.736152	3	3
13.09.2020	1155402	59.710209	10.735906	1	3
10.03.2021	1155402	59.7102836	10.735819	2	3
21.09.2020	1155403	59.705868	10.73831	1	1
13.09.2020	1155421	59.710209	10.735906	1	3
10.03.2021	1155421	59.7101148	10.7362419	2	3
13.09.2020	1155433	59.710209	10.735906	1	3
08.02.2021	1155433	59.7102524	10.7358282	2	3
10.03.2021	1155433	59.7101824	10.7359248	3	3
21.09.2020	1155435	59.705868	10.73831	1	1
13.09.2020	1155437	59.710209	10.735906	1	3
10.03.2021	1155437	59.7101853	10.7358322	2	3
13.09.2020	1155438	59.710209	10.735906	1	3

08.02.2021	1155438	59.7101528	10.735971	2	3
13.09.2020	1155441	59.710209	10.735906	1	3
07.02.2021	1155441	59.7107347	10.7358303	2	3
08.02.2021	1155441	59.7107352	10.7357936	3	3
10.03.2021	1155441	59.7107309	10.7358204	4	3
21.09.2020	1155452	59.708509	10.736808	1	2
10.03.2021	1155452	59.7084618	10.7369215	2	2
21.09.2020	1155456	59.705868	10.73831	1	1
08.02.2021	1155456	59.7063905	10.7384171	2	1
13.09.2020	1155457	59.710209	10.735906	1	3
13.09.2020	1155474	59.710209	10.735906	1	3
21.09.2020	1155481	59.705868	10.73831	1	1
08.02.2021	1155481	59.7059488	10.7382765	2	1
10.03.2021	1155481	59.7059546	10.7383085	3	1
13.09.2020	1155484	59.710209	10.735906	1	3
21.09.2020	1155485	59.705868	10.73831	1	1
08.02.2021	1155485	59.7059174	10.7382809	2	1
10.03.2021	1155485	59.7059388	10.7383853	3	1
21.09.2020	1155493	59.705868	10.73831	1	1
10.03.2021	1155493	59.7056758	10.7384016	2	1
13.09.2020	1155497	59.710209	10.735906	1	3
08.02.2021	1684224	59.7067121	10.738587	1	0
10.03.2021	1684224	59.7067262	10.7385809	2	0
13.09.2020	2224003	59.710209	10.735906	1	3
08.02.2021	2224003	59.707142	10.7383454	2	3
10.03.2021	2224003	59.7071654	10.7384673	3	3
09.09.2020	2224009	59.716415	10.731068	1	5
07.02.2021	2224009	59.7163955	10.7311682	2	5
09.03.2021	2224009	59.716379	10.7311064	3	5
09.09.2020	2224013	59.716415	10.731068	1	5
07.02.2021	2224013	59.7163776	10.7311442	2	5
07.02.2021	2224013	59.7164057	10.7311436	3	5
09.03.2021	2224013	59.7163931	10.7310729	4	5
09.09.2020	2224038	59.716415	10.731068	1	5
09.03.2021	2224038	59.7159588	10.731287	2	5
09.09.2020	2224040	59.716415	10.731068	1	5
09.09.2020	2224043	59.716415	10.731068	1	5
09.09.2020	2224048	59.716415	10.731068	1	5
07.02.2021	2224048	59.7164259	10.7310528	2	5
09.03.2021	2224048	59.7164525	10.731032	3	5
13.09.2020	2224055	59.710209	10.735906	1	3
08.02.2021	2224055	59.7081966	10.7369986	2	3
13.09.2020	2224071	59.710209	10.735906	1	3

09.09.2020	2224072	59.716415	10.731068	1	5
09.09.2020	2224075	59.716415	10.731068	1	5
07.02.2021	2224075	59.7164414	10.7310684	2	5
09.03.2021	2224075	59.7164817	10.7309965	3	5
13.09.2020	2224077	59.710209	10.735906	1	3
13.09.2020	2224084	59.710209	10.735906	1	3
07.02.2021	2224084	59.7145288	10.7325382	2	3
09.03.2021	2224084	59.7146018	10.732369	3	3
13.09.2020	2224108	59.710209	10.735906	1	3
07.02.2021	2224108	59.7141512	10.7329921	2	3
09.03.2021	2224108	59.7141191	10.7329765	3	3
13.09.2020	2224120	59.710209	10.735906	1	3
07.02.2021	2224120	59.7107863	10.7357657	2	3
08.02.2021	2224120	59.7107753	10.7357593	3	3
10.03.2021	2224120	59.7108045	10.7357469	4	3
09.09.2020	2224121	59.716415	10.731068	1	5
07.02.2021	2224121	59.7163938	10.7311413	2	5
09.03.2021	2224121	59.7163817	10.7311423	3	5
09.09.2020	2224125	59.716415	10.731068	1	5
07.02.2021	2224125	59.7163162	10.7312247	2	5
09.03.2021	2224125	59.7163261	10.7311587	3	5
09.09.2020	2224140	59.716415	10.731068	1	5
07.02.2021	2224140	59.7162785	10.7312593	2	5
09.03.2021	2224140	59.716328	10.7312072	3	5
13.09.2020	2224145	59.710209	10.735906	1	3
08.02.2021	2224145	59.7102603	10.7358844	2	3
10.03.2021	2224145	59.7103435	10.735821	3	3
09.09.2020	2224147	59.716415	10.731068	1	5
09.09.2020	2224153	59.716415	10.731068	1	5
07.02.2021	2224153	59.7163946	10.7311656	2	5
09.09.2020	2224161	59.716415	10.731068	1	5
04.02.2021	2224161	59.7176596	10.729632	2	5
08.03.2021	2224161	59.7175285	10.7297077	3	5
09.09.2020	2224167	59.716415	10.731068	1	5
09.03.2021	2224167	59.7163465	10.7311968	2	5
13.09.2020	2224176	59.710209	10.735906	1	3
07.02.2021	2224176	59.7115919	10.735074	2	3
09.09.2020	2224188	59.716415	10.731068	1	5
13.09.2020	2224199	59.710209	10.735906	1	3
08.02.2021	2224199	59.7101765	10.7359234	2	3
13.09.2020	2224202	59.710209	10.735906	1	3
13.09.2020	2224206	59.710209	10.735906	1	3
07.02.2021	2224206	59.713064	10.7337795	2	3

