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Final report EMRA

Environmental planning, measures and restoration actions in regulated water systems.

A Swedish-Finnish cross-border-project in the arctic region.

Länsstyrelsen
Norrbotten

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Introduction

EMRA (Environmental planning, measures and actions in regulated water systems) is a cross-border project between Finland and Sweden. The project aims to improve and recreate a natural environment for aquatic animals and plants in river systems affected by hydropower dams and from timber floating. The project includes parts of Lule älv river (Sweden) and Kemijoki (Finland). One major objective has been the exchange of knowledge between the two countries. The project has also gained new knowledge about the genetics of the fish populations within the river systems. During the habitat restoration the methods have improved. Additionally, gathering information about the culture heritage along the rivers regarding fish and fishing has been an important part of the project.

EMRA has been financed by Interreg Nord, Swedish Agency for Marine and Water Management (Sweden), Vattenfall Vattenkraft AB (Sweden), Kemijoki OY (Finland), Regional Council of Lapland (Finland), Ministry of the Environment (Finland) The project has been carried out as a collaboration between the County Administration Board of Norrbotten, the Centre for Economic Development, Transport and the Environment, Metsähallitus, the Natural Resources Institute Finland, Vattenfall Vattenkraft AB and Kemijoki OY.

This report describes the activities that have been performed in the project. A final report has also been submitted to Interreg Nord. Most of the translation has been done within the project. It is not always an exact translation, and we ask for indulgence from the reader. Each author/-s are responsible for their own chapter.

// Participating partners in EMRA

Table of contents

1. Restoration in Pärlälven river

Authors: Linda Johansson, Sofia Perä, Länsstyrelsen i Norrbottens län

1.1. Summary

Pärlälven river is a large tributary to Lule river. In contrast to the Lule river, Pärlälven river does not have any hydropower dams.

To facilitate the timber floating, Pärlälven river was straightened, and boulders and stone were removed. Habitats were eradicated and the consequences were devastating for the aquatic life. The most striking measures were the channelization of the river.

Now, when the timber floating has ended, it is time to repair the damage done during that period.

In project EMRA, restoration work has been conducted during two field seasons, 2021 and 2022 and a total 19,57 km of streams has been restored of which 19 side channels has been reopened. Additionally, a total of 27 spawning beds for trout have been created.

Knowledge from previous, similar projects has been used during the project time and the methods have developed continuously. Excavators have been used to move the boulders and gravel. The final work of the spawning beds was done manually with special tools using the Hartijoki method. The method is developed in the northern part of Norrbotten and a well-known method of recreating spawning beds.

After the project, the important species, brown trout, freshwater pearl mussel and otter have more natural habitats. For brown trout the measures have increased the habitats available for them. That means larger habitats for reproduction and foraging and an opportunity for the fish populations to increase.

The measures done for fish also benefits freshwater pearl mussel since it needs a salmonid as a host during its larvae stage. That, in combination with more suitable habitats for the mussels makes the status for the mussels more favorable. The recovery of freshwater pearl mussel populations is dependent upon the distribution and successful reproduction of its hosts.

The otter’s main diet is fish, so when fish stocks increase the otter population is favored. When water courses are restored, many rapids are re-created. The otters need open water during the winter, so they can search for food. Slower running waters freezes to ice during the winter, but the rapids have open water where the otters can search for food.

The statuses of the water bodies WA97511897 and WA5633653 in Pärlälven river are “moderate” due to migration barriers and the timber floating modifications. No evaluation has yet been carried out to assess whether the measures within the project have led to improvements in the ecological status of the waterbodies in Pärlälven river, as the next reassessment will not be carried out until 2027. However, as the presence of migration barriers and the damage done by the timber floating have been identified as the major reasons why the waterbodies are assigned a status that is less than good, it is expected that the waterbodies will be reclassified as a result of the measures carried out as part of EMRA.

The measures, performed by EMRA, will bring us one step closer to achieving the goals set by the Water Frame Directive and our national environmental quality objectives.

1.2. Introduction

Pärlälven river is a tributary to Lule river system, situated west of the municipality Jokkmokk, Sweden, figure 1. Lule river has several hydropower dams but Pärlälven river is unregulated, the river does not have any hydropower dams. The dams in the Lule river are making it impossible for salmon and sea-migrating trout to migrate to Pärlälven river. However, Pärlälven river has a population of stationary brown trout.

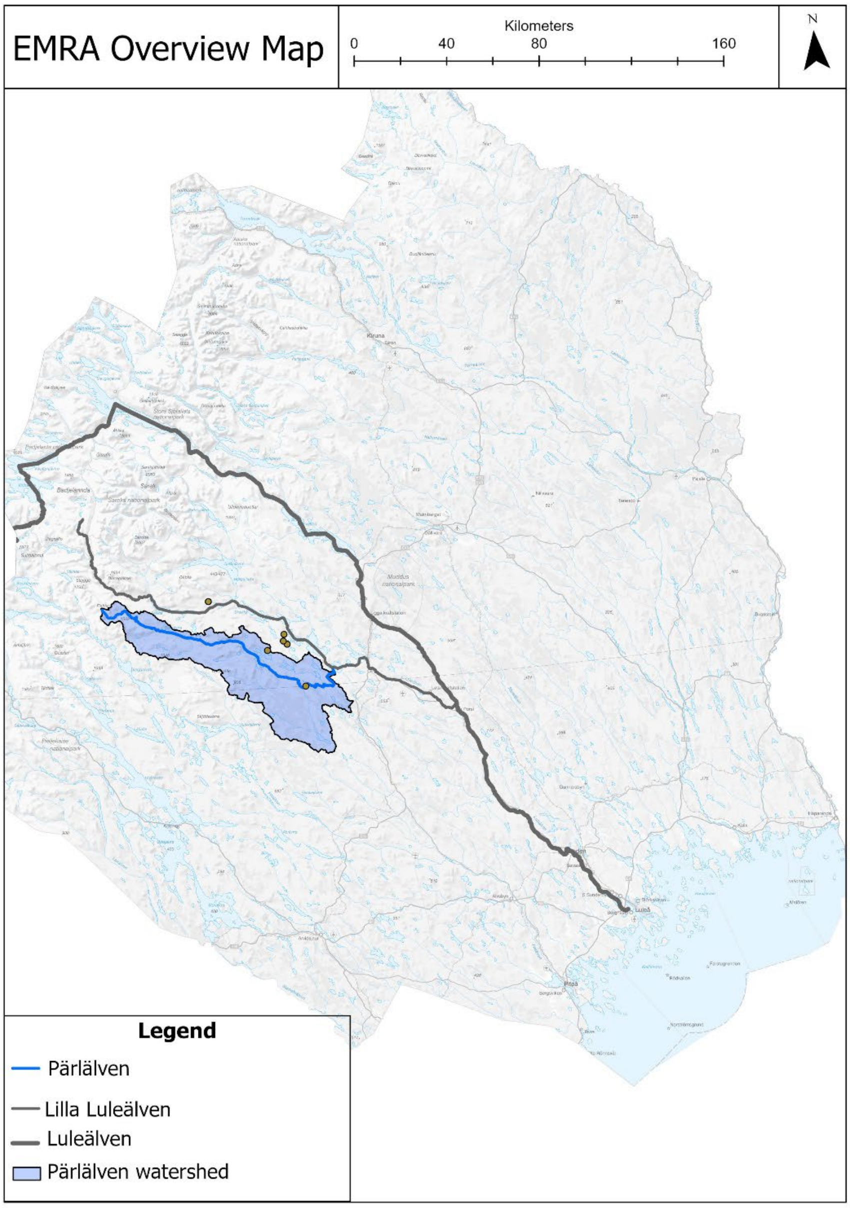

Figure 1. The map shows the area of Pärlälven river watershed situated in Norrbotten county.

During the 19th century, a large-scale timber floating era began. To transport timber from the forest-rich inlands to the sawmill industries at the coast in Norrbotten rivers and streams were used. To facilitate the timber floating, the streams were straightened, and boulders and stone were removed. This was devastating for the aquatic life when habitats were eradicated. Today, many of the species are endangered.

Pärlälven river was used for timber floating and is heavily affected by the activity, the most striking measures were the channelization of the river.

The river is also characterized by several natural side channels, smaller streams that parts from the main river and return to the river further downstream. To prevent timber from floating into the side channels and get stuck, the inlets were closed by manmade stone structures. Additionally, by concentrating the water flow to the main river more water was available for the timber floating.

Since no timber should pass the side channels, no effort was made to remove boulders and stones and the side channels are unaffected by human activity. By removing the stone structures at the inlets of the channel's, more wet areas have been gained that are natural and untouched by human activity.

Some well-preserved stone structures have high culture values. Together with the archaeologists working at the County Administrative Board, it was decided to leave some of the structures intact.

Several animal and plant species have suffered in the modified habitats. For instance, when the riverbed has lost their heterogenicity, small cavities in the riverbed where smaller fish hide and lager cavities were larger fish rest or feed, have disappeared or highly decreased. The important spawning beds for trout that contain smaller gravel has been flushed away or buried into the riverbed.

It is essential to have good knowledge about the ecology of aquatic animals to make measures successful. Other factors such as the water level in the river is also important. High water levels make it more difficult to perform the measures and it leads to the need for adjustments the forthcoming season. On the other hand, extremely low water levels make it difficult to estimate how the restoration work and the structures will look like in normal water levels. If autumn rainfalls are heavy, it will cause high water levels and problems for the project actions. It can shorten the field seasons with several weeks.

The restoration of natural habitat from the impact of timber floating and the removal of migration barriers have been identified as a priority on both a national and a regional scale – by the Swedish Agency for Marine and Water Management and the regional Water Authorities. The Water Authorities are regional agencies responsible for coordinating the efforts by other authorities and municipalities.

The Water Framework Directive states that all waterbodies must have good or high ecological status.

The statuses of the water bodies WA97511897 and WA5633653 in Pärlälven river are "moderate" due to migration barriers and the timber floating modifications.

1.3. Material and Methods

Permits and consents

Before the conservation measures started, several permits had to be issued. This included information and consultation with local stakeholders. In order to conduct conservation actions on private land, consents from the landowners were required. For EMRA, a majority of the targeted areas are owned by forest companies (Sveaskog and SCA) and the National Property Board (Statens fastighetsverk) which have made the process with permit from landowners easier.

For the restoration actions in Pärlälven river a permit has been issued from the Environmental court, which has required an application containing an Environmental Impact Assessment, EIA. An important aspect of the EIA is the cultural-historical value of the objects created during the timber-floating era, stone arms, dams etc. of high craftsmanship quality. In order to get permit to remove most of the cultural objects, a thorough cultural-historical documentation of the entire rivers stretches, and the timber-floating remnants have been done. Additionally, the project has together with the archaeologists working at the County Administrative Board, decided to leave some of the structures intact. The results were drawn into photos taken by a drone.

Before any work started, required permits have been collected: exemption to drive in terrain (issued by County Administrative Board), exemption to work in the shoreline (issued by County Administrative Board) and exemption to move freshwater pearl mussel (issued by County Administrative Board).

Additionally, areas or objects have been identified with high terrestrial ecological values, e.g., presence of species protected by the Habitat directive or endangered species listed on the Swedish red list.

There has been a continuous dialogue with persons, organisations and companies (landowners, fishing association, forest companies and reindeer owners) that could be affected by the restoration work.

The restoration measures in Pärlälven river

By using satellite maps and vegetation maps it has been possible to determine where it is best to transport the excavators to the river to avoid damage. To confirm and adjust the routes for the excavators, visits to the locations has been carried out. Since the machines are heavy and move on steel tracks, caution has been taken to minimize damages. As far as possible, old forestry machine tracks have been used. When the excavator has passed more sensitive areas, excavator ground protection mats built by logs, have been used.

Pärlälven river is heavily affected by the timber floating modifications. Restoration measures have been carried out at sections where we can achieve highest ecological benefits.

Historically, when the rivers were modified to facilitate timber floating, rocks and boulders were relocated from the water up to the shorelines, which narrowed the stream considerably comparing to its original width. The river shoreline has since then been covered by the rocks and boulders (originating from the riverbed), which have formed an unnatural protection stopping erosion between terrestrial and aquatic environments. The pristine river meandering path was straightened (channelised), and most of its side channels were closed.

The restoration work in Pärlälven river is conducted in teams with one foreman and one excavator operator in each team, figure 2. In 2021 there were four excavators (four teams) in Pärlälven river and in 2022 there were three excavators (three teams). All teams are supervised by a coordinator. The coordinator is an aquatic ecologist with experience of restoration measures from previous projects (e.g., the LIFE project ReBorN). The coordinator has an overall responsibility of the measures.

The foremen have experience from similar previous work, and they have been employed by the County Administrative Board or worked as consultants (after public procurement).

The most common way of restoring a river stretch, is to start upstream and work downstream along with the current. The excavator extends its arm out from the water, almost into the forest, to reach all the material that belongs to the riverbed. It clasps the rocks and positions it wherever the foreman decides. Before any excavator starts digging, the foremen together with the coordinator, plan, and design how the restoration work will take place. Together they create a goal of what the stream section will look like and what structures it shall have when the restoration work is completed.

Figure 2. A constructive cooperation between the foreman and the excavator operator is very important. It creates good results and a pleasant working environment. Photo: County Administration Board Norrbotten

By restoration and re-opening side channels, the rivers have returned to a more natural state. This implied wider watercourses and an increased quantity of water habitat where numerous flora- and fauna species thrive. One of the consequences from the lack of natural erosion between terrestrial and aquatic environments is the absence of dead wood (large wooden debris) in the system. During the restoration, the foremen and excavators have pushed down big trees in the streams. This action can sometimes start an erosion process, where trees gradually will fall into the stream, filtering substrate and creating new habitat for smaller fish and invertebrates.

The restoration has aimed to improve and recreate damaged or destroyed aquatic habitats. Mainly, the river substrate has been relocated from the shorelines composes of big boulders and large number of rocks and gravel, and primarily excavators have been used to restore the rivers, which is a long time developed best-practice method. It was required that the excavators were equipped with a custom designed spoon (designed in earlier restoration work), with the ability to clasp rocks, boulders and to stratify gravel. The measure of 80 mm between bars and gaps on the spoon gives the ability to sift for gravel - suitable for spawning sites, figure 3.

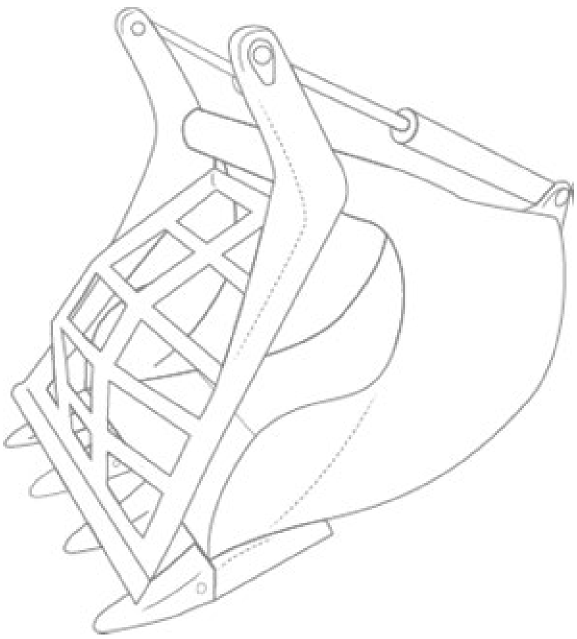

Figure 3. Illustration of custom designed excavator spoon. Illustration: County Administrative Board of Västerbotten.

The spawning grounds are usually (both naturally and restored) located at the top of a rapid (river neck, where calm water bursts into a rapid), and that is where focus has been to relocate the gravel substrate. To assure the created spawning areas are stable and have a secured supply of gravel for years to come, blocks have been arranged upstream the spawning sites that creates riffles which silt for more gravel. Additionally, areas have been created where natural erosion will provide the spawning grounds with new gravel.

Simultaneously, habitats for juvenile fish as well as for bigger fish were created by making the stream bed heterogenous, in terms of depth, width and substrate size- and type. Bigger fish prefer big, deep pools and smaller, younger fish are located shallow, closer to shore where they can hide from predators. Additional species also benefits by heterogenous riverbed, like the benthic fauna, where they can find suitable habitats.

Creating spawning sites is necessary to succeed with ecological restoration goals. The quality of spawning sites is by far the largest factor affecting restocking of depleted fish populations. The final touch of the spawning beds has been performed manually with custom made tools. The method used is a special technique called Hartijoki, developed in the northern part of Norrbotten. The method has, during time, been altered to fit the work with excavators. The creating of spawning sites was done in two steps. Large material was removed with excavators equipped with special spoons with gripping bars, and final adjustments were made manually with, for the purpose, special tools. Spawning beds were preferably done in areas with intermediate current. A finished bed contains natural gravel in a mixture of small stones from 0.5 cm-8 cm in diameter. The boulders and oversized stones were used to create a support on the downstream end of the spawning area and to regulate flow in and over the bed. The goal was to get a waterflow to pass through the gravel bed.