09.09.2020	2224212	59.716415	10.731068	1	5
07.02.2021	2224212	59.716388	10.7311787	2	5
09.03.2021	2224212	59.7163682	10.7310097	3	5
09.09.2020	2224220	59.716415	10.731068	1	5
07.02.2021	2224220	59.7163014	10.7312685	2	5
09.03.2021	2224220	59.7164349	10.731286	3	5
09.09.2020	2224244	59.716415	10.731068	1	5
21.09.2020	2224502	59.705868	10.73831	1	1
08.02.2021	2224502	59.7058799	10.7382811	2	1
10.03.2021	2224502	59.7058412	10.7383166	3	1
21.09.2020	2224506	59.705868	10.73831	1	1
21.09.2020	2224515	59.705868	10.73831	1	1
21.09.2020	2224518	59.705868	10.73831	1	1
08.02.2021	2224518	59.705965	10.7382681	2	1
10.03.2021	2224518	59.7059534	10.7383234	3	1
21.09.2020	2224519	59.705868	10.73831	1	1
08.02.2021	2224519	59.7062667	10.7383307	2	1
10.03.2021	2224519	59.7062709	10.7383017	3	1
21.09.2020	2224522	59.705868	10.73831	1	1
08.02.2021	2224522	59.7058335	10.7383288	2	1
10.03.2021	2224522	59.7058081	10.7383487	3	1
21.09.2020	2224528	59.705868	10.73831	1	1
21.09.2020	2224531	59.705868	10.73831	1	1
10.03.2021	2224531	59.705858	10.7383069	2	1
21.09.2020	2224532	59.708509	10.736808	1	2
21.09.2020	2224533	59.705868	10.73831	1	1
08.02.2021	2224533	59.706254	10.7384102	2	1
21.09.2020	2224539	59.705868	10.73831	1	1
08.02.2021	2224539	59.7072393	10.7384911	2	1
21.09.2020	2224544	59.705868	10.73831	1	1
08.02.2021	2224544	59.7063489	10.7383737	2	1
10.03.2021	2224544	59.7064349	10.7384292	3	1
21.09.2020	2224545	59.705868	10.73831	1	1
09.03.2021	2224545	59.7150842	10.7321818	2	1
21.09.2020	2224548	59.705868	10.73831	1	1
21.09.2020	2224556	59.705868	10.73831	1	1
21.09.2020	2224563	59.705868	10.73831	1	1
10.03.2021	2224563	59.7057828	10.7383572	2	1
21.09.2020	2224565	59.705868	10.73831	1	1
08.02.2021	2224565	59.7057014	10.7383937	2	1
10.03.2021	2224565	59.705714	10.7383901	3	1
21.09.2020	2224566	59.708509	10.736808	1	2
07.02.2021	2224566	59.7126981	10.7342698	2	2

21.09.2020	2224567	59.705868	10.73831	1	1
08.02.2021	2224567	59.7088306	10.7366507	2	1
10.03.2021	2224567	59.7087922	10.7366887	3	1
21.09.2020	2224576	59.705868	10.73831	1	1
10.03.2021	2224576	59.7082422	10.7369861	2	1
21.09.2020	2224583	59.705868	10.73831	1	1
08.02.2021	2224583	59.7063841	10.7384841	2	1
10.03.2021	2224583	59.7064208	10.738423	3	1
21.09.2020	2224586	59.705868	10.73831	1	1
21.09.2020	2224587	59.708509	10.736808	1	2
08.02.2021	2224587	59.7084612	10.7368584	2	2
10.03.2021	2224587	59.7084618	10.7369215	3	2
21.09.2020	2224590	59.705868	10.73831	1	1
08.02.2021	2224590	59.705849	10.7382567	2	1
10.03.2021	2224590	59.7058394	10.7383162	3	1
21.09.2020	2224592	59.705868	10.73831	1	1
08.02.2021	2224592	59.707086	10.7384278	2	1
10.03.2021	2224592	59.7070642	10.7385122	3	1
21.09.2020	2224594	59.705868	10.73831	1	1
08.02.2021	2224594	59.7059085	10.7382796	2	1
10.03.2021	2224594	59.7059211	10.7383931	3	1
21.09.2020	2224596	59.705868	10.73831	1	1
08.02.2021	2224596	59.7058265	10.7383738	2	1
10.03.2021	2224596	59.7072639	10.7383947	3	1
21.09.2020	2224597	59.705868	10.73831	1	1
08.02.2021	2224597	59.7059626	10.7382761	2	1
21.09.2020	2224598	59.708509	10.736808	1	2
08.02.2021	2224598	59.7085524	10.7368119	2	2
10.03.2021	2224598	59.7085426	10.736895	3	2
21.09.2020	2224599	59.705868	10.73831	1	1
08.02.2021	2224599	59.7068823	10.7384345	2	1
10.03.2021	2224599	59.7072223	10.7384256	3	1
21.09.2020	2224604	59.705868	10.73831	1	1
07.02.2021	2224604	59.7150488	10.7320332	2	1
09.03.2021	2224604	59.7150026	10.7321809	3	1
21.09.2020	2224610	59.705868	10.73831	1	1
21.09.2020	2224611	59.705868	10.73831	1	1
08.02.2021	2224611	59.7057268	10.7384011	2	1
10.03.2021	2224611	59.7057303	10.738365	3	1
21.09.2020	2224612	59.705868	10.73831	1	1
08.02.2021	2224612	59.7057697	10.7383808	2	1
10.03.2021	2224612	59.7057809	10.7383561	3	1
21.09.2020	2224618	59.708509	10.736808	1	2

21.09.2020	2224619	59.705868	10.73831	1	1
08.02.2021	2224619	59.7063088	10.7384323	2	1
10.03.2021	2224619	59.7063589	10.7383825	3	1
13.09.2020	2224620	59.710209	10.735906	1	3
07.02.2021	2224620	59.7128621	10.7339344	2	3
09.03.2021	2224620	59.7129444	10.7339926	3	3
21.09.2020	2224622	59.705868	10.73831	1	1
08.02.2021	2224622	59.7061307	10.7384087	2	1
10.03.2021	2224622	59.7061598	10.7384472	3	1
21.09.2020	2224623	59.708509	10.736808	1	2
07.02.2021	2224623	59.7158447	10.7316414	2	2
09.03.2021	2224623	59.7156979	10.7313754	3	2
21.09.2020	2224628	59.708509	10.736808	1	2
10.03.2021	2224628	59.7117246	10.7350063	2	2
21.09.2020	2224630	59.708509	10.736808	1	2
21.09.2020	2224631	59.705868	10.73831	1	1
08.02.2021	2224631	59.7061075	10.7384496	2	1
10.03.2021	2224631	59.7061419	10.7384598	3	1
21.09.2020	2224633	59.708509	10.736808	1	2
10.03.2021	2224633	59.7085178	10.736861	2	2
21.09.2020	2224635	59.705868	10.73831	1	1
08.02.2021	2224635	59.705556	10.7386366	2	1
10.03.2021	2224635	59.7055651	10.7385433	3	1
11.09.2020	2224638	59.71089	10.735638	1	4
07.02.2021	2224638	59.7107671	10.7357548	2	4
08.02.2021	2224638	59.7107352	10.7357936	3	4
10.03.2021	2224638	59.7107519	10.7357969	4	4
21.09.2020	2224645	59.705868	10.73831	1	1
21.09.2020	2224646	59.705868	10.73831	1	1
21.09.2020	2224656	59.705868	10.73831	1	1
21.09.2020	2224658	59.705868	10.73831	1	1
08.02.2021	2224658	59.7062481	10.7383896	2	1
10.03.2021	2224658	59.7078589	10.7374771	3	1
21.09.2020	2224662	59.705868	10.73831	1	1
08.02.2021	2224662	59.7061377	10.7385583	2	1
10.03.2021	2224662	59.7061836	10.7384775	3	1
21.09.2020	2224664	59.705868	10.73831	1	1
10.03.2021	2224664	59.7059534	10.7383234	2	1
21.09.2020	2224671	59.705868	10.73831	1	1
08.02.2021	2224671	59.7055471	10.7385888	2	1
10.03.2021	2224671	59.7055422	10.7384907	3	1
21.09.2020	2224672	59.705868	10.73831	1	1
21.09.2020	2224676	59.705868	10.73831	1	1

08.02.2021	2224676	59.7060435	10.7383135	2	1
10.03.2021	2224676	59.7078472	10.7375046	3	1
21.09.2020	2224677	59.705868	10.73831	1	1
08.02.2021	2224677	59.7073114	10.7384616	2	1
10.03.2021	2224677	59.7072556	10.7384297	3	1
21.09.2020	2224678	59.708509	10.736808	1	2
21.09.2020	2224688	59.705868	10.73831	1	1
07.02.2021	2224688	59.7157398	10.7314523	2	1
08.02.2021	2224689	59.7064848	10.7384367	1	0
10.03.2021	2224689	59.7065292	10.7384656	2	0
21.09.2020	2224691	59.705868	10.73831	1	1
21.09.2020	2224692	59.705868	10.73831	1	1
08.02.2021	2224692	59.7057312	10.7383855	2	1
10.03.2021	2224692	59.7056406	10.7383705	3	1
21.09.2020	2224693	59.705868	10.73831	1	1
10.03.2021	2224693	59.7059211	10.738355	2	1
21.09.2020	2224697	59.708509	10.736808	1	2
10.03.2021	2224697	59.7085006	10.7369254	2	2
21.09.2020	2224700	59.705868	10.73831	1	1
04.02.2021	2224700	59.7182753	10.7292213	2	1
08.03.2021	2224700	59.7180586	10.7292606	3	1
21.09.2020	2224704	59.705868	10.73831	1	1
08.02.2021	2224704	59.7079966	10.7373997	2	1
10.03.2021	2224704	59.7080005	10.7369648	3	1
21.09.2020	2224707	59.705868	10.73831	1	1
21.09.2020	2224709	59.708509	10.736808	1	2
08.02.2021	2224709	59.7085845	10.7368151	2	2
10.03.2021	2224709	59.708536	10.7368283	3	2
21.09.2020	2224713	59.708509	10.736808	1	2
08.02.2021	2224713	59.7081909	10.7370471	2	2
10.03.2021	2224713	59.7082212	10.7368815	3	2
21.09.2020	2224720	59.705868	10.73831	1	1
21.09.2020	2224727	59.705868	10.73831	1	1
10.03.2021	2224727	59.7056446	10.7383657	2	1
21.09.2020	2224728	59.705868	10.73831	1	1
08.02.2021	2224728	59.7064113	10.7384181	2	1
10.03.2021	2224728	59.7064665	10.7383899	3	1
21.09.2020	2224729	59.705868	10.73831	1	1
08.02.2021	2224729	59.7064838	10.7384768	2	1
10.03.2021	2224729	59.7065665	10.7384377	3	1
21.09.2020	2224731	59.708509	10.736808	1	2
04.02.2021	2224731	59.7188906	10.7287099	2	2
08.03.2021	2224731	59.7188197	10.7288729	3	2