During the second season, a service team was formed. Their work tasks have been to cut down trees and prepare for the excavators, picked up and relocated freshwater pearl mussels, manually adjust spawning beds and to transport fuel to excavators. The service teams have helped the foremen and have made the work more efficient when preparations have been done before the excavators have arrived at the sites.

To avoid accidents and to save time with foremen walking back and forward to the excavator on rocky riverbed, sometimes in heavy current and climb up the machine to the operator (who had to stop the machine) hearing protectors has been used with a built-in two-way radio. By using hearing protectors, better results have been received from the restoration work with less machine stops, saved time, the foreman and the operator communicated more effectively with less misunderstandings and most importantly – without having the foreman close to the potentially dangerous excavator.

For safety reasons, the foremen have been wearing reflective safety vests. Another necessary equipment is e.g., waders, safety clothes for cutting down trees etc.

The areas have been photographed with the help of a drone before and after restoration. Drone surveys are depending on natural circumstances as wind, rain, shading and water levels to get accurate results. This makes it time consuming and combined with no-go flight zones (military or civil air zones) and new overall regulations for flights out of sight makes it impossible sometimes. On the drone photos the objects, stone structures, that can be removed or that will be saved due to high cultural value have been marked. In the northern part of Sweden there is a very short timeframe when the conditions are optimal, the yearly variation is between 1-3 weeks after the spring flood decreases and before there is a dense vegetation cover. Monitoring is more suitable for large systems than smaller because of the vegetation cover.

Pärlälven river is largely surrounded by both forests and wetlands with high nature values. To avoid damage on the vegetation when transporting fuel, a machine called iron horse, with caterpillar belt have been used. The machine can easily transport around 240 liters of fuel.

The Water Framework Directive

The restoration of natural habitat from the impact of timber floating and the removal of migration barriers have been identified as a priority on both a national and a regional scale – by the Swedish Agency for Marine and Water Management and the regional Water Authorities. The Water Authorities are regional agencies responsible for coordinating the efforts by other authorities and municipalities.

The Water Framework Directive states that all waterbodies must have good or high ecological status.

A range of assessment criteria are used when assessing the status of a waterbody. The waterbody is assigned a status that ranges from good to bad. There are five levels: high, good, moderate, bad, and poor. If the status is lower than good, an action plan must be put in place.

A waterbody that is affected by timber floating or where there is a migration barrier, the ecological status can never be good or high. By restoration measures and by removing the barriers, the ecological status can be improved. However, the removal of migration barriers does not automatically lead to an improvement of the ecological status as the status is determined by a range of other factors. Other factors that determine the ecological status are, e.g., land use, eutrophication, and the presence of ditches.

However, in the northernmost counties the modification of rivers and creeks to facilitate timber floating and the presence of migration barriers (primarily culverts and dams) have been identified as the leading causes behind low ecological status, while eutrophication and acidification are of less concern.

The statuses of the water bodies WA97511897 and WA5633653 in Pärlälven river are "moderate" due to migration barriers and the timber floating modifications.

1.4. Results

After two field seasons, a total of 19,7 km has been restored. In total 32 stretches have been restored in which 19 side channels has been fully or partially re-opened. 27 spawning beds for trout have been created in the EMRA project, table 1. Spawning beds are essential for fish population and are a key factor for a successful restoration.

Table 1. Results of two years of measures along Pärlälven river, Jokkmokk.

	No. Of machines	No. Of foreman	Length of restored stretches (m)	Reopened side channels	No of spawning beds
Total	7	7	19 566	19	27

In figure 4 Pärlälven river watershed is represented and shows the location of the detailed maps, site 1 – 4, regarding site 3-4 refer to chapter Remediation of migratory barriers. Figure 5 is a detailed map of site 1 and shows the lower part of Pärlälven river and where measures have been performed and where spawning beds has been recreated. I this site, also one migratory barrier has been remediated. Figure 6 is a detail map of the upper part of Pärlälven river.

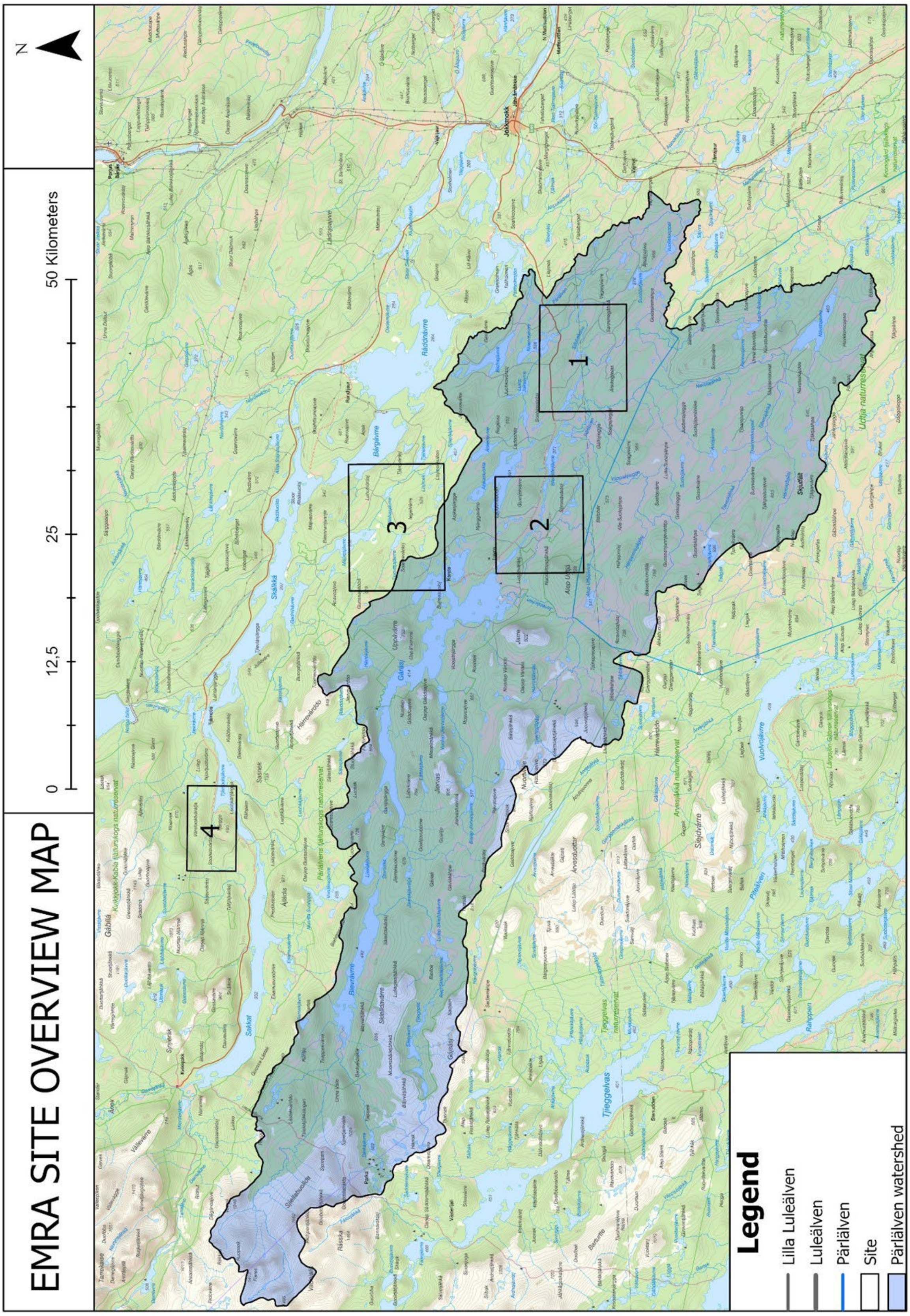

Figure 4. The map is showing an overview map of Pärlälven watershed and the location of the different sites.

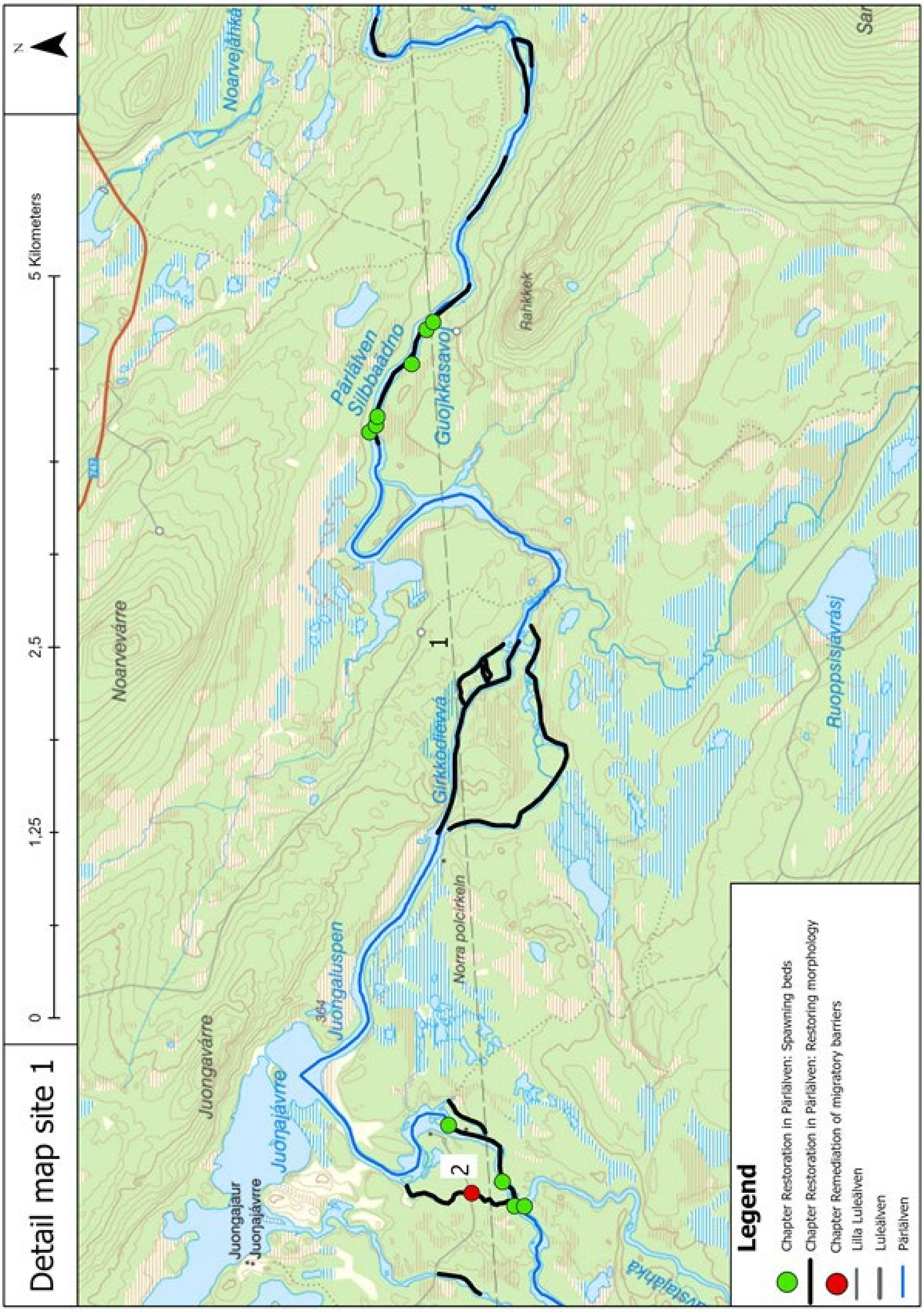

Figure 5. The map is showing the lower part of Pärlälven river.

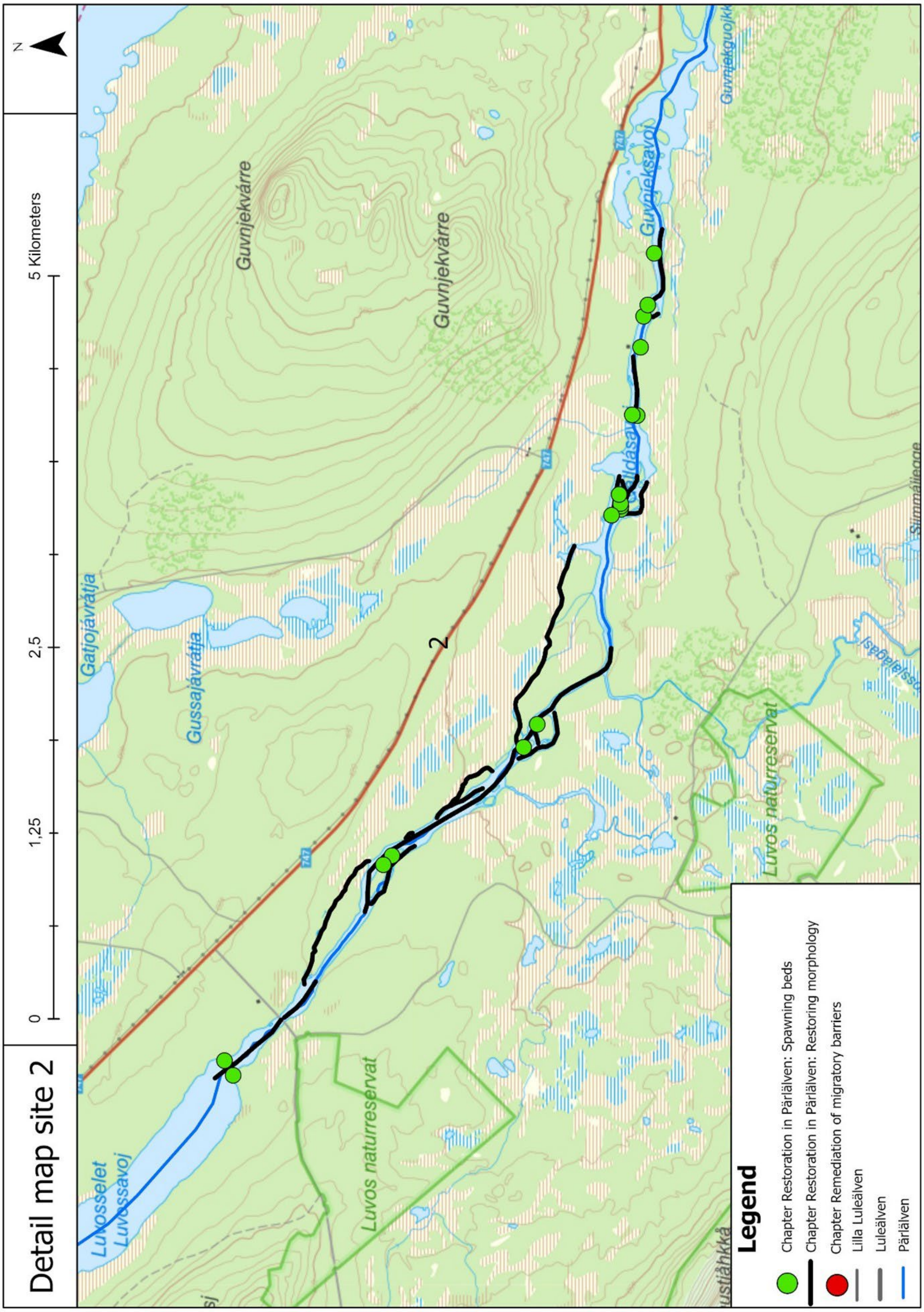

Figure 6. The map is showing the upper part of Pärlälven river.

In figure 7 you see two photos taken by a drone of the same part of Pärlälven river. The upper photo is photographed in 2020 before restoration and the lower photo is photographed after restoration, autumn 2022. The stone structures have been marked in different colors, what should be removed or what should be saved due to high cultural value.

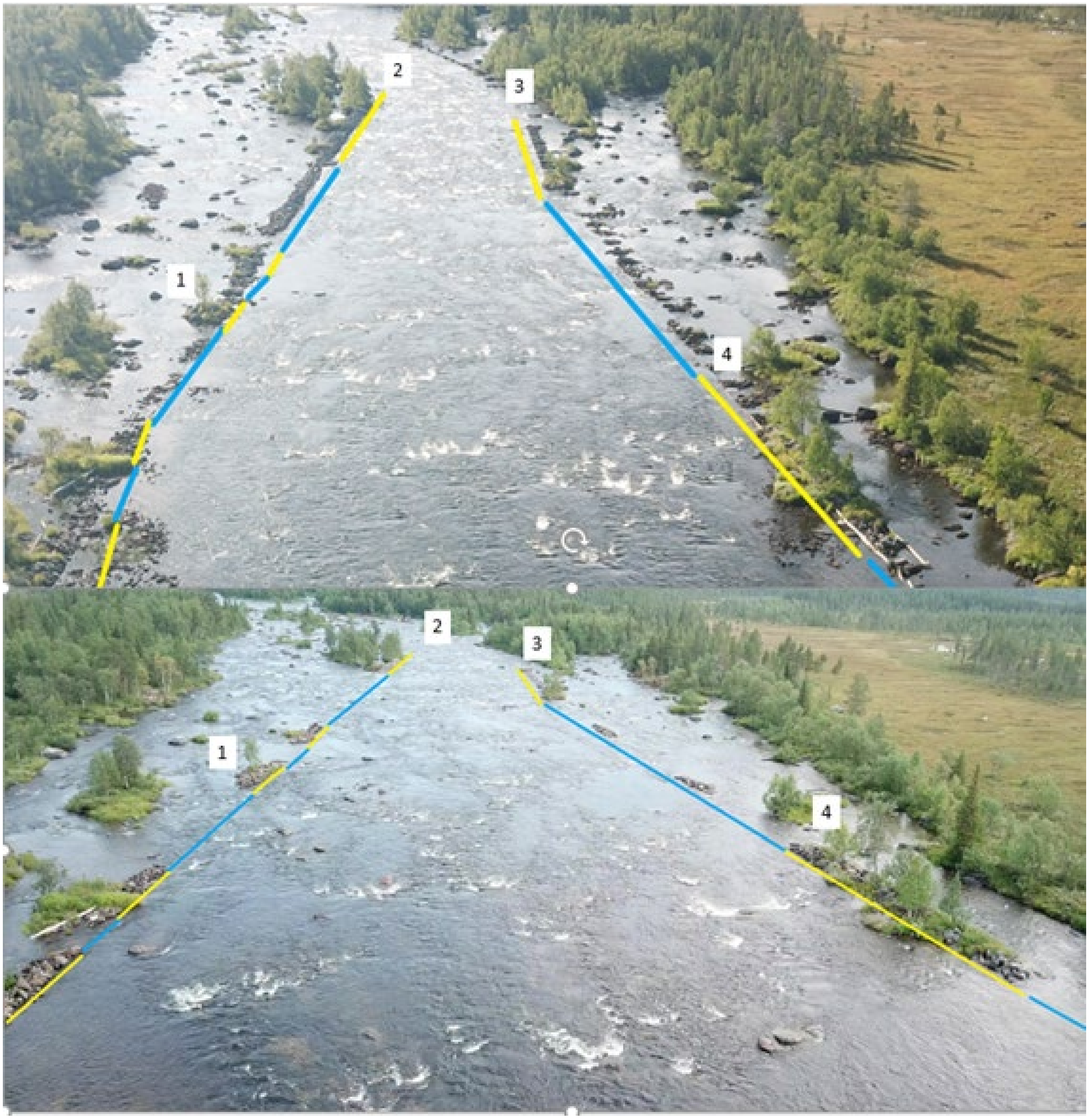

Figure 7. Photos taken by a drone. The photo above is taken before restoration in 2020 and the photo below is taken in autumn 2022 after restoration. In dialogue with the archaeologists, it was decided that the areas with the yellow lines should be saved and the area with the blue line could be removed. The number in the photo are for orientation. Photo: County Administration Board of Norrbotten.

In this project, the gained wet area after the project has not been monitored. However, in a previous project (LIFE project ReBorN) we have seen an increase with approximately 20% after the restoration is done (Ström, R. 2022 and Ojanlatva, D. 2022).

The Water Framework Directive

The statuses of the water bodies WA97511897 and WA5633653 in Pärlälven river are “moderate” due to migration barriers and the timber floating modifications.

No evaluation has yet been carried out to assess whether the measures within the project have led to improvements in the ecological status of the waterbodies in Pärlälven river, as the next reassessment will not be carried out until 2027. However, as the presence of migration barriers and the damage done by the timber floating have been identified as the major reasons why the waterbodies are assigned a status that is less than good, it is expected that the waterbodies will be reclassified as a result of the measures carried out as part of EMRA.

1.5. Discussion

The restoration measures done in Pärlälven river have improved the habitats for aquatic animals and enhanced the chance to improve that statuses of the water bodies.

The key-species species, brown trout, freshwater pearl mussel and otter have more natural habitats. For brown trout the measures have increased the habitats available for them. That means larger habitats for reproduction and foraging and an opportunity for the fish populations to increase.

The measures done for fish also benefits freshwater pearl mussel since it needs a salmonid as a host during its larvae stage. It is also the only way for a freshwater pearl mussel to migrate when it is attached to the gills on a salmonid. Many species of freshwater mussels are host specific. Larvae of the freshwater pearl mussel depend on young trout and salmon. The freshwater pearl mussel releases its larvae in the late summer and live as parasites on their gills for almost a year before they leave their host and bury in the substrate. The larvae stay buried in the substrate for 4-5 years until they measure approximately 5 cm. Hence, freshwater pearl mussel populations depend on the successful reproduction of salmon and trout in order to survive.

That, in combination with more suitable habitats for the mussels makes the status for the mussels more favorable. The recovery of freshwater pearl mussel populations is dependent upon the distribution and successful reproduction of its hosts. An impact on the freshwater pearl populations following the successful reproduction of brown trout will not be possible to detect until 6-7 years after a spawning event, when the young mussels can more easily be monitored as they leave their invisible existence buried in the sediment and start living at the surface.

The otter’s main diet is fish, so when fish stocks increase the otter population is favored. When water courses are restored, many rapids are re-created. The otters need open water during the winter, so they can search for food. Slower running waters freezes to ice during the winter, but the rapids have open water where the otters can search for food.

The modification of rivers and creeks to facilitate timber floating has been identified as the major reason why many waterbodies are assigned a status that is less than good. Two water bodies have been restored in the EMRA project. The statuses for the water bodies are moderate due to migration barriers and the timber floating modifications. However, the restoration does not automatically lead to an improvement of the ecological status as the status is determined by a range of other factors. In some cases, the ecological status of a waterbody does not improve following the ecological restoration unless these other factors are also addressed. In the northernmost counties the modification of rivers and creeks to facilitate timber floating and the presence of migration barriers have been identified as the leading causes behind low ecological status, while eutrophication and acidification are of less concern. In the next cycle 3 (2022-2027) the work done in EMRA will be considered.

EMRA contributes to achieving the national Swedish Environmental Quality Objectives number 8 (Flourishing Lakes and Streams), 12 (Sustainable Forests) and 16 (A Rich Diversity of Plant and Animal Life). EMRA also contributes to achieving to the Sustainable Development Goals number 3 (Good health and well-being), 6 (Clean water and sanitation), 14 (Life below water) and 15 (Life on land).

The measures, performed by EMRA, will bring us one step closer to achieving the goals set by the Water Frame Directive and our national environmental quality objectives.

With the measures done in the EMRA project the aquatic species will have a promising future. However, the measures are just one part in our environmental work. Other issues such as fishery management and wetland restoration need to continue. In the beginning of the 1990s, several projects in the Norrbotten county have been carried out to improve the health of the aquatic ecosystem and the availability of habitat. These include the restoration of rivers from the impact of timber floating, restoration of feeding grounds, nursery areas and spawning areas for salmon and trout and removing migratory barriers.

The Swedish Forest Agency and the Swedish Transport Administration have been remediating inaccurately constructed culverts for many years. The forestry companies are also making improvements to road-river crossings when carrying out maintenance work (e.g., repairing culverts). In addition, the County Administrative Board of Norrbotten has continuously been working on removing migration barriers within the scope of other projects. The work done is following the guidelines and policies stated in national and international agreements, e.g., the Swedish Environmental Objectives and the Water Framework Directive.

Much of the impact the measures will have on the aquatic community will not be possible to detect and measure until after a certain time, which can be several years. While it is possible to quickly assess whether trout is using newly created spawning grounds and thereafter measure reproduction success by recording the abundance of juvenile fish the impact on trout recruitment will not be apparent until the next generation returns to the stream to spawn (approximately 5-7 years later). As populations of brown trout and freshwater pearl mussel are continuously being monitored by the County Administrative Board of Norrbotten, it is expected that future monitoring will reveal effects on the populations of those species that will only be possible to detect and measure once several years have passed.

The long-term economic benefits of the project can mostly be connected to benefits for fishing tourism and ecotourism. Both industries have large potential in Northern Sweden and is one of the largest growing industries. Through the measures, our project has improved the possibility for populations to thrive. The targeted species trout, freshwater pearl mussel and otter are favored by our measures, but other species of fish and aquatic animals are also favored. This will benefit the sport fishing tourism and with that kind of tourism comes an increase in sold fishing licenses, income for accommodation, food etc.

The gained experience from the project have encourage us to apply for more projects and both larger and smaller projects are running, and other projects are about to start. All new projects are creating jobs for people in the region, such as for foremen, excavator operators as well as administrative jobs.

During the project time, the methods have constantly been developed.

Excavators have been used to move boulders and gravel. The final work of the spawning beds was done manually with special tools using the Hartijoki method. The Hartijoki method is developed in the northern part of Norrbotten and a well-known method of recreating spawning beds.

We have constantly improved and evolved our restoration methods. We have learned how the excavators should be used so we will get the best results. We have also learned more about what type of excavator we should use, by using a bigger excavator, you can move larger boulder and reach further with the spoon but if the surrounding area is sensitive (for example wetlands) a smaller excavator can be better to use. By having a service team, we have made the restoration more time efficient since the preparation work has been done before the excavators entered the rivers.

1.6. References

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2. Remediation of migratory barriers

Authors: Linda Johansson, Sofia Perä, Länsstyrelsen i Norrbottens län.

2.1. Summary

Many animals that live in streams are dependent on being able to move freely within the water system. Most aquatic animals require free migration routes to spread and reproduce. Terrestrial animals are also depended on water systems and use them to forage and as transportation routes.

A migration barrier creates a barrier for fish and other animals that live in the stream or along the shore. A migration barrier can be a dam or a culvert.

In the EMRA project six migration barriers, six culverts, have been replaced and over 40 km of streams have been reconnected with water areas downstream. The connectivity has increased which will benefit migratory fish within the water system.

Six culverts have been replaced by four bridges and two arches. Where bridges have been built, larger stones have been placed under the bridges to facilitate otters and other animals' passage under the bridges.

The remediation of migratory barriers has provided access to habitats previously closed for aquatic animals by barriers. For trout to colonize new areas upstream, rather than spawn in the area where they were born, the abundance of spawning individuals and the competition for space must be high enough to force some individuals to continue their migration upstream. However, in many areas competition for spawning areas is already very high, and in these areas spawning adults are more likely to migrate to the new reproduction sites upstream right away.

Three of the streams are water bodies according to Water Framework Directive. The statuses for the water bodies are moderate due to migration barriers and the timber floating modifications. However, the removal of barriers does not automatically lead to an improvement of the ecological status as the status is determined by a range of other factors. In some cases, the ecological status of a waterbody does not improve following the ecological restoration unless these other factors are also addressed. However, in the northernmost counties the modification of rivers and creeks to facilitate timber floating and the presence of migration barriers have been identified as the leading causes behind low ecological status, while eutrophication and acidification are of less concern. In the next cycle 3 (2022-2027) the work done in EMRA will be considered.

EMRA contributes to achieving the national Swedish Environmental Quality Objectives number 8 (*Flourishing Lakes and Streams)*, 12 (*Sustainable Forests)* and 16 (*A Rich Diversity of Plant and Animal Life)*. EMRA also contributes to achieving to the Sustainable Development Goals number 3 (*Good health and well-being),* 6 (*Clean water and sanitation),* 14 (*Life below water)* and 15 (*Life on land).*

The measures, performed by EMRA, will also bring us one step closer to achieving the goals set by the Water Framework Directive, as well as the goals for the Natura 2000 species and habitats.

2.2. Introduction

A migration barrier creates a barrier for fish and other animals that live in the stream or along the shore. A migration barrier can be a dam or a culvert underneath a road or a railroad or a bridge without banks. The dams are often remnants from the timber floating era and are no longer in use but are still there as barriers in the streams.

Regarding culverts several factors contribute to turning them into migration barriers:

• High water velocities, due to steep incline and lack of bottom substrate inside the culvert.

• Long culverts lacking bottom substrate and therefore lacking resting sites for fish and other animals.

• Too shallow water depth makes the culverts difficult to swim through.

• A perched culvert creates a drop at the outlet.

For fish, movement in the water is vital in order to migrate between spawning, nursery and feeding areas.

Smaller animals, for instance insects, also need to move within the water system. Some terrestrial animals are depended on water systems and use them to forage and as transportation routes. Badly designed bridges and culverts can force animals to crossroads, where they are at risk of being run over by cars. One example is that traffic is the most common cause of death for otters (Hammarsten, E. 2015).

The restoration of natural habitat from the impact of timber floating and the removal of migration barriers have been identified as a priority on both a national and a regional scale – by the Swedish Agency for Marine and Water Management and the regional Water Authorities. The Water Authorities are regional agencies responsible for coordinating the efforts by other authorities and municipalities. The Water Framework Directive states that all waterbodies must have good or high ecological status. Three of the water streams are water bodies according to the Water Framework Directive. The waterbodies have been assessed (WA84616787, WA22513312 and WA56363653) as “moderate” due to migration barriers and timber floating.

2.3. Material and Methods

Permits and consents

Before we started the removal of barriers, some permits had to be issued such as consents from the landowners and permits from the County Administrative Board according to the Swedish Environmental Code Chapter 11 §9a.

At one location, object no. 2 we have used the less complicated legislation in the Environmental Code Chapter 11 §12 which does not require an EIA. Chapter 11 §12 states that no permit according to The Swedish Environmental Code is needed if it is obvious that nor public or private interests are harmed. Consultation have been held with archaeologists at the County Administrative Board regarding cultural and natural values and landowner consent have been collected. The action in object 2 was to open a side channel and to replace a culvert with an arch with a natural riverbed.

Remediation of migratory barriers

One of the major causes for a culvert to become a migration barrier is that the diameter of the culvert is too small. If the water is compressed into the culvert the water velocity will increase. High water velocity inside culverts can be a barrier for some fish. With the higher water velocity, the water has more energy, and it can cause erosion at the outlet of the culvert. The lower part of a newly built culvert can be on the same height as the surrounding ground but if there is a flood with high water levels the water can erode the ground and remove the sediment at the outlet of the culvert and create a fall.

There are different ways to remediate migration barriers:

• The culvert is replaced with an arch or a bridge

• The original culvert is replaced with a culvert with wider dimensions and the stream bed is recreated.

• The water level inside the culvert has been raised by creating a rocky ridge downstream

• The dam is removed, and the stream bed is recreated

To make it easier for otters and other medium-sized mammals to move along the shore of the streams we have adjusted several bridges by constructing different types of underpasses:

• Dry banks – new dry banks are created underneath the bridge. The banks are constructed with large boulders and is a good alternative when the water is not too deep.

• Ledges – A ledge can be constructed underneath bridges and inside larger culverts. The ledge should be a natural extension of the bank and be placed so it can be used at most flow regimes.

• Dry culverts – if it is difficult to modify the existing culvert or bridge, a dry culvert can be constructed in the vicinity of the bridge. To direct the animals towards the dry culvert, structures and sometimes even fences that help guiding the animals towards the culvert may be necessary. It turns out that the dry culverts are working very well and have been used frequently by different species of animals.

• Fence – are being put up to direct the animals towards the underpass

In the EMRA project six migration barriers, six culverts, have been replaced. Four culverts have been replaced by bridges and two culverts have been replaced by an arch. Where bridges have been built, larger stones have been placed under the bridges to facilitate otters and other animals' passage under the bridges.

The Water Framework Directive

The restoration of natural habitat from the impact of timber floating and the removal of migration barriers have been identified as a priority on both a national and a regional scale – by the Swedish Agency for Marine and Water Management and the regional Water Authorities. The Water Authorities are regional agencies responsible for coordinating the efforts by other authorities and municipalities. The Water Framework Directive states that all waterbodies must have good or high ecological status.

A range of assessment criteria are used when assessing the status of a waterbody. The waterbody is assigned a status that ranges from good to bad. There are five levels: high, good, moderate, bad, and poor. If the status is lower than good, an action plan must be put in place.

A waterbody that is affected by timber floating or where there is a migration barrier, the ecological status can never be good or high. By restoration measures and by removing the barriers, the ecological status can be improved. However, the removal of migration barriers does not automatically lead to an improvement of the ecological status as the status is determined by a range of other factors. Other factors that determine the ecological status are, e.g., land use, eutrophication, and the presence of ditches.

However, in the northernmost counties the modification of rivers and creeks to facilitate timber floating and the presence of migration barriers (primarily culverts and dams) have been identified as the leading causes behind low ecological status, while eutrophication and acidification are of less concern.