21.09.2020	2224734	59.705868	10.73831	1	1
08.02.2021	2224734	59.7057803	10.7383937	2	1
10.03.2021	2224734	59.7057838	10.7383309	3	1
21.09.2020	2224738	59.708509	10.736808	1	2
07.02.2021	2224738	59.7154032	10.7317805	2	2
09.03.2021	2224738	59.7156056	10.731599	3	2
21.09.2020	2224742	59.705868	10.73831	1	1
08.02.2021	2224742	59.708091	10.7370129	2	1
10.03.2021	2224742	59.7080741	10.7371191	3	1
21.09.2020	2224749	59.705868	10.73831	1	1
13.09.2020	2224995	59.710209	10.735906	1	3

Appendix B: Dates for fieldwork and tunnel washing.

Table B-1. *Dates of fieldwork 2020–2021.*

	Fieldwork 2020/2021																						
	Day in month																						
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
September									🟩		🟩		🟩								🟩		
October			🟥																				
November																							
December																							
January																							
February				🟦			🟦	🟦															
March								🟦	🟦	🟦													
April								🟨				🟨	🟨										
May																							
June		🟨																					
	🟩	Electro-fishing		🟥	Habitat-mapping		🟦	PIT-scanning		🟨	Water-sampling												

Table B-2. *Dates of tunnel washing 2019–2020 (Torgersen, NPRA, 2021).*

Sep. - Aug. 2019-2020	**September**					**October**					**November**				**December**				**January**					**February**				**March**				**April**				**May**					**June**				**July**				**August**				
V6	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	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	32	33	34	35
Follo																																																					
Nordby North		🟩 2					▨ 6					🟦 11.12				🟩 11				▨ 5			🟩 27				▨ 23			🟩 15				▨ 14				🟦 11.12					▨ 14						🟩 29				
Nordby South		🟩 3					▨ 7					🟦 12.13					🟩 15			▨ 6			🟩 28				▨ 24			🟩 16				▨ 15				🟦 12.13					▨ 15							🟩 5			
Smiehagen		🟩 4				▨ 2							🟦 19				🟩 18			▨ 6		▨ 20			🟩 12				▨ 9				🟦 6					▨ 13						▨ 23						🟩 3			
Vassum		🟥 4				▨ 2							🟥 19				🟥 18					▨ 20							▨ 9				🟨 6																	🟥 3			
																			🟥	Half wash flushing									🟨	Whole wash																		▨	Sweeping				
																			🟩	Half wash brushing									🟦	Whole wash brushing																							

Table B-3. *Dates of tunnel washing 2020–2021 (Torgersen, NPRA, 2021).*

Sep. - Aug. 2020-2021	**September**					**October**					**November**				**December**					**January**					**February**				**March**				**April**				**May**					**June**				**July**				**August**				
V 3	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	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	32	33	34	35
Follo																																																					
Nordby North		🟩 31				▨ 29				🟦 28.27					🟩 30					▨ 4				🟩 1				▨ 2			🟩 22				▨ 19						🟦 31.1				▨ 28									
Nordby South		🟩 1				▨ 28				🟦 27.26					🟩 1					▨ 5				🟩 2				▨ 3			🟩 23				▨ 20						🟦 1.2				▨ 29									
Smiehagen			🟩 7											🟦 23				🟩 22			▨ 11		▨ 28			🟩 15				▨ 16				🟦 12					▨ 18						▨ 28									
Vassum			🟥 7											▨ 23									▨ 28							▨ 16				🟨 12																				
																				🟥	Half wash flushing									🟨	Whole wash																		▨	Sweeping				
																				🟩	Half wash brushing									🟦	Whole wash brushing																							

Appendix C: Movement maps of recaptured salmonids (PIT-tags).