Three have been assessed (WA84616787, WA22513312 and WA56363653) and the statuses “moderate” due to migration barriers and the timber floating modifications.

2.4. Results

Remediation of migratory barriers

Following the removal of migration barriers consisting of culverts, over 40,21 km of streams that were previously inaccessible to fish migrating in tributaries to Lilla Lulealv river, such as and brown trout, due to the presence of migration barriers, have been reconnected with water areas downstream, table 2. The connectivity has increased which will benefit migratory fish within the water system.

Table 2. Length of stretch on the water stream that has been available as a results of remediation efforts. Together, the distance amount to approximately 40,21 km.

ID.nr.	Name	Distance in meter	Before Reme-diation	After Reme-diation	Water body identification nr.	Ecological status
1	Sajvajavrasj (Vareluokta)	5 177	Culvert	Bridge	Other water	Not assessed
2	Juonga	978	Culvert	Arches	WA56363653 (side channel to Pärlälven river)	Moderate

3	Inlopp bädnakjávrásj	8 538	Culvert	Bridge	Other water	Not assessed
4	Utlopp bälkasjavrre	2 162	Culvert	Bridge	WA84616787	Moderate
5	Havgokjavratja	454	Culvert	Arches	Other water	Not assessed
6	Inlopp bälkasjavrre	22 898	Culvert	Bridge	WA22513312	Moderate
Sum		40 207	-	-	-	-

The culverts are in tributaries to Lilla Lule älv river, figure 4 and 8-9.

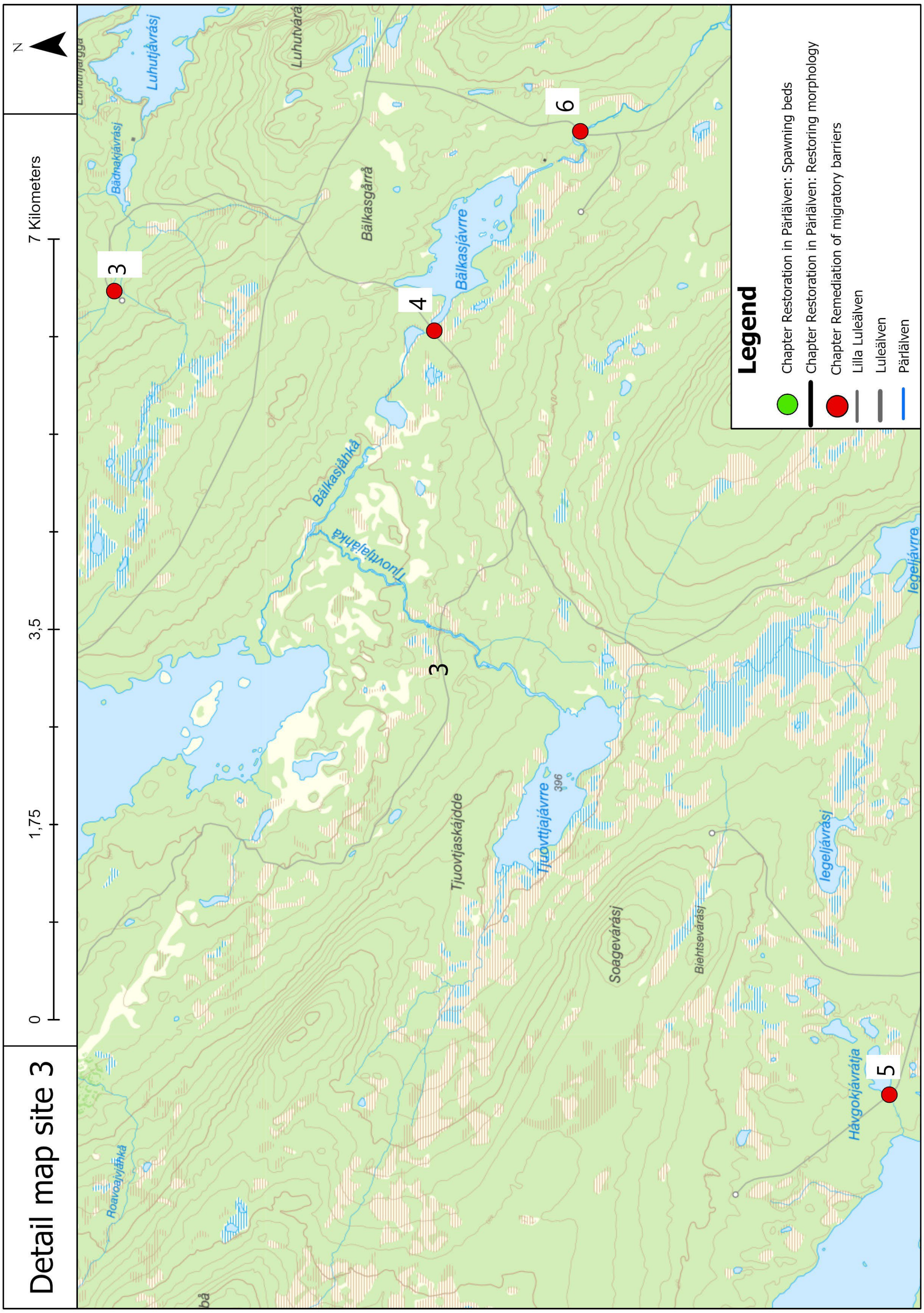

Figure 8. The map shows the location of the remediated migratory barriers.

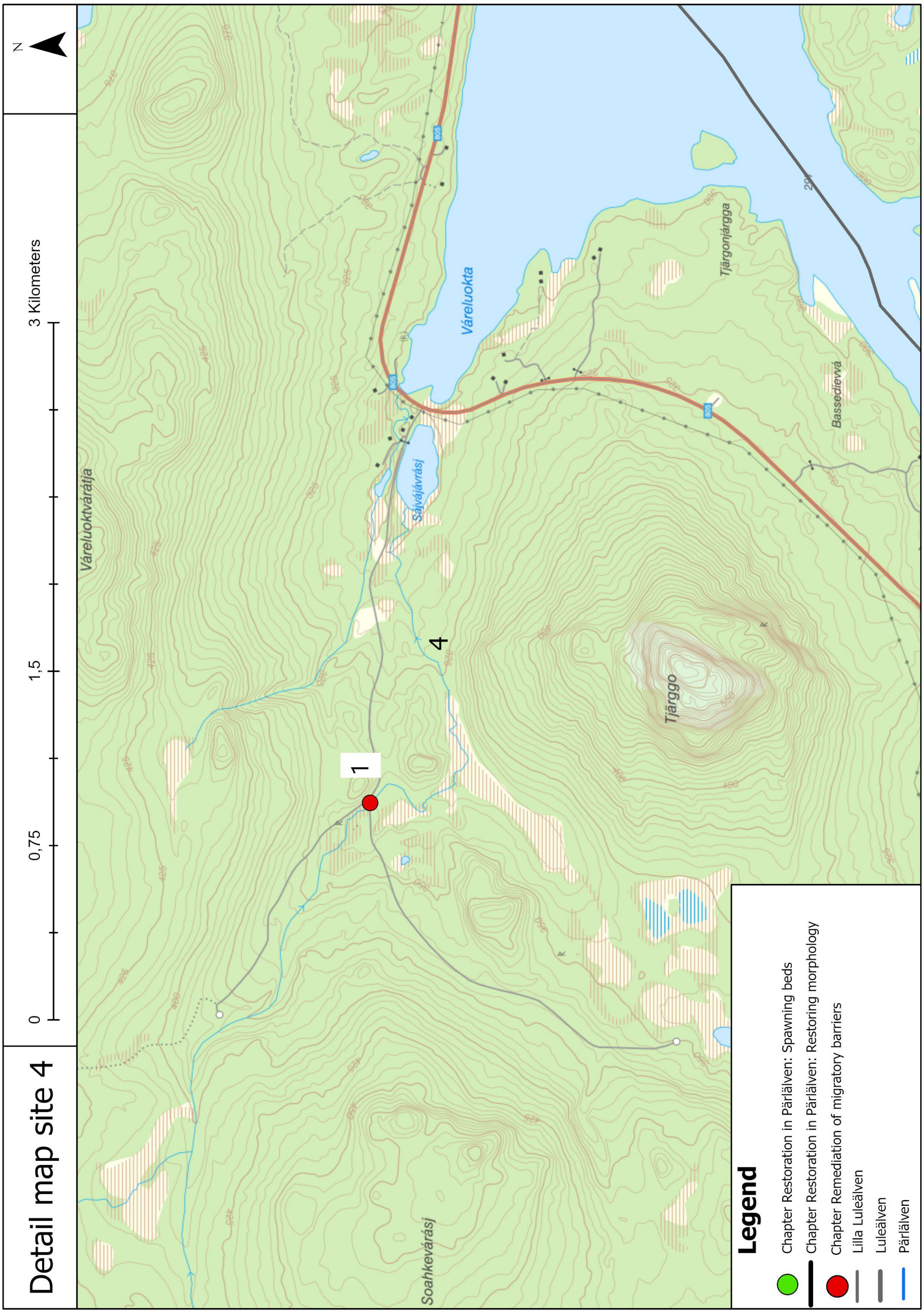

Figure 9. The map shows the location of the remediated migratory barriers.

Photos of the barriers taken before and after remediation can be seen in figure 10-15.

Figure 10. The photos are taken before and after remediation of migration barrier, object 1. Two culverts which both created a drop at the outlet. The culverts were also lacking bottom substrate. The long culverts have been replaced with a bridge so that the water stream can regain its original width and now also have bottom substrate mixed with bigger stones. Photo: County Administration Board.

Figure 11. The photos are taken before and after remediation of migration barrier, object 2. A side channel to Pärlälven river was reopened in the inlet and the increased waterflow required a wider bridge adapted to high water velocities and to avoid a too steep incline. Photo: County Administration Board.

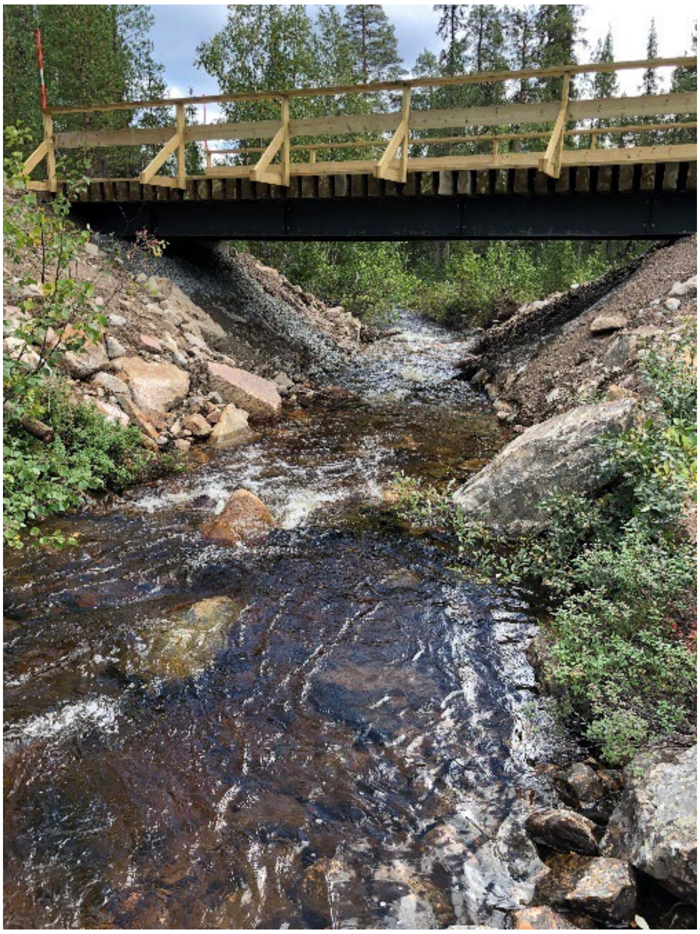

Figure 12. The photos are taken before and after remediation of migration barrier, object 3. The old bridge had narrowed the water stream significantly. After remediation the water stream have regained the original width, also note that now bottom substrate is presence. Photo: County Administration Board.

Figure 13. The photos are taken before and after remediation of migration barrier object 4. The old bridge had narrowed the water stream significantly. After the new bridge has been installed the water stream is wider. Photo: County Administration Board.

Figure 14. The photos are taken before and after remediation of migration barrier object 5. The old culvert was to narrow and the lack of bottom substrate didn´t offered any resting size for fish. After remediation the water stream is wider. Inside the arch there is now the presence bottom substrate together with bigger stones. Photo: County Administration Board.

Figure 15. The photos are taken before and after remediation of migration barrier object 6. Before the remediation the bridge was to narrow, and it created a to high water velocity. After remediation the water velocity has decreased, the stream has regained its width and under the bridge there are now bottom substrate in different size. Photo: County Administration Board.

The Water Framework Directive
Three of the water streams are water bodies according to the Water Framework Directive. The statuses of the water bodies (WA84616787, WA22513312 and WA56363653) are assessed “moderate” due to migration barriers and the timber floating modifications

No evaluation has yet been carried out to assess whether the measures within the project have led to improvements in the ecological status of the waterbodies in Pärlälven river, as the next reassessment will not be carried out until 2027. However, as the presence of migration barriers and the damage done by the timber floating have been identified as the major reasons why the waterbodies are assigned a status that is less than good, it is expected that the waterbodies will be reclassified because of the measures carried out as part of EMRA.

2.5. Discussion

The remediation of migratory barriers has provided access to habitats previously closed for aquatic animals by barriers. By removing barriers, species such as brown trout, freshwater pearl mussel and otter can safely migrate to areas further upstream. New areas mean larger habitats for reproduction and foraging and an opportunity for the fish populations to increase.

Much of the impact the removal of these migration barriers will have on the aquatic community will not be possible to detect and measure until after a certain time, which can be several years. While it is possible to quickly assess if trout is using newly accessible spawning grounds located upstream a former migration barrier, and thereafter measure reproduction success by recording the abundance of young fish, the impact on trout recruitment will not be apparent until the next generation returns to the stream to spawn (approximately 5-7 years later).

For trout to colonize new areas upstream, rather than spawn in the area where they were born, the abundance of spawning individuals and the competition for space must be high enough to force some individuals to continue their migration upstream. However, in many areas competition for spawning areas is already very high, and in these areas spawning adults are more likely to migrate to the new reproduction sites upstream right away.

When evaluating the impact of the removal of migration barriers on reproduction success of trout, it is important to remember that for successful reproduction to occur at a given site two criteria must be met: First, adults must be able to reach the site and/or occur in high enough densities. Second, spawning grounds of good quality must be available at the site. Consequently, if adults can migrate to a site that lacks spawning grounds, reproduction will not occur. If there are spawning grounds at a site, but adults either cannot access them due to the presence of migration barriers, arrive too late due to the presence of a series of partial migration barriers, or have not yet colonized the area (or no not occur in high enough densities), reproduction will not occur.

The results from future monitoring of trout reproductive success and of the population structure of freshwater pearl mussels will provide more information of the long-term impact of the removal of the migration barriers.

The modification of rivers and creeks to facilitate timber floating has been identified as the major reason why many waterbodies are assigned a status that is less than good. Three of the water streams are water bodies and the statuses for the water bodies are moderate due to migration barriers and the timber floating modifications. However, the restoration does not automatically lead to an improvement of the ecological status as the status is determined by a range of other factors. In some cases, the ecological status of a waterbody does not improve following removal of barriers unless these other factors are also addressed. However, in the northernmost counties the modification of rivers and creeks to facilitate timber floating and the presence of migration barriers have been identified as the leading causes behind low ecological status, while eutrophication and acidification are of less concern. In the next cycle 3 (2022-2027) the work done in EMRA will be considered.

EMRA contributes to achieving the national Swedish Environmental Quality Objectives number 8 (*Flourishing Lakes and Streams)*, 12 (*Sustainable Forests)* and 16 (*A Rich Diversity of Plant and Animal Life)*. EMRA also contributes to achieving to the Sustainable Development Goals number 3 (*Good health and well-being),* 6 (*Clean water and sanitation),* 14 (*Life below water)* and 15 (*Life on land).*

The measures, performed by EMRA, will bring us one step closer to achieving the goals set by the Water Frame Directive, our national environmental quality objectives, and the international environmental goal set by Agenda 2030 as well as the goals for the Natura 2000 species and habitats.

2.6. References

Hammarsten, E. 2015. *Uttern i Sverige Miljögifters effekter i relation till populationsstorlek och patologiska förändringar*. Uppsala: SLU, Inst. För biomedicin och veterinär folkhälsovetenskap.