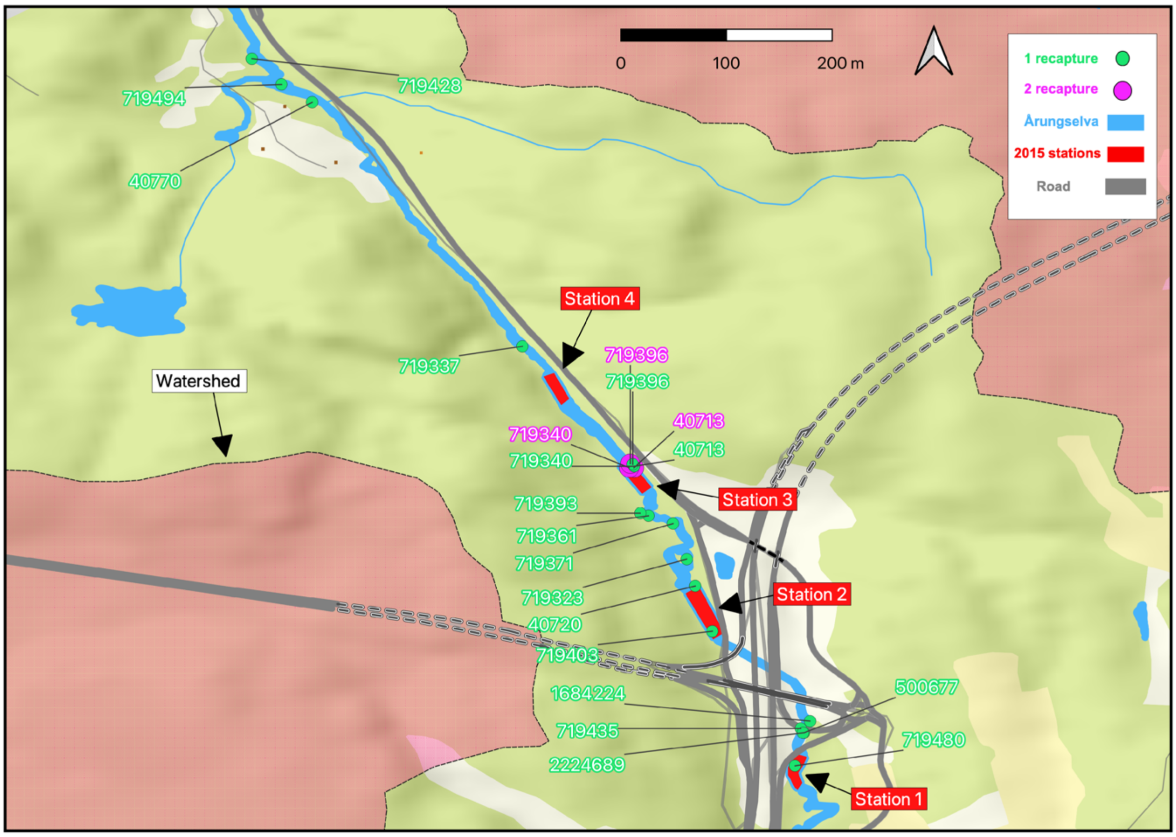

Figure C-1. Recaptures from Solberg (2016) and unknown PIT-tags.

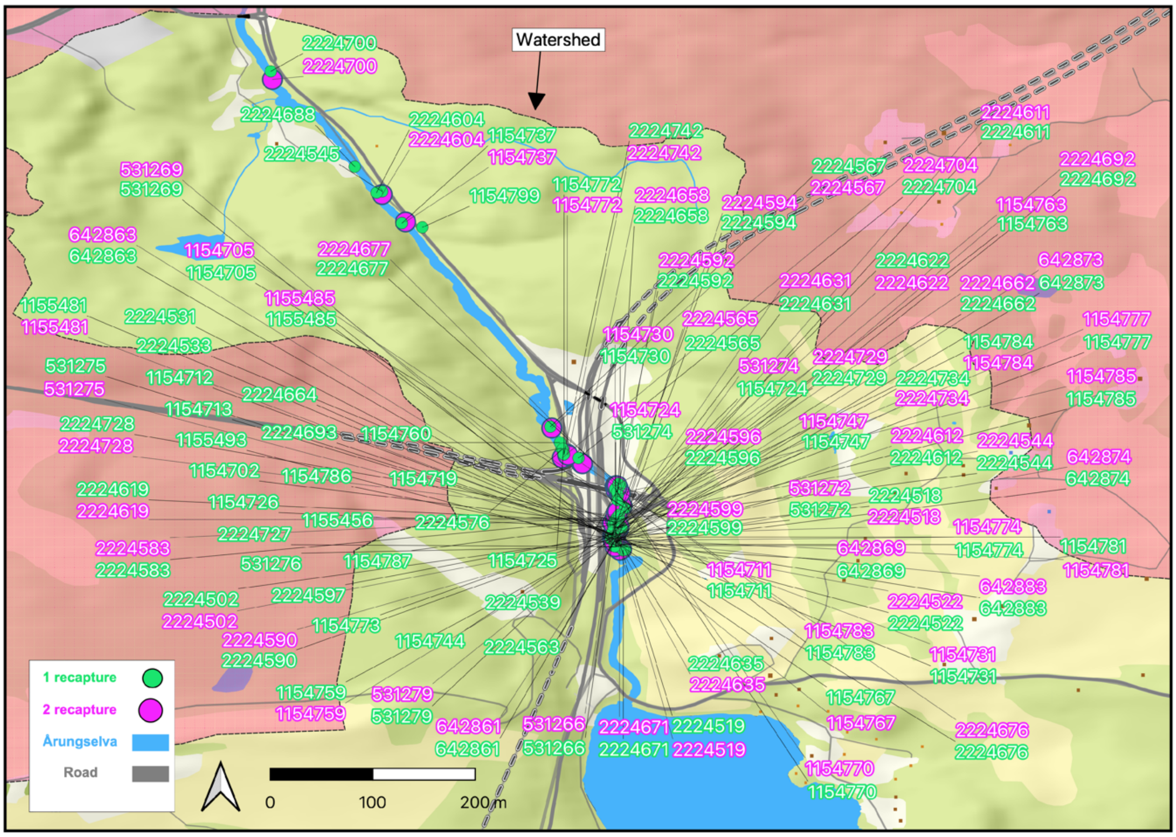

Figure C-2. Recaptures from station 1.