3. The importance of brown trout in Arctic Region

Authors: Esa Inkilä & Seija Tuulentie, LUKE, Finland

3.1. Summary

Trout are an important species of fish found in many parts of the world, including Finland and Sweden. Trout can be divided into three different ecological forms: sea trout, lake trout, and small resident trout of streams, which are also referred to as brown trout. While all of these forms spawn in flowing water, sea trout migrate to the sea to feed, while lake trout migrate to the lake. Small resident trout, on the other hand, could live their entire lives in their home river or stream. The distinction between these ecological forms is not always clear, and there are also intermediate forms of trout that are found in different water bodies. In Finnish and Swedish fishing regulations, there is no distinction between the different forms of trout, as scientists consider them to be a single species with several migration strategies. Trout's habitat covers the entirety of Finland and Sweden, and migratory and local individuals can live in the same water bodies. If there are no migration barriers in the water bodies, these individuals can even reproduce with each other. The share of migratory and local trout in a water body is partly influenced by hereditary factors and partly by the environment.

Brown trout, in particular, has traditionally been of great importance in people's everyday life and as food in Finnish Lapland and Kainuu areas, as well as in northern parts of Sweden. It has often been the first fish caught by inland children and has served as extra food during harvest time and as part of reindeer herding activities. Despite its significance, the importance of brown trout as food and as a part of cultural and settlement history has not received much attention in studies. The value of traditional knowledge and local knowledge has been recognized alongside scientific knowledge, and in addition, traditional and local knowledge has been found to provide new perspectives to local operating conditions and research priorities. However, traditional knowledge and local knowledge often contrast with scientific knowledge and regulations. This can create feelings of injustice and guilt, particularly in discussions related to brown trout. Human activities, such as drainage, logging, and forest fertilization, have caused major changes in the habitat of brown trout, leading to a decline in their population. All sea-migratory trout stocks are critically.

Scientists have faced challenges in understanding the biology of trout, and there are different understandings even among scientists. For example, smaller brown trout have been thought to be sea-migrating trout that have not yet reached sexual maturity. Understanding the age and size of brown trout at sexual maturity is crucial in making estimates about the appropriate catch size and how fishing should be directed. In streams and tributaries of many water bodies, brown trout usually become sexually mature at 2-5 years old, while being less than 20 centimeters long. There have been disagreements between the local population and the fishing authorities in discussions related to brown trout. The study and documentation of these problems have been overshadowed by major controversies such as the regulation of the capture of migratory fish in rivers. In 2016, the Finnish Fishing Act stipulated that trout stocked for fishing purposes must have their adipose fins trimmed so that they can be distinguished from wild fish. Trout with adipose fins have been completely protected in the Gulf of Finland and other Finnish sea areas. Inland waters that come to the side of latitude 64º00'N, the with adipose fin has been completely protected as well. However, this does not apply to brown trout caught in a stream or lake that has no migration

connection from the sea or from a bigger lake. The catch size of brown trout with adipose fins from a stream or lake without a migration connection may not exceed 45 cm. The lower dimension of adipose fin cut brown trout planted for fishing needs is at least 50 cm across the country.

The report provides a comprehensive overview of the cultural significance of brown trout in fishing culture and the societal and political discussions surrounding it. The study draws on various sources, including literature, interviews, writing collections, and surveys, to provide a detailed examination of the importance of brown trout to both the fishing community and broader society. One of the key themes that emerges from the report is the importance of brown trout fishing in northern Finland and Sweden. Despite changes in fishing culture and the natural environment, the tradition of brown trout fishing remains an integral part of the local fishing habits. Many of the respondents in the survey indicated that they had learned to fish for brown trout in their youth and were now passing on this valuable skill to their children and grandchildren.

In addition to the cultural significance of brown trout fishing, the report also highlights the changes that have occurred in the fishing sites of brown trout over time. The decline in brown trout populations is a concern for many northern fishermen, who attribute this decline to factors such as forestry practices, the introduction of alien species, and other changes in the natural environment. These changes have also sparked debates about the merits of "catch and release" fishing, with some seeing it as a positive development, while others are strongly opposed to this practice. Fisheries policy decisions play a crucial role in determining the future of brown trout fishing. The report identifies a range of fishing policy issues related to brown trout, including the need for greater consistency between legislation and local customs, the importance of mapping the situation and planning operations, and the need for deep consideration and background work in whatever actions are taken.

The report also explores the tourism opportunities offered by brown trout fishing. Northern Finland and Sweden are popular destinations for fishing tourism, and the report suggests that there is considerable potential for the development of brown trout fishing tourism in these regions. However, this will require careful planning and coordination to ensure that tourism activities are sustainable and do not adversely affect the natural environment or local communities. Overall, the report provides a valuable insight into the cultural significance of brown trout fishing and the challenges and opportunities associated with this practice. It highlights the need for greater awareness of the importance of brown trout to northern Finnish and Swedish fishing communities and the importance of developing sustainable fishing practices and policies that consider the needs of both local communities and the natural environment.

3.2. Introduction

Trout can be separated according to habitat and migration behavior into three different ecological forms: sea trout, lake trout and the small resident trout of streams (Salmo trutta mainly ‘tammukka’ in Finnish, ‘bäcköring’ in Swedish). All these forms spawn in flowing water, but sea trout migrate to the sea to feed, while lake trout migrate to the lake. Small resident trout lives its entire life in its home river or stream. In this report we use term trout when discussion includes all trout’s ecological forms and when discussion is about the small resident trout of streams, we use term brown trout to specify and make it clearer. The border between different ecological forms is blurred because different intermediate forms of trout are also found. Both Finnish [(1)] (Kalastuslaki 10.4.2015/379) and Swedish fishing regulations there is no distinction between different forms of trout and scientists also see that there is only one trout species which has several migration strategies [(2)] (Ruokonen et al., 2019). Trout's habitat covers the whole of Finland and Sweden. Migratory and local individuals can live in the same water bodies. These can reproduce with each other if there are no migration barriers in the water bodies. The share of migratory and local trout in a water body is partly influenced by hereditary factors and partly by the environment [(3)] (Salminen & Böhling, 2019, p. 313).

Brown trout has traditionally been of great importance in people's everyday life and as food in Finnish Lapland and Kainuu areas. Also, in the northern parts of Sweden, brown trout has played an important role in people's everyday life and traditions. It has often been the first fish caught by inland children. It has served as extra food during harvest time and as part of reindeer herding activities but also at home dining tables. The importance of brown trout as food and as a part of cultural and settlement history has not received that much of attention in studies.

The value of traditional knowledge and local knowledge has been recognized alongside scientific knowledge, and in addition, traditional and local knowledge has been found to give new perspectives to local operating conditions and research priorities. Traditional knowledge and local knowledge can help researchers and at the same time bring new perspectives to areas and customs that are relevant to the preservation of culture [(4)] (Helander-Renvall & Markkula, 2011, p. 25). In relation to brown trout, traditional knowledge contrasts strongly with scientific knowledge and regulations. This breeds feelings of injustice and guilt.

The biology of trout has been a challenge for scientists and there are different understandings even among scientists. Smaller brown trout have been thought to be sea-migrating trout that have not reached sexual maturity. It is essential to know the age and size of brown trout at sexual maturity when making estimates about what is the appropriate catch size and how fishing should be directed. In streams and tributaries of many water bodies, brown trout usually become sexually mature at 2-5 years old, while being even less than 20 centimeters long [(3)] (Salminen & Böhling, 2019, p. 317). Disagreements have prevailed between the local population and the fishing authorities in discussions related to the brown trout. The study and documentation of these problems have been overshadowed by major controversies such as the regulation of the capture of migratory fish in rivers.

In 2016, Finnish Fishing Act [(1)] (Kalastuslaki 10.45.2015/379) provided that trout stocked for fishing purposes must have their adipose fins trimmed so that they can be distinguished from wild fish. The trout with adipose fin has been completely protected in the Gulf of Finland and in other Finnish sea areas. In inland waters that come to the side of latitude 64º00'N, the trout with adipose fin has been completely protected as well. This does not apply to brown trout caught in a stream or lake that has no migration connection from the sea or from the bigger lake. The catch size of brown trout with adipose fin from a stream or lake, which does not have a migration connection from the sea or bigger lake, may not exceed 45 cm. The lower dimension of adipose fin cut brown trout planted for fishing needs is at least 50 cm across the country. All sea-migratory trout stocks are critically endangered, and inland populations south of the Arctic Circle are critically endangered. Inland trout populations north of the Arctic Circle are under special observation related to be endangered [(5)] (Kalahavainnot Luke, 2022). There is no general minimum size limit for trout in Sweden, but its regulations vary depending on which part of the country it is about [(6)] (Blomkvist, 2022). There have been major harmful changes in the habitat of brown trout due to human activities such as drainage, logging, forest fertilization, etc.

This report creates an overview of the cultural significance of brown trout and the societal and political discussion about it based on literature, interviews, writing collections and surveys. Attention is drawn to the special features of the brown trout in fishing culture and what its significance has been over time. In addition, we will find out what kind of changes have been observed in the fishing sites of the brown trout and consider the tourism opportunities offered by the brown trout. Fisheries policy decisions play a significant part in how the catch of brown trout will be allowed or restricted in the future. In the report, there will be discussion about fishing policy issues related to the catch of the brown trout.

3.3. Material and Methods

The target groups of the study consisted of people who are influential in fishing in a wide range of ways. The respondents represented, among other things, active recreational fishermen, professional fishermen, researchers, and people from fishing cooperatives. The collection of writings about brown trout fishing was targeted for anyone interested in the topic mainly in the northern parts of Finland. An active effort was made to search for people with local knowledge and an interest in fishing and catching brown trout. The material was collected from both Finland and Sweden. The material was collected between 2020 and spring 2022. The data collection methods and the number of respondents is defined more detail below, figure 16.

Interviews

A total of 12 semi-structured interviews were conducted in Finland. The interviews were conducted either by phone or Teams. Representatives of Lapland's fishing areas, recreational fishermen, researchers, and professional fishermen were selected to be interviewed. The main criterion was the activity of one's own fishing activity and interest in the discussion related to the brown trout. Thus, with their own experiences and observations, the respondents can contribute to mapping the past and present situation of the brown trout. The interviews were conducted between 2020 and the beginning of 2022. Interview guide, appendix 1.

A total of 51 structured interviews were conducted in Sweden. The interviews were conducted by telephone on the basis of a questionnaire, appendix 1. The interviewees had the opportunity to elaborate on their answers if they wished. The interviewees were selected based on local knowledge, who were known to fish in different areas. In turn, the snowball sampling, was made so that the interviewees were asked about other possible interviewees who might have knowledge and experience in catching brown trout. The interviews were conducted between November 2021 and January 2022.

Surveys

In Sweden, in addition to interviews, data collection was carried out using an online survey. The Facebook page of the provincial government had a link to the survey. The questions were open-ended, in which the respondents could write freely. The questions in this survey were not as comprehensive compared to the telephone interviews conducted in Sweden. The number of respondents to participate in a survey were 21.

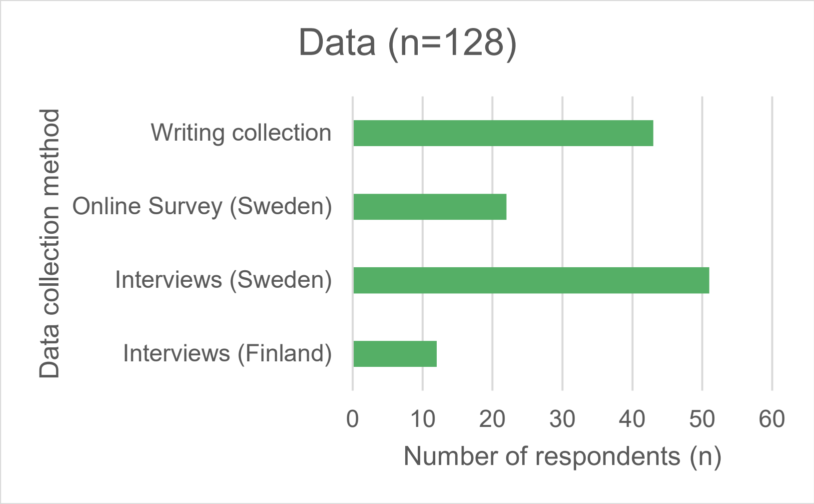

Figure 16. The data consists of four separate collection methods. In writing collection, there were respondents from both Sweden and Finland.

Writing collection

There was an announcement about the writing collection in about 20 regional and local newspapers in different parts of Northern Finland. In addition to that, the writing collection was also announced in a few Finnish fishing magazines. In the announcement, those interested in the topic were asked to tell, for example, their experiences of fishing for brown trout and the importance of brown trout in their fishing tradition, figure 17. In addition to this, the announcement asked for information on whether there has been a change in the water bodies where brown trout has previously been caught, as well as opinions on the current legislation and cultural change regarding brown trout fishing. The writings were collected during spring 2020 and a total of 43 of them arrived.

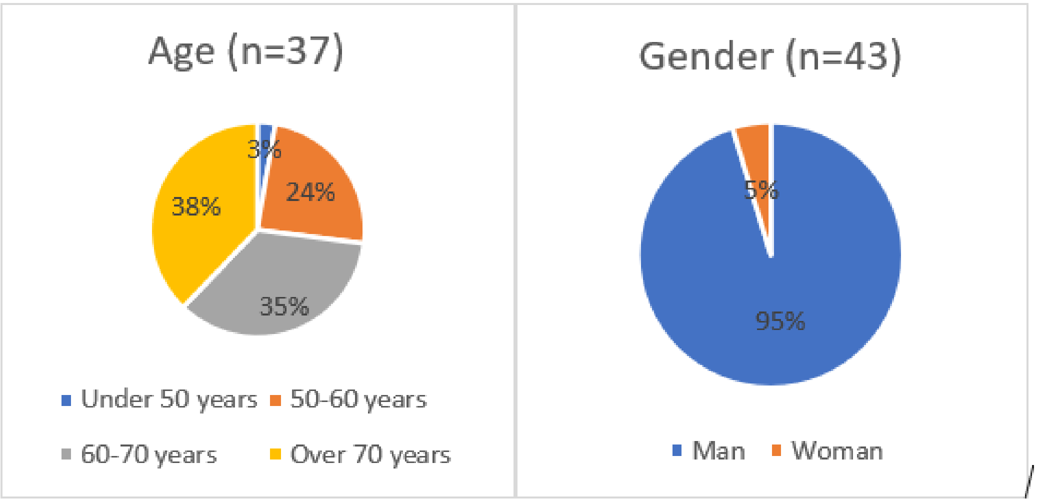

Figure 17. Most of the respondents in the writing collection were over 50 years old and male. The chart describes the age and gender distribution of the other data as well.

3.4. Results

The importance of brown trout in the food tradition and cultural heritage of the northern people in the settlement history has not been studied earlier. In addition to this, the interpretation of its biological meaning is challenging, and it is partly wrongly interpreted as a juvenile trout. For this reason, an overview from a cultural research perspective based on interviews, surveys and literature was created for the project. With the help of the data, the aim is to get an idea of the value of the brown trout - Is it an experience, food or a natural site in need of protection? What brings the angler to the brown trout stream at a time when e.g., salmon also rise in the rivers of the north?

Importance for the northern culture

For the northern fishing culture, the fishing for brown trout has had different dimensions. Fishing of brown trout is part of the northern culture and has traditions and customs, although no legal basis has been recognized for it. It is considered culturally valuable, and many see it desirable to preserve its form and method of fishing even in the future, even though the sections of the fishing legislation make it difficult to engage in the practice of fishing. Brown trout fishing has had the same spiritual significance as reindeer herding in people's everyday lives. It has not necessarily been considered a hobby, but it has been a part of life and a big part of the dinner table. In addition to fishing for household needs, stories and mysticism are associated with the brown trout, which are connected to its difficult fishability. Several fascinating things are evident in its fishing culture. It can be compared, for example, to catching a fowl, because it requires similar kind of vigilance.

For many of the respondents, brown trout fishing and angling have been related to childhood, and they have been a way to get to know nature, figure 18. When a child or a young person first fish a brown trout and learns to catch a timid fish, the young person is able to understand the nature of migratory fish as brown trout and the skill of catching them. The respondents regard that in terms of the preservation of the culture, it would be important for children to be able to learn brown trout fishing. In the past, many young people used to go along the forests and stream banks in the summer to fish brown trout, but it is believed to be on the wane these days. Today, some who visit the streams say that catches are not as important as they used to be. Experiences are sought out along the streams and childhood fishing trips are remembered. The next generation is taken along on these trips and in a way the brown trout culture and tradition is to some extent still passed on.