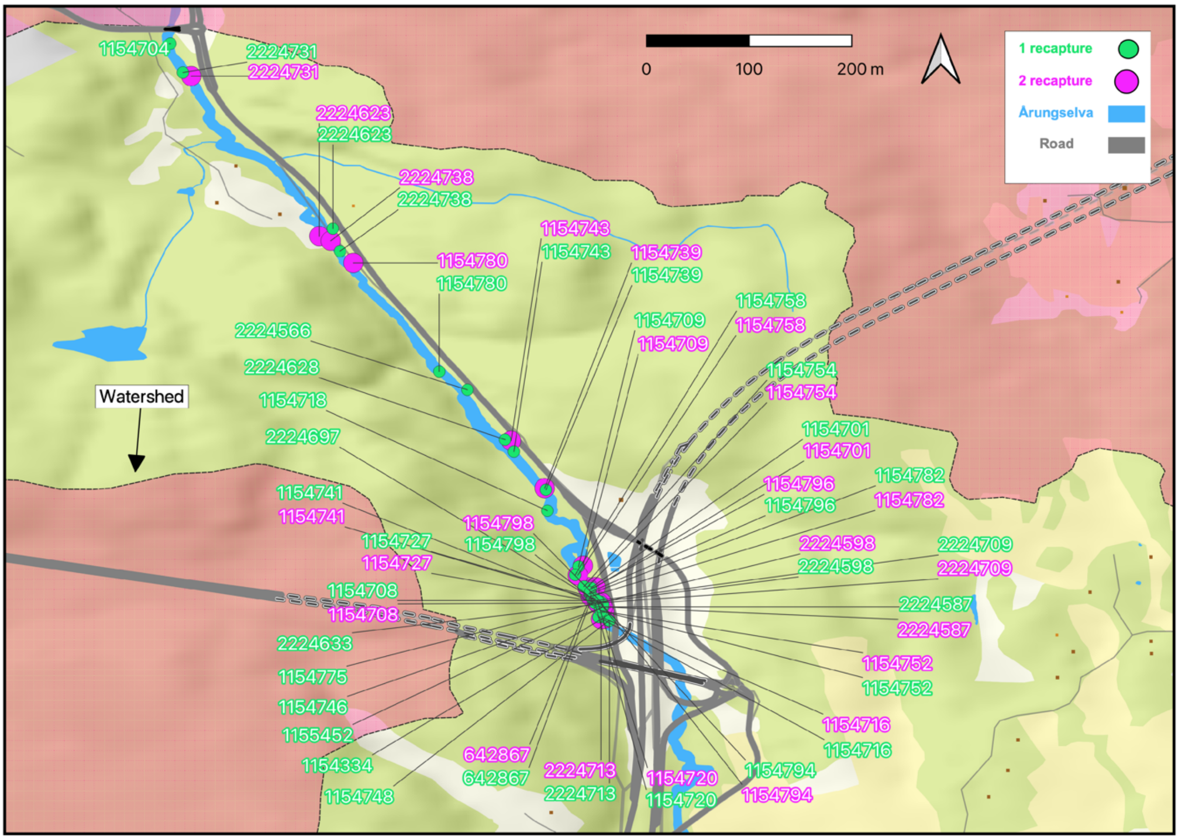

Figure C-3. *Recaptures from station 2.*

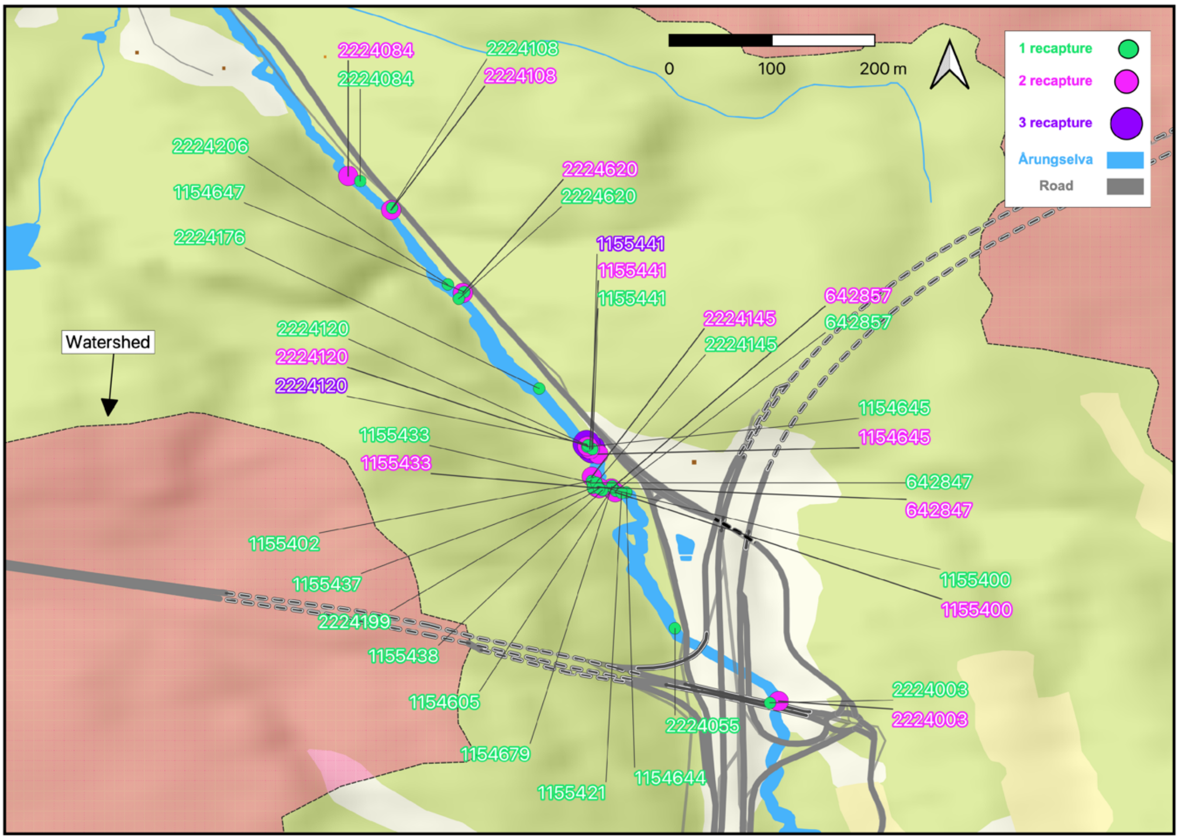

Figure C-4. *Recaptures from station 3.*

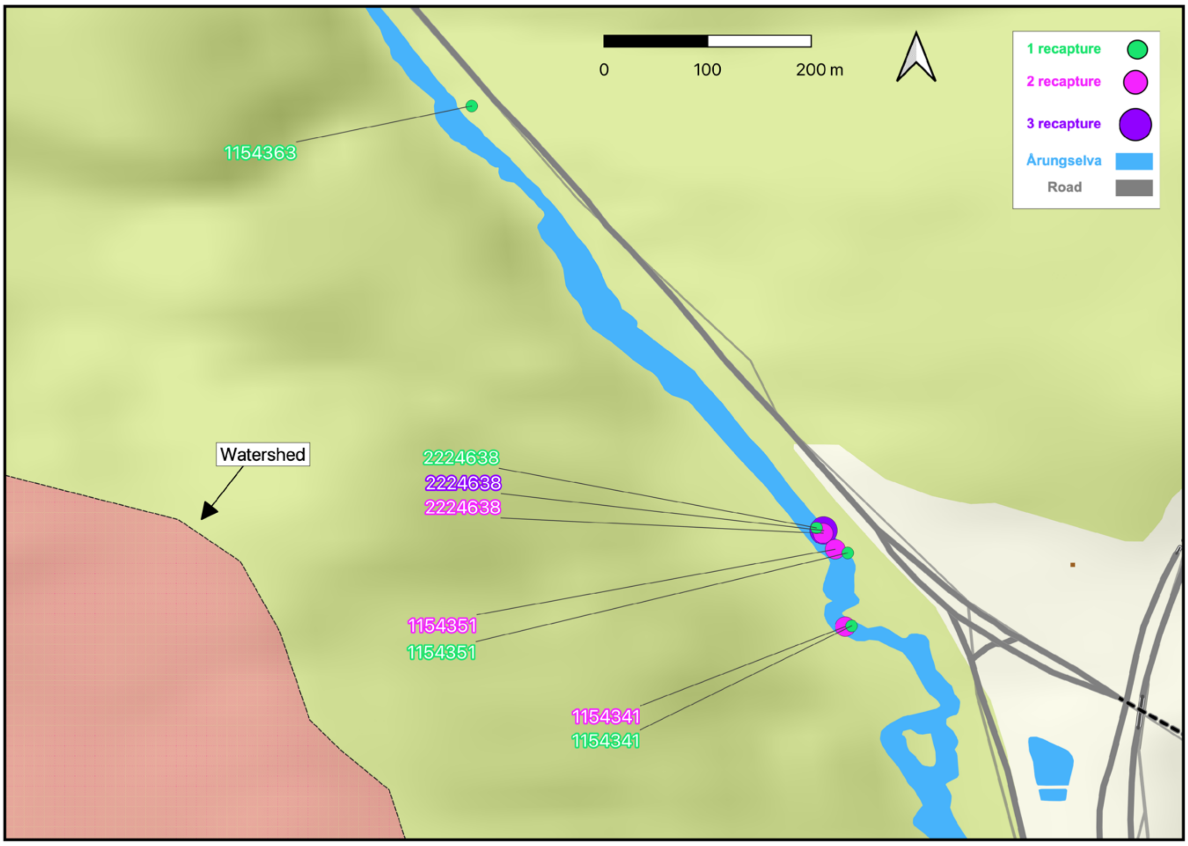