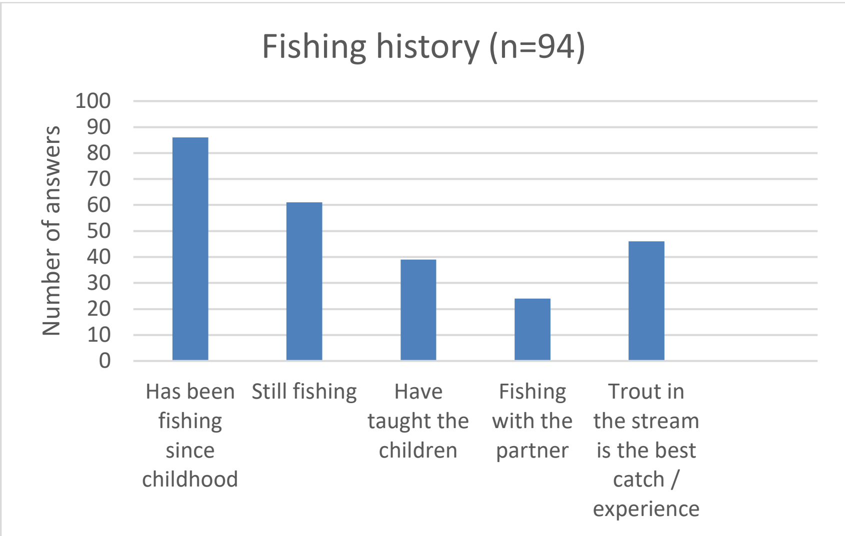

Figure 18. Most of the respondents have been fishing brown trout since childhood.

In the 1950s and 1960s, a lot of hay was made in riverside meadows. Fishing was also part of the haymaking culture practiced at swamps and forests. There were also hay barns in the places surrounding brown trout brooks. Many respondents described how during the breaks in the hay work brown trout and other fish were caught as a food fish, which was a significant addition to the diet of the fish catching from the ditches. The brown trout culture is a kind of hidden culture. It's an old way and it's practiced, but it's not talked about very openly these days due to restrictions in legislation. It is important to many people, but the brown trout is fished without attracting any attention.

On the other hand, in the interviews, many people thought that the catch and existence of brown trout has decreased significantly. It is affected by several things, such as the difficulty to interpret Finnish legislation, which is explained in the legislation section. Some people find it worrying that children cannot fish for brown trout if they were law-abiding. Then it is not possible to keep culture alive as it is forbidden. It is believed that young people still enjoy fishing, but a certain type of fishing with mosquitos, in wet swamps and dense streamside places is not necessarily the most attractive form of fishing.

The brown trout is considered one of the best fish for its taste. Pan-fried, stick fish or salted fish are typical ways of brown trout has been prepared as food. It used to be a summertime food. When there were no freezers, the most typical way was to make salted fish. The traditional way to prepare brown trout is to stick fish in the fire immediately after catching it in the stream.

” When brown trout is put on a stick, it was well cooked because the skin protected it and it didn't burn. I gutted it so that a small incision is made on the side of the stomach so that the intestine goes across. Then the gill cover so that all the guts are pulled out. That stick is put from the fish's mouth through the whole body and poked up to the tail as a spike. That stick is whittled flat, not round. As a flathead, the fish does not start spinning on the stick. Cuts on the side, small grooves, where salt was put, and a stick just set through.

Man 60 years. (Finland)

Figure 19. Frying brown trout on a stick over a campfire has been one traditional way of preparing fish for eating. Photo: Esa Inkilä

Catching of brown trout

The brown trout fishing is considered to be a world of its own and a form of fishing. It is a form of fishing where people get closer to nature and learn to understand it. The brown trout fishing is very challenging, and it is demanding to get the fish up, but learning it is also really rewarding.

The brown trout prefer cool, clear and nutrient-poor waters. The oxygen content of the waters is more than 5.5 milligrams per liter (mg/l). In addition to sufficient water quality, the natural life cycle of brown trout requires good spawning and young areas. The route should be unobstructed from the feeding area in the sea or lake to the spawning area in the river. The brown trout also spawn in small rivers and streams, where sea and lake salmon do not come up. Local brown trout inhabit the smallest streams, streams and headwaters of rivers. In the north, especially in the fell area, there are also many small lakes where local brown trout live. They spawn in streams connected to small lakes. Clean, gravelly northern rivers are suitable for the brown trout spawning. It is important for the spawning area that there are areas that are suitable for each juvenile stage in terms of currents, shelters and food [(3)]. (Salminen & Böhling, 2019, p. 314)

According to an old belief, when the salmon flower, that is the marsh-marigold, begins to bloom, the brown trout season begins. The brown trout fishing is special and mysterious. It requires, among other things, caution, sneaking and patience, because as a fish it is very timid. The fisherman must not give any sign of himself, and it is not appropriate to wear colorful clothes. Just a shadow on the surface of the water can scare the brown trout. You must hide behind the willow and fish from there. The respondents emphasized that foot stomping and other unnatural noises frighten the fish. Stream side is a place of relaxation. For many people, catching brown trout is really fascinating, because it is taken very quickly, and it is immediately caught if the brown trout is hungry. Worm-fishing has been a very traditional way of catching brown trout but using worm bait in fishing brown trout and salmon in general has sparked debate for and against. In Finland, angling with worm bait is prohibited in the rapids and currents of water bodies containing salmon and whitefish while in Sweden the use of worm bait is allowed. Therefore, traditional fishing with a worm bait is prohibited in Finland, which does not support the traditions of brown trout fishing.

” It’s such a fairytale feeling when a little boy starts to think about it. Then, when you are really somewhere in an exotic, treeless fell of Northern Lapland and there is a small, beautiful, slow-flowing stream that is deep and you can't even see there, and from there you carefully start to land a small fly baited very gently from a distance. Suddenly a speckled brown trout catches, so it's at that stage, in that context, the fulfillment of that background dreaming and glowing, when it happens there. They were great experiences then and I still remember them.”

Man 58 years. (Finland)

The streams of brown trout are part of local history. The brown trout sites are often kept private and guarded in the same way as cloudberry sites. You don't tell others about good places, unless you happen to be on the same stream banks at the same time as another fisherman. There is something wild and free-thinking about brown trout fishing, and you wouldn't believe that very small streams can yield good-sized brown trout.

Figure 20. To the stream must be approached carefully so that brown trout does not startle. Photo: Erkki Jokikokko

Changes in water bodies

River damming, dredging and other activities related to water bodies often have a debilitating effect on spawning and brood areas as well as hiking connections. In addition to that, the nutrient and solid load caused by especially by forestry but also agriculture has weakened the condition of streams typical for brown trout and made them an unsuitable habitat. Excessive fishing has also influenced the decline of brown trout stocks. The brown trout populations that live locally in small streams have also decreased due to various reasons such as forest drainage, eutrophication, pollution, and fishing [(3)] (Salminen & Böhling, 2019, p. 313-314). In surveys and interviews, the effects of forestry and drainages on water bodies and its consequences on the reduction or even disappearance of brown trout populations were mentioned several times. However, there were only few mentions of overfishing when it came to small streams.

“About 90 percent of the brown trout waters have been ruined by drainage, there has been a lot of it. Such a stream, where there were a lot of those little brown trout, was a meter wide, a meter deep, there were plenty of fish. Now that there is ten centimeters of water and a meter wide and the sand is completely flat, there is no place to hide, now it is easy for the otter to catch fish, and then the second thing is that those spawning places disappear, the bottom becomes a smoothly slurry so there are fewer a good spawning places.”

Man 74 years. (Finland)

In general, the cause and threat factor of the endangerment of species in endangered aquatic habitats is water construction. In addition to the direct digging, damming, and bank embankments of the water environment, water construction refers to the strong land use changes that take place in the catchment and drainage areas of lakes, which can have an impact on the hydrology of water bodies, figure 21. Chemical adverse effects are, like water construction, the most significant threat factors. Among the chemical adverse effects, the most significant are the nutrient load that makes the waters eutrophic and various types of pollution. Drainage and peat extraction also have their effects as a cause of endangered species in aquatic habitats. In addition to these, the effects of alien species, forest renewal and management measures, overgrowth and construction have been mentioned as causes and threats (7) (Hyvärinen, Juslén, Kemppainen, Uddström, & Liukko, 2019, p. 64-65).

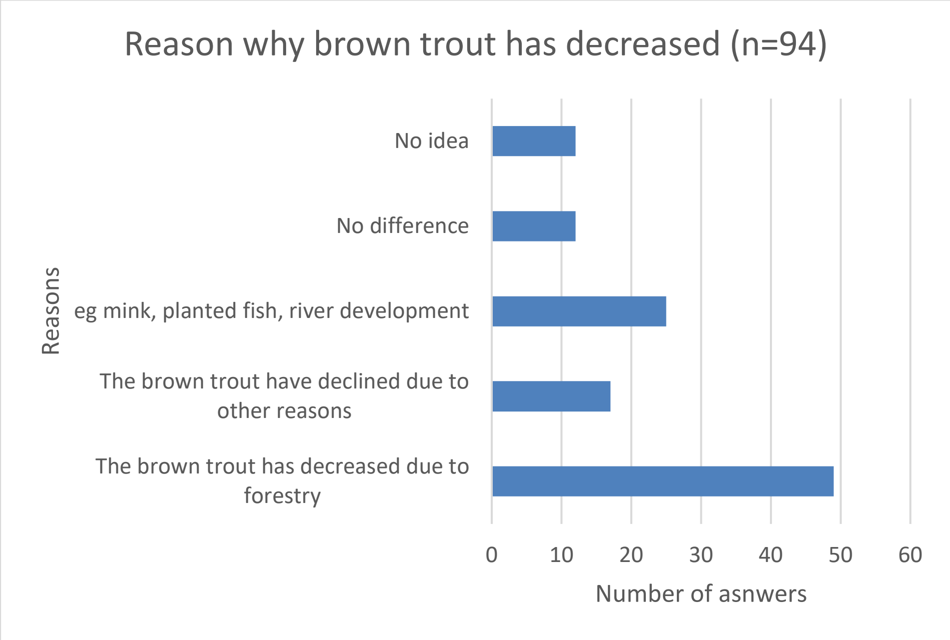

Figure 21. The diagram is showing that digging of forests and swamps was considered the main reason of significant ruin of brown trout streams.

Alien species are considered to have an impact on brown trout populations. Especially on the Swedish side, many interviewees felt that mink has had a great impact. It has been considered that the mink has had a negative impact not only on the brown trout but also on the arctic char, because it is easy for the mink to prey on fish from the backwater, where they gather in the winter (4) (Helander-Renvall & Markkula, 2011, p. 25). In addition to mink, the otter is considered to influence the number of fish stocks, which was evident from the interviews. At least small carnivore hunting might effect on fish stocks as well.

Respondents also mentioned other random factors are, for example, exceptionally dry years that strongly affect the height of the water level. Climate warming can endanger the survival of species that live in cold and cool waters, such as many salmon fish and northern aquatic insects. The decrease in water volume and flow has a weakening effect on the brown trout habitat. The culverts used in road underpasses may be so high in some places that the brown trout cannot climb them. In some places, stone paths have been made at the points of the culverts, so that the fish can get up to the culvert and from there under the road.

Matters related to land use are particularly emphasized further south, but not so much in the very north. Of course, in the Finnish regions of Ostrobothnia, Northern Ostrobothnia and southern Lapland, land use affects headwaters and tributaries. Whether it is peat removal, forest drainage, agriculture or anything related to land use, it has an effect and has probably changed the state of water bodies. As the amount of humus increases, roaches and perches take over such water bodies. They do not spawn on for gravel bases in the same way as brown trout, although that is not the cause, but rather a consequence of the changes in the water system. The pike also thrives better in muddy waters, whose proliferation has taken away the living space from the brown trout as they eat them. According to interviewee, should try to look at things broadly and see what is causing the decrease in fish stocks. Not all water bodies can be categorized according to the same model, but the differences can be very local.

The possibilities of tourism

As a tourism product, brown trout fishing is not seen as very desirable. However, some pointed out that as a tourism product it would be totally dependent on a guide specialized in the fishing brown trout as it is so hard to find and catch. Thus, it would provide employment and by combining it with stories, it would be a good product. The importance of nature tourism has grown globally, and in addition, as a tourism country, the Arctic is profiled more and more as a producer of cultural and nature tourism services, and fishing tourism is a significant form of nature tourism [(8)] (Mäki-Petäys, Louhi, Orell & Karjalainen, 2014, p. 50). In general, from the point of view of the development of fishing tourism, it is essential that local operators have a sufficient understanding of the development goals of river and sea tourism. If the productization of the services were left to external consultants, it could bring new and unfamiliar practices to the locality. At worst, such a development could threaten, for example, the cultural work carried out by the locals, which has been built and changed along with nature and local customs and experiences. From the point of view of tourism, it is important to maintain and renovate old fishing culture sites, but it is equally important to mold culture to meet the needs of today. Here is also the practical and conceptual opportunity offered by cultural ecosystem services. Ecosystem service refers to free, tangible and intangible services for humans produced by the ecosystem [(9)] (Eskelinen, Seppänen, Forsman, Hiedanpää, Mellanoura, Mäkinen & Salmi, 2013, p. 16-17).

Brown trout fishing is considered an experience worth experiencing, but production any case it cannot become a safari-like mass tourism product as it would lose its attractiveness. The small streams and their stems would not necessarily be able to withstand the strain that large numbers of tourists would bring there. However, some of the interviewees believed that there would be a demand for streams of brown trout and small water bodies among tourists. If the fish stock is vibrant and abundant, it is not believed to be suffered by small numbers of tourists. Brown trout fishing is a different nature experience, and it requires a different attitude from the tourist as well.

“Man gets closer to nature and learns to understand nature. Not the kind of people who spend money on sledge safaris and salmon rowing, which I have also offered to my guests. It's not a nature experience. It's not really that. Maybe it has the excitement of a big fish, but that's about it.”

Man 65 years. (Finland)

Brown trout fishing is considered more important to the locals, and not so significant from a tourism point of view. It is related to the mentality important for the locals, so they can visit and go to brooks, but at the same time respect the number of fish stocks. It would be better for tourists to go fishing in larger waters than smaller streams, but then action is not anymore brown trout fishing. Travelers are often willing to pay for a well-productized service. The exoticism of brown trout and its challenging fishing could appeal to tourists. With the guide's help and stories, the brown trout might be an interesting enough fish.

As a small-scale tourism product, it is believed that the brown trout has a potential that is a little more remote than that of tourists. Under no circumstances can it be the subject of mass tourism for any large-scale activity. In a limited destination and in connection with some other tourist attraction, it could be imagined to some extent as possible. The brown trout fishing could serve the tourist destination's services and its supply. It could not be the case that all regions and all operators have free hands to create a tourism product from the brown trout. It would not be ethically right, and it doesn't make any sense in the name of biological carrying capacity.

Figure 22. According to one interviewee, brown trout is the most beautiful fish in the world. Photo: Esa Inkilä

However, if brown trout fishing it is marketed as a tourism product the present legislation needs to be changed. In any case, developing a tourism product is questionable in any case as it might not be a sustainable solution in terms of fish stocks.

Legislation

The current Finnish legislation is considered difficult, and during the current law it is considered almost impossible to practice traditional brown trout fishing in Finland. Even today, those who have still been fishing brown trout say that the laws and their interpretations have made this tradition difficult and destroyed the fine brown trout fishing, figure 23.

There is no general minimum size limit for trout, but it varies depending on which part of the country it is about. In rivers with migratory sea trout there is a minimum size-limit of 50 cm in most rivers, except Norrbotten, but on the west coast, where the trout are smaller, it can be 40 or 45 cm. In the county of Norrbotten, there is a slot-size-limit and bag-limit in the sea trout rivers, where it is possible to keep one trout per day between 30-45 cm. This regulation aims to protect small and growing fish and adult mature sea trout, while legislation allow a limited trout harvest of trout that to a high degree would be of a stationary form. In waters that are considered to not be connected to the sea trout/salmon rivers do not have general size regulations but only local regulations. In the Norrbotten mountain area have a general minimum size limit of 35 cm for trout, but there are also areas with slot-size limits similar to the sea trout rivers. Sveaskog also has a minimum size limit of 35 cm in its waters which are not connected with sea trout rivers [(6)]. (Blomkvist, 2022.)

In Finland, according to paragraph 15 of the fisheries regulation, trout stocks intended for fishing that are at least one year old must be marked by cutting off the adipose fin. This allows fish to be saved to be identified and released. Catching trout with adipose fin is prohibited in the entire sea area and inland waters south of 64°00'N latitude. Between latitudes 64°00'N and 67°00'N in inland waters, the minimum allowable catch size for trout with adipose fin is 60 centimeters, north of latitude 67°00'N 50 centimeters. This applies to all types of trout, including brown trout [(3)] (Salminen & Böhling, 2019, p. 231.) What specifically applies to the fishing of brown trout is the following sentence recorded in section 2 of the fishing regulation; If trout is caught from a stream or lake, which has no migration connection from the sea or bigger lakes, the catch size must not be more than 45 centimeters [(3)] (Salminen & Böhling, 2019, p. 231).