***Figure C-5.** Recaptures from station 4.*

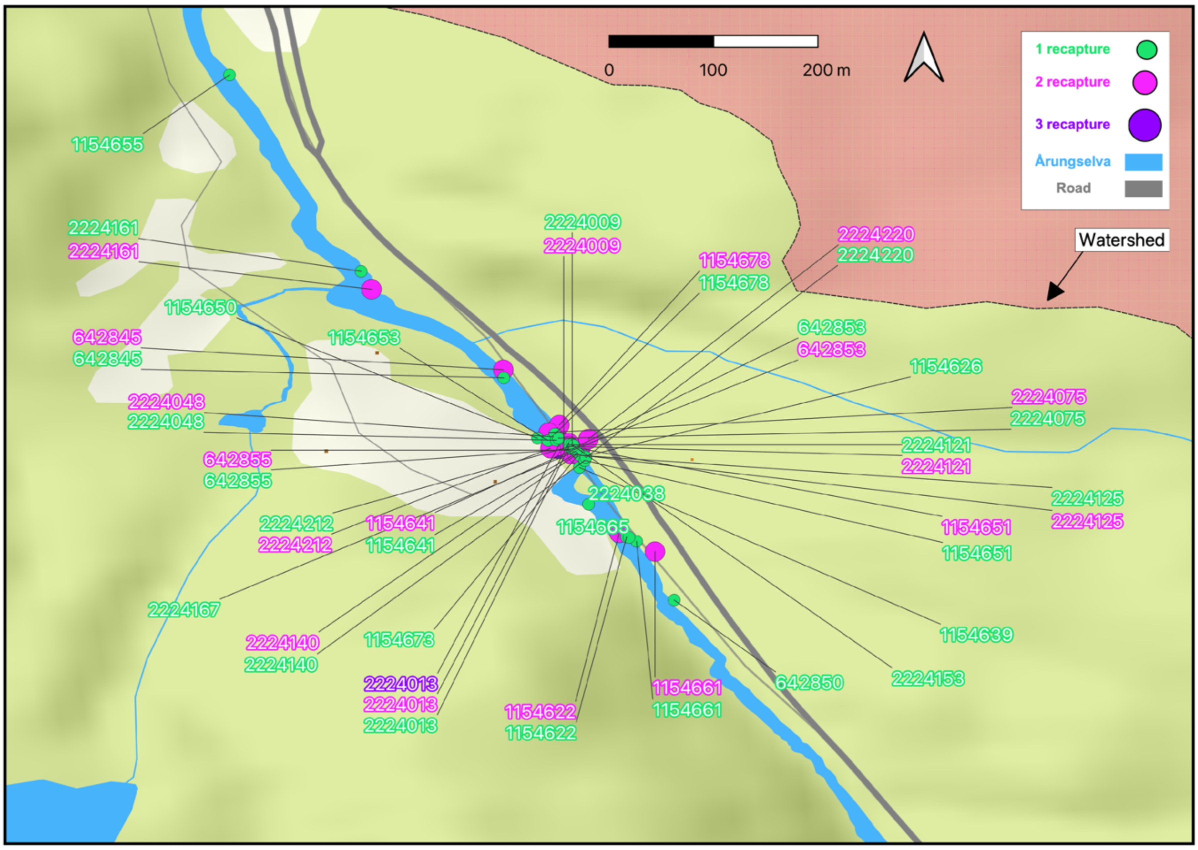

***Figure C-6.** Recaptures from station 5.*

Appendix D: Temperature and precipitation data (03.2020–06.2021).

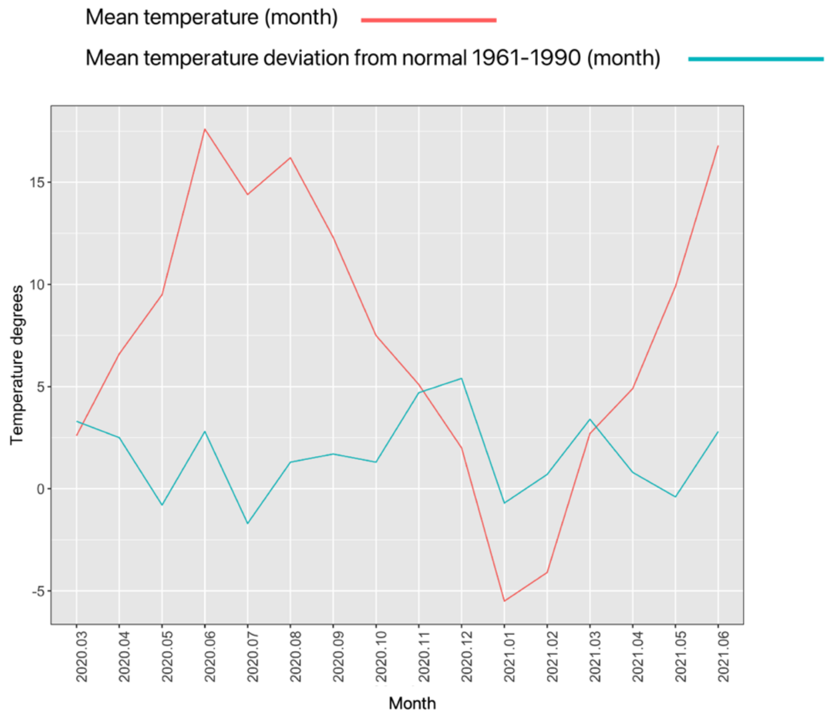

Figure D-1. *Mean temperature and mean temperature deviation from normal 1961–1990 (month).*

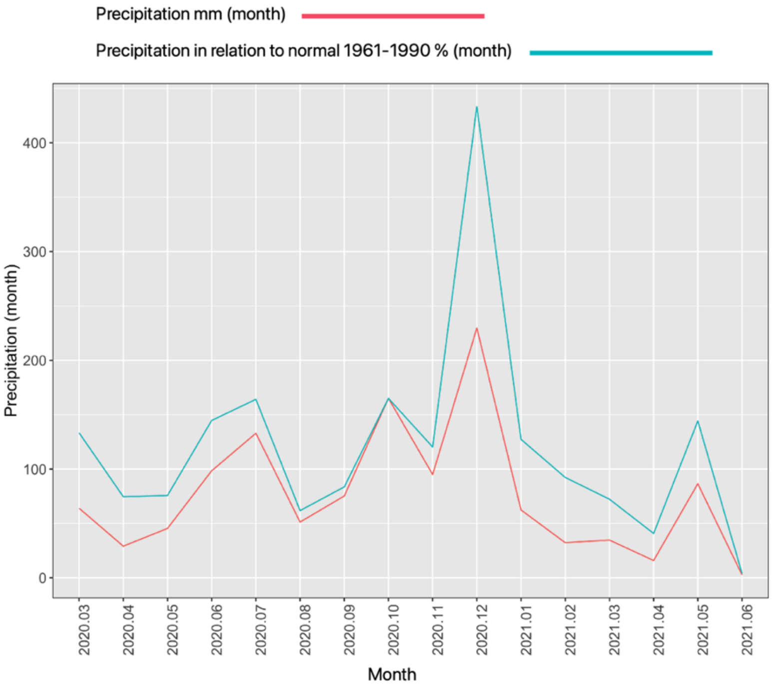

Figure D-2. *Precipitation (mm) and precipitation in relation to normal 1961–1990 (%) (month).*

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