The migration connection and its definition and the definitions of the lack of migration connection are considered by the interviewees very vague. What does it mean that there is no migration connection from the stream or from the lake? Does the water not flow from there to somewhere? If the regional, environmental and fisheries authority or fisheries areas were to make a survey of all small streams and lakes, where there is a migration connection and where there would be a brown trout population, it would be quite a big project. Some interviewees see that the definition of a migration connection could also be waived if the water bodies for legal brown trout fishing were defined and mapped. And on the other hand, the mapping would show which are the waters that are potential for migrating trout. Then there would be no need to focus on defining the migration connection. However, the essential thing is to define the migration connection and what it really means if it is to remain in the fishing regulation.

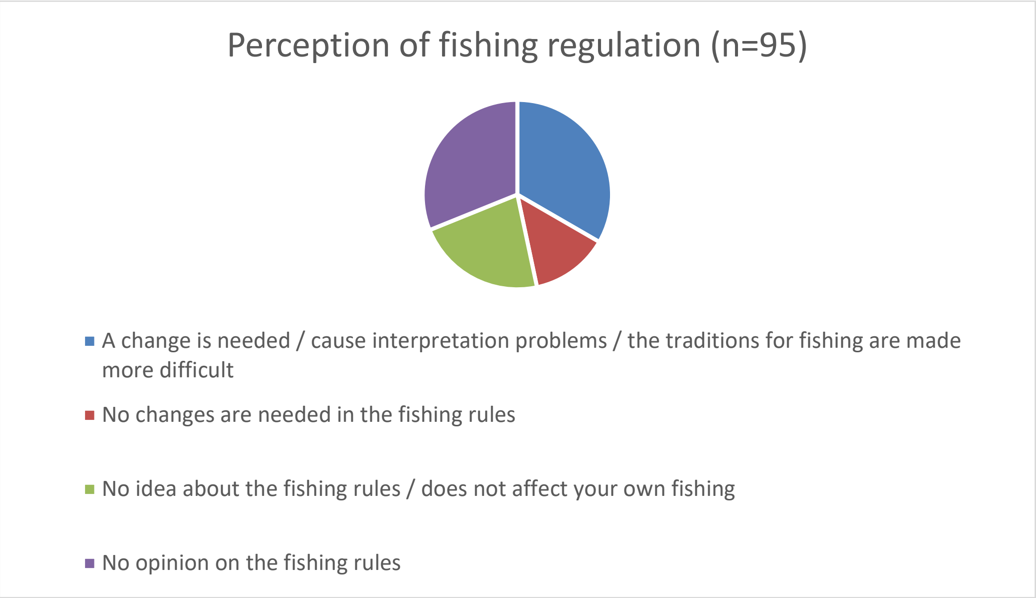

Figure 23. The diagram shows the perception of fishing regulation. Approximately a third want changes to the current fishing law related to brown trout.

The state of natural fish stocks, the lack of knowledge and understanding of recreational fishermen's views, as well as their low participation in decision-making has led to the need to find out the fishermen's views to an ever-increasing extent. The lack of information weakens the fisheries administration's ability to consider the needs of recreational fishermen. Area restrictions, time regulation, gear regulation and catch quotas are used in recreational fishing in general around the world. In the few countries where recreational fishermen can use a net, regulation is more effective than in Finland. In Sweden, several lakes have significantly stricter equipment, time, and area restrictions than in Finland. Fishermen's and local views should be considered in fisheries resource management plans, where goals can be set, for example, from the protection of critical areas in terms of migration and reproduction to the future use and management plans of fisheries areas. In those areas where fish stocks are critical, calming the entire waterways is one of the most important regulatory development targets [10] (Muje, Veistämö, Rautiainen & Syrjänen, 2019, p. 50, 62, 64).

In the interviews, various suggestions emerged on how the law should be changed. The suggestion of one of the interviewees is that the undersize should be dropped to 25 centimeters. It could be scaled by region. The upper size, on the other hand, aims to define that it is small-growing, eternally small, isolated brown trout. In contrast to this, the interviewee sees that an isolated population with no connection to a lake or the sea needs protection – differently that the present law prescribes. According to him, on the other hand, fishing for brown trout stocks in brooks and streams should be allowed, because even 10–15-centimeter fish are sexually mature. In general, it is thought that if it were possible to legally fish brown trout, there should be changes to the rules.

Some of those who responded to the surveys said that the legislation has not restricted some people's fishing of brown trout. On the other hand, some have started to think that now that brown trout fishing has become a crime, there is no longer a desire to go to the streams for brown trout fishing. Fishing control also came up. Fishing areas have important fishing spots that require closer supervision, and there might not be enough fishing inspectors for small streams. It would also require more resources from the fisheries control, if control is increased for small streams around Lapland. According to one of the interviewees, the brown trout fishing is more a matter of conscience when considering its legality at the moment.

There is no general prohibition in the legislation for natural baits for trout fishing in Sweden. However, there are many local regulations in this direction and for example in Norrbotten it is prohibited to fish with natural baits in rivers and streams in state owned waters in the mountain area which is the area that Länsstyrelsen manage. This area is very big and comprise about 50% of Norrbottens area. Also, Svea Skog which is the biggest landowner and fishing rights holder below the mountain area has a prohibition against natural baits in streams, so it is a very widespread regulation even if it is not in the general legislation. [6] (Blomkvist, 2022).

In fishing, legal interpretations and wording is decisive. Can something be done or not? In our data, brown trout fishing is thought of as a form of fishing that exists and should be defined in such a way that no one needs to be afraid when going brown trout fishing. In Finland, it has been specified that the use of worm bait in rapids and currents is prohibited. Worms have been one of the traditional baits when catching brown trout, and many think it is a shame that worms can no longer be legally used as bait. Angling with worm bait is prohibited in the rapids and currents of trout watercourses. Everyman's Rights therefore do not give the right to fish for brown trout or other salmon fish in streams and rapids with a worm. This has caused a lot of discussion. Many see it as a very good and important bait for brown trout, although fly-fishing and other baits are of course used as well.

The future of brown trout fishing culture

Of course, nature itself and the brown trout do not need humans. According to data, the brown trout fishing culture is starting to disappear with the current legal regulations quite definitely, even if many local people in north want to keep its fishing techniques and skills alive. Along with the legislation, concentration on migratory fish has been seen as causing threat for brown trout fishing. Migratory fish are, as it were, the denominator of everything when discussing the vitality of fish stocks and what their habitat condition is like. Local issues, customs and traditions are seen as being forgotten when fishing legislation is made. Many respondents claim that the local voice has not been heard.

As a means of sharing fishermen's knowledge based on experience and the accessibility of research information, the Internet serves as an important component. Public campaigns promoting sustainable fishing have apparently increased fishermen's awareness of the state of fish stocks. In general, the hobby of fishing is considered to have been in decline since the 1990s, but it is still quite strong and alive. Can the significant positive attitude of fishermen towards measures supporting the sustainability of fish stocks be shown by the recent change in fishing culture, where the importance of the catch has decreased and at the same time the quality of water bodies and fish stocks are becoming more important? Regulation that takes fishermen's views into account better than at present could significantly support the natural cycle of endangered species and strengthen the sustainability of the fishing industry on a large scale [10] (Muje, Veistämö, Rautiainen & Syrjänen, 2019, p. 64).

The use of local knowledge in stream restoration is regarded necessary. The primary starting point in the planning of fishing management is the provisions of the Fisheries Act and Regulation. If they are not sufficient from the point of view of the brown trout stock to be managed, the fisheries area can include regional regulations in its use and management plan proposal. They can concern, for example, fishing gear, fishing times, fishing areas or catch measure [3] (Salminen & Böhling, 2019, p. 231). In Finland, the government has drawn up a fishway strategy, the purpose of which is to protect native and endangered migratory fish stocks. In addition, necessary measures are taken to protect migratory fish stocks. These include, for example, restoration of fish and natural resources in rivers. The goal of the strategy is to promote the efficiency goals of the fishery in order to preserve our fish stocks and ensure sustainable use [11]. (Kansallinen kalatiestrategia, 2012.) Many of the interviewees hoped that such streams would be planned, rehabilitated and built for the brown trout. Many brooks have become incapable of surviving for brown trout for various reasons. For example, suitable hiding and spawning places for brown trout should be renovated in the streams.

Today, the diverse range of hobbies may also affect how eagerly children and young people find streams. First, they would have to find their way into nature and get enjoyable experiences. It often happens that if parents' fish, then the next generation learns through it. According to one of the interviewees, children and young people have hardly been seen fishing along the streams, and the future of the brown trout fishing culture is not very bright. If you cannot do it as a child, then it does not exist as a whole culture, says one interviewee.

” I have not seen children or young people fishing here. Brown trout anglers are endangered species. It either charms or it doesn't't”.

Man, 65 years. (Finland)

Brown trout lives usually in small wilderness streams, and that diverse nature shows itself in a completely different way compared to, for example, rowing on Tornio River in the middle of agricultural landscape. Introducing young people to nature brings adventurous experiences. One interviewee wonders if catching small brown trout is the right way to get to know nature and learn brown trout fishing. If it were allowed to catch young and small fish that may migrate to the river or sea, would it be in any way reasonable and ethically acceptable?

Today, for example, in Eastern part of Finnish Lapland, in the area of Savukoski municipality, river fishing is focused on recreational fishing. Household fishing is of course still practiced, but fish catch no longer plays such an important role in making a living. From this it can be concluded that fishing has taken on the role of people's leisure time hobby instead of work [12]. (Välikangas, 2014a.) However, when thinking about brown trout fishing, it would be important to know that the locals have the right to go and catch brown trout, even if it is not important for household fishing. For many, it has been a tradition and a custom that they hope will be preserved.

3.5. Discussion

Brown trout fishing has traditionally been an important activity in the northern parts of Finland and Sweden. Our data shows that it is still part of the fishing habits of local fishermen – and also of some fisherwomen. Brown trout is appreciated as a good-tasting fish but even more important is that catching it requires a lot of skills and experience of reading nature. Many of the respondents in our data have learned to fish brown trout in their youth and they are teaching the skill to their children and grandchildren. What is especially emphasized is the relationship to nature and the valuable experience of being in nature in bright summer nights while the catch does not seem to be so important.

Changes both in natural conditions and fishing culture cause worries among northern fishermen. Especially forestry is referred to as a cause of deterioration of brown trout streams but also alien species and other changes in nature are discussed. In fishing culture, the emergence of ‘catch and release’ fishing divides the opinions. Some see it as a good change in culture but on the other hand there are really strong opinions against that kind of fishing.

Inconsistency between legislation and local customs causes an experience of injustice and makes people to act against the law – especially as controlling the fishing activities in small and remote brooks is very difficult or even impossible. The situation is similar to that which Hiedanpää (2013) refers in his analysis of institutional misfit in relation to Finnish wolf policies: local communities continue to encourage certain codes of conduct that are not the most honorable or law-abiding, but which are expected to safeguard the continuity of rural life. Many Finnish respondents in our data demand changes to the Fishing Act.

In brown trout fishing, it would be good to put common resources into mapping the situation and planning operations. It is a question of small water bodies and small fish stocks. The main numbers in the fish stocks are nowhere big. Wrong decisions and actions can easily cause irreparable and priceless damages. According to data the law interpretations and forms of law related to fishing can mean a lot and are in a decisive position and it needs to be done. Cultures and traditions are valuable and should be cherished – similarly to this traditional and emotionally-provoking fish, brown trout. Deep consideration and background work are needed, whatever is planned to do with brown trout issue. Whether it is changing legislative entries, developing tourism, promoting local people's fishing opportunities or the culture of brown trout fishing.

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4. Genetic analysis of trout and grayling in Finland and Sweden

Authors: Andreas Broman, County Administration Board Norrbotten, Ari Huusko Luonnonvarakeskus,Tuomas Leinonen (LUKE).

4.1. Summary

Grayling (Thymallus thymallus)
In this study grayling samples from 26 locations in the river systems of Luleälven, Kemijoki, Kalixälven, Oulankajoki, Iijoki, Juutanajoki and Olanga were analyzed. Populations in River Kalixälven, where there are no hydroelectric dams or other artificial migration barriers, showed closer relation to each other than grayling populations in the regulated rivers Luleälven and Kemijoki. Grayling populations in River Luleälven specifically showed signs of genetic isolation. This might be an effect of hydropower dams and the regulation of the river. Measures to decrease the impact on population genetics should be considered when new permits are to be decided.

Brown Trout *(Salmo trutta)*
Brown trout samples from over 60 tributary streams locating in regulated River Kemijoki and River Luleälven, and free-flowing River Tornionjoki and River Kalixälven basins were used for the analysis of brown trout length by age and maturity by length and genetic diversity and differentiation of the populations in the river basins. The results revealed that brown trout in tributaries in the regulated rivers showed typical growth patterns and maturing schedule of stream-resident brown trout populations observed elsewhere. Genetic analyses of brown trout populations in tributary streams of the regulated River Kemijoki and River Luleå basins indicated that signs of sea- or lake-migrating brown trout forms in the genotypes of tributary stream populations were largely missing compared to the observations of the free-flowing river, such as River Tornionjoki basin. The closure of the main river by dams highlights the distribution and genetic diversity of local brown trout populations, either resident or fluvial form, that are still prevailing in the catchment.

4.2. Introduction

The hydropower dams in River Luleå lack fish passages and the situation is similar in River Kemijoki except that there is a fishway in the Isohaara power station located nearest to the sea (Bothnian Bay). Dams have prevented fish from migrating in the river systems since they were built. Especially brown trout populations have thus been isolated from each other and gene flow between sea migrating and local fish has stopped. Isolation of populations can lead to a genetic depression and inbreeding. To see if that was the case in River Luleå and River Kemijoki systems, genetic samples were taken from brown trout and grayling populations from different parts of the catchment areas. The genetic diversity of populations from River Luleå and River Kemijoki was then compared within both river systems and also with populations that are free to migrate in River Kalix and River Tornionjoki systems.

The evaluation of the genetic status in brown trout and grayling populations in River Luleå and River Kemijoki systems will increase the knowledge about the genetic processes in the case of longtime isolation of populations. The aim of the genetic study was to compile a comprehensive genetic map of local brown trout populations and thus try to define the rivers and streams with local and/or migrating brown trout populations. This knowledge is very valuable when managing fish populations, to safeguard young migratory brown trout on one hand and on the other hand allowing traditional fishing of local brown trout in areas without migration (see chapter 3 of this report). The results can also be used to enhance future stocking methods and see if previous stocking practices have caused some undesirable effects to existing brown trout populations.

4.3. Material and Methods

Grayling *(Thymallus thymallus)*

Places to sample fish were chosen based on previous knowledge of grayling. In Luleälven river system sampling sites with good connectivity to main river channels were chosen. To get as wide selection as possible, both places with possible migration between populations and places with isolated populations due to dams were chosen (figure 24).

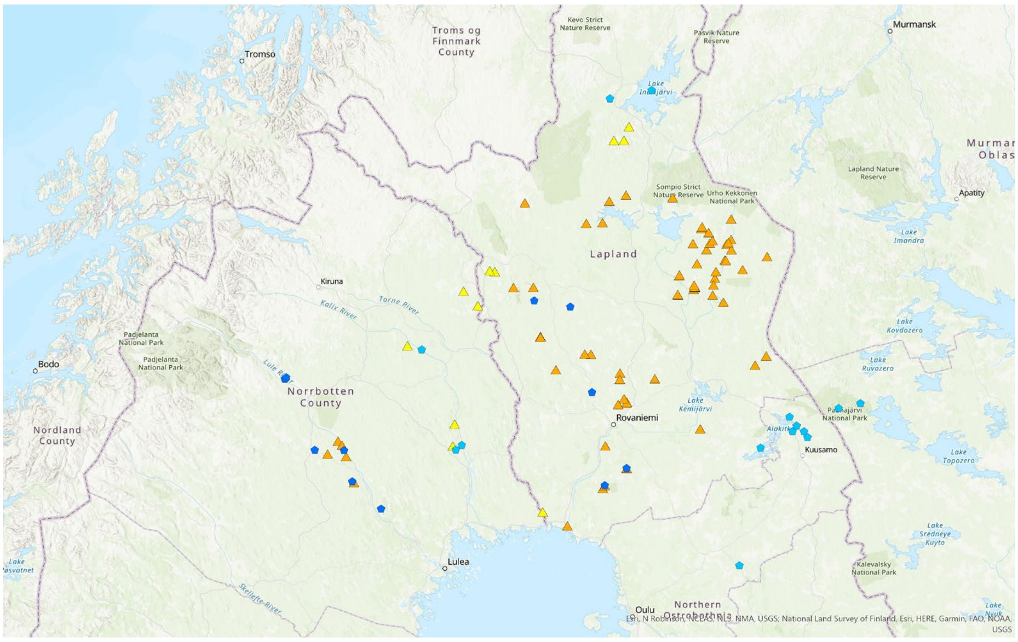

Figure 24. Map of sample and reference sites. Dark blue pentagons show sampling sites for grayling. Light blue pentagons show reference sites for grayling. Orange triangles show sampling sites for trout. Yellow triangles show reference sites for trout.

Grayling was also sampled in Kalixälven river systems to be used as reference material from rivers without hydropower dams. Sample sites in these river systems had a good connectivity to the main river channels and populations were free to migrate to the sea forming thus a baseline to sea trout genetics (triangles in figure 24). Old scale samples from Iijoki and Oulankajoki river systems and Lake Inari basin were also analyzed in the laboratory as reference material.

In Kemijoki river system sampling was made on as large area as possible. However, the main focus was on brown trout sampling, and grayling samples were taken when it turned out that a grayling population was dwelling in the headwater stream. Thus, grayling samples were caught without any prescience more or less by accident. The analyzed samples originated from the tributaries flowing into the lower and middle reach of River Kemijoki, and River Ounasjoki system, figure 24.

Fish were caught with electric fishing or by fishing with rod. The tip of pectoral fin or the whole fin was taken for a genetic sample and either preserved in ethanol and individually stored in Eppendorf test tube or they were put in paper scale bags and preserved dry. When fish were handled in Sweden scales for age determination were taken and the length of fish was measured and after that they were released. In Finnish sampling fish caught with rod were exterminated and released if electrofishing was used. When fish were released, the scales were taken, and the length was measured and for exterminated fish also weight in grams, sex and maturity (Kesteven) was documented. Scale samples from Iijoki and Oulankajoki river systems were preserved in paper scale bags.

Genetic analyzes of grayling were made by SLU in Umeå. Methods for extraction of genetic material and analyzes of the grayling genetics are described in a separate reports from SLU that are included as an appendix to this report (appendix 2).

Brown trout *(Salmo trutta)*

Brown trout were sampled in as large area as possible in the river Kemijoki basin. In addition to the known brown trout streams, sampling places were identified based on map surveys and on fishermen interviews. The aim was to collect brown trout samples from headwater tributary streams flowing into the main channel of River Kemijoki and its largest headwater river basins (River Ounasjoki, Raudanjoki, Kitinen, Luiro and Kemihaara basins), figure 24, see also See figure 1 in the appendix 3 for detailed distribution of the basins and streams). Number of streams sampled was 50.

In River Luleå basin brown trout sampling sites with good connectivity to main river channels were chosen. To get as wide a selection as possible, both places with possible migration between populations and places with isolated populations due to dams were selected (figure 24). Number of sampled streams was five.

Brown trout were also sampled in River Kalixälven and River Tornionjoki basins to be used as reference material from rivers without hydropower dams. Sampled headwater tributary streams in these river systems have a good connectivity to the main river channels and populations were free to migrate to the main river channel and further to sea, figure 24. Number of sampled streams from River Tornionjoki basin was five and from River Kalix basin three.

In total, 2008 brown trout samples, of which 1639 were caught with electrofishing and 369 with rod and line fishing, were collected from headwater tributary streams of River Kemijoki, Tornionjoki, Kalix and Luleå basins. Rod and line fishing was applied only in the river Kemijoki basin. In addition, samples of brown trout (sea-migrating populations) ascending to spawn in River Tornionjoki (46 individuals) and River Kemijoki (34 individuals) were provided for the genetic analyses by the sea-migrating brown trout monitoring projects of these rivers (projects managed by Luke and Lohijokitiimi ry, Keminmaa Finland). Furthermore, for comparison to the core study area samples, 135 brown trout samples were included to the sample set from the river Kirakkajoki basin, flowing to the Lake Inari, a watershed flowing east into the Barents Sea.

The tip of pectoral or pelvic fin was taken for a genetic sample and either preserved in ethanol and individually stored in Eppendorf test tube or they were put in paper scale bags and preserved dry. When brown trout were handled in Sweden, scales for age determination were taken and the total length of fish (in mm) was measured and after that they were released. In the Finnish sampling, fish caught with rod and line were exterminated and their total length (in mm), weight (in grams), sex and maturity (Kesteven 1960) were documented, and a scale sample was taken. When using electrofishing, the catch was handled similarly to the sampling in Sweden. An overview of brown trout length by age and maturity by length was constructed based on either the whole data set (total length by age) or the samples collected by rod and line fishing in the river Kemijoki basin (maturity by total length/gender, samples from 15 streams).

Genetic analyses of brown trout were done in the genomics lab of Luke in Jokioinen using previously established methods (Tanhuanpää 2021). Methods for extraction of genetic material, statistical analyses, and results of the analyses are described in separate report included as appendix to this report (appendix 3). A total of 2255 brown trout were genotyped in 2022 for the analysis of genetic diversity and differentiation of the trout populations in the target river basins. Genotypes were obtained for 2244 samples. In addition, 350 brown trout samples from earlier genetic analyses done in the joint molecular genetic laboratory of the University of Helsinki and Luke were used in the analyses as reference samples. In total, 2594 brown trout samples genotyped at 16 microsatellite loci were used in the analyses. The samples comprised 17 groups: 9 river basins and 8 sets of reference samples (appendix 3).

4.4. Results

Grayling genetics

The populations River Kalixälven system all grouped together in same group. The genetic distances between Ängesån-Vinnäset and Vinnäset-Männikö were very low, while the distance between Ängesån-Männikö was larger, table 3.

Table 3. Genetic distances between populations in River Kalixälven.

Location	Kugerbacken	Manniko	Vinnaset	**DAPC group**
Ängesån		***	**	11
Mannikö	0,12		**	11
Vinnäset	0,07	0,04		11

Significance above diagonal. ***<0,001, **<0.01, *<0,05.

In River Luleälven Sarves-Ahppo and Skielt-Jokkmokk-Kouka grouped together (group 11 and 5 respectively), while Flarkån and Görjeån were alone in their groups. The genetic distances between the populations in Luleå River were in general greater than in Kalix River, with exceptions of Ahppo-Sarves and Jokkmokk-Kouka, table 4.

Table 4. Genetic distances between populations in River Luleälven.

Location	Flarkån	Gorjeån	Jokkmokk	Kuouka	Ahppo	Sarves	Skielta	**DAPC group**
Flarkån		***	***	***	***	***	***	13
Gorjeån	0,37		***	***	***	***	***	10
Jokkmokk	0,20	0,38		***	***	***	***	5
Kuouka	0,16	0,30	0,09		***	***	***	5
Ahppo	0,25	0,40	0,23	0,15		*	***	1
Sarves	0,23	0,37	0,22	0,14	0,02		***	1
Skielta	0,29	0,44	0,19	0,19	0,37	0,36		5

Significance above diagonal. ***<0,001, **<0.01, *<0,05.

In River Kemijoki only Marrakoski and Venejoki grouped together. The Korkimaanoja population grouped with coastal graylings even though the sampling location is high up in the river system, table 5.

Table 5. Genetic distances between populations in River Kemijoki.

Location	Konttijoki	Korkimaanoja	Marrakoski	Saukko-oja	Venejoki	DAPC group
Konttijoki		***	***	***	***	3
Korkimaanoja	0,20		***	***	***	14
Marrakoski	0,20	0,12		***	***	15
Saukko-oja	0,42	0,34	0,25		***	9
Venejoki	0,24	0,17	0,08	0,25		15

Significance above diagonal. ***<0,001, **<0.01, *<0,05.

Brown trout growth in length and maturity

Brown trout growth in length in headwater streams was slow in general and differed from the sea-migrating brown trout, which were clearly longer at the age of their maturity, i.e., when ascending from the sea to rivers for spawning (figure 25). Based on data from rod and line fishing samples, in the tributary stream populations in River Kemijoki catchment brown trout males reached the maturity on average at smaller size than females, the difference corresponding to 1-2 years' growth in length for females (figure 25). However, there seemed to be obvious stream-specific variation in the length at maturation especially among females, indicated by the length class distribution of mature females in the data pooled over several headwater streams, figure 25.

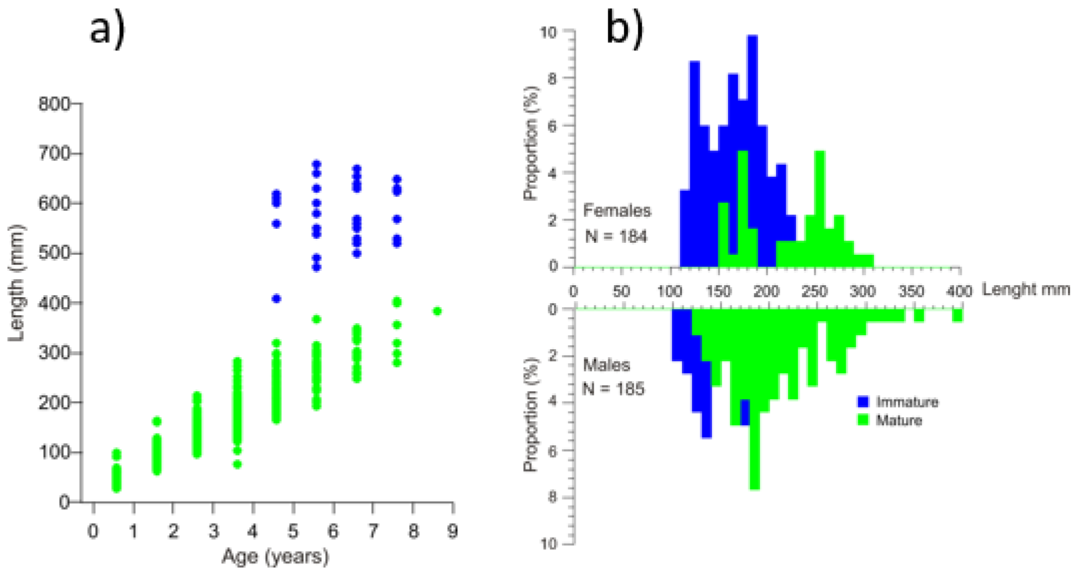

Figure 25. a) Total length at age of brown trout in the headwater tributary streams in the river basins of the EMRA project (N = 1836, green dots) and total length at age of sea-migrating brown trout in the River Tornionjoki and River Kemijoki (few samples from brown trout caught in the fishway at Isohaara power station) at their spawning run (N = 41, blue dots). b) Proportion of mature individuals of brown trout by total length in the samples collected by rod and line fishing in the tributary streams of River Kemijoki basin.

Brown trout genetics

In general, brown trout populations from the tributary streams closer to the Bothnian Bay were closer to the sea-migrating brown trout (reference populations of River Kemijoki, Iijoki and Tornionjoki) in their genotype than brown trout populations further from the sea, which shared a larger proportion of their genome with the resident brown trout (reference populations of River Kemihaara basin) (appendix 3). Comparison among river basins revealed four clear groups (appendix 3): samples of hatchery populations of adfluvial (lake-run) brown trout (Rautalampi water course and River Oulujoki water course) grouped together as did the Lake Inari (adfluvial brown trout, hacthery) and River Kirakkajoki basins' samples. They were clearly different from the samples of the river Kemijoki catchment, which were roughly divided into two groups, the samples from the northeastern river basins (River Kemihaara basin and River Kitinen-Luiro basin) and the samples from the other basins of the river Kemijoki catchment, including the sea-migrating brown trout references samples and Swedish river basins.

In most of the brown trout populations from the tributary streams the effective population sizes were small and under the bare minimum rule-of-thumb level for a population viable in short term (Ne > 50) (table 3 in appendix 3). The Ne's in the Swedish populations were higher than those in the Finnish streams. The relatedness was also relatively high in many of the sampled populations (table 3 in appendix 3), which is characteristic to small populations.

The number of sampled populations from the free-flowing River Tornionjoki and River Kalix basins was low (8 in total), and many of them represented very small headwater tributaries. Thus, the results should be interpreted with caution in relation the genetic structure of brown trout populations in the whole river basins. In both river basins, there were populations showing some mixing with the sea-migrating brown trout reference populations, while the rest of the sampling sites (populations) in small tributary streams – with a high proportion of siblings - appeared more distinct (appendix 3).

The river Kemijoki catchment was divided to five river basins and the genetic diversity and structure was analyzed accordingly (appendix 3). In all the river basins, there were clearly differentiated stream-specific populations but also highly mixed ones (appendix 3). In few tributary streams there was a clear distinction even between the upper and lower reaches of the stream although no barriers for movements between the stream sections existed, revealing existence of very localized populations. Compared to the other River Kemijoki basins, there appeared to be very little gene flow and mixing among the populations in headwater tributary streams flowing into the lower and middle reach of River Kemijoki. Contrary to this, the populations from the river Kemihaara basin, locating farthest from the sea, were less well defined and there was more indication of gene flow among populations than among the populations in the other river basins. In this basin, most of the samples clustered together with the river Kemihaara resident brown trout hatchery populations, suggesting an influence of the hatchery stock in the area. Alternatively, the hatchery population resembles the wild populations in the area, because the brood stock for the hatchery population is collected from the wild populations in the same river basin. In all, the headwater tributary populations in the River Kemijoki catchment did not show any strong mixing with the sea-migrating or lake-run forms of brown trout populations used as references. Only the stream Kuorajoki population, locating in River Kitinen-Luiro basin and flowing into Porttipahta reservoir, turned out to be influenced by the lake-run hatchery population from Lake Inari basin, which have been stocked in Porttipahta. However, no other brown trout populations in the tributary streams flowing into Porttipahta showed signs of a similar impact (appendix 3).

In the River Luleå basin brown trout populations in two streams (Görjeån and Kanibaäcken) indicated the existence of differentiated resident populations while the populations in Harrejaurebäcken, Messaurebäcken and Suoksijåhka appeared more mixed ones and were closer to the sea-migrating brown trout (reference population of River Tornionjoki) in their genotype (appendix 3). Unfortunately, there are no sea-migrating brown trout left in the River Luleå for a reference, to reveal whether the above mentioned three populations would have shown affinity to the original sea-migrating brown trout of the River Luleå.

4.5. Discussion

Grayling *(Thymallus thymallus)*
Even though the populations in River Kalixälven all grouped together there were genetic differences, table 3. The genetic distances between the populations can be correlated to the geographics (figure 26). The natural partial migration barrier in Jockfall might explanation why the genetical distance between Männikö-Ängesån is greater than between the other populations. Graylings from the populations in Ängesån and Vinnäset will have a hard time migrating up to Männikö (only a few graylings are counted yearly in the fish passage in Jockfall) while graylings from Männikö can swim down to Vinnäset with ease. Individualls that swim down to Vinnäset from Männikö will, by the same reason as above, have a hard time going back to Männikö and there is a high probability that these individuals mix with the Vinnäset population. Because of the geographic distance to Ängesån it is less likely that fish from Männikö will mix with the Ängeså population than with the Vinnäset population.

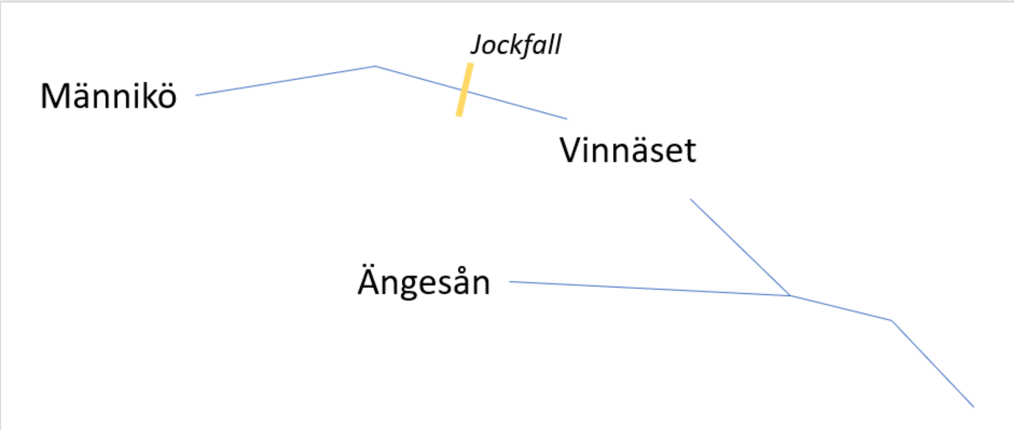

Figure 26. Schematic map of sample locations in River Kalixälven and connectivity between them. The partial migration barrier in Jockfall is marked with a yellow line.

The River Luleälven populations were clearly separated from all other populations (figure 27). Correlation to the geographics though could be seen and Ahppo and Sarves were very close genetically as they also are in geographic distance (figure 28). There are no migration barriers between these populations and both tributaries flow into Lake Stora Lulevattnet, only 6 kilometers apart.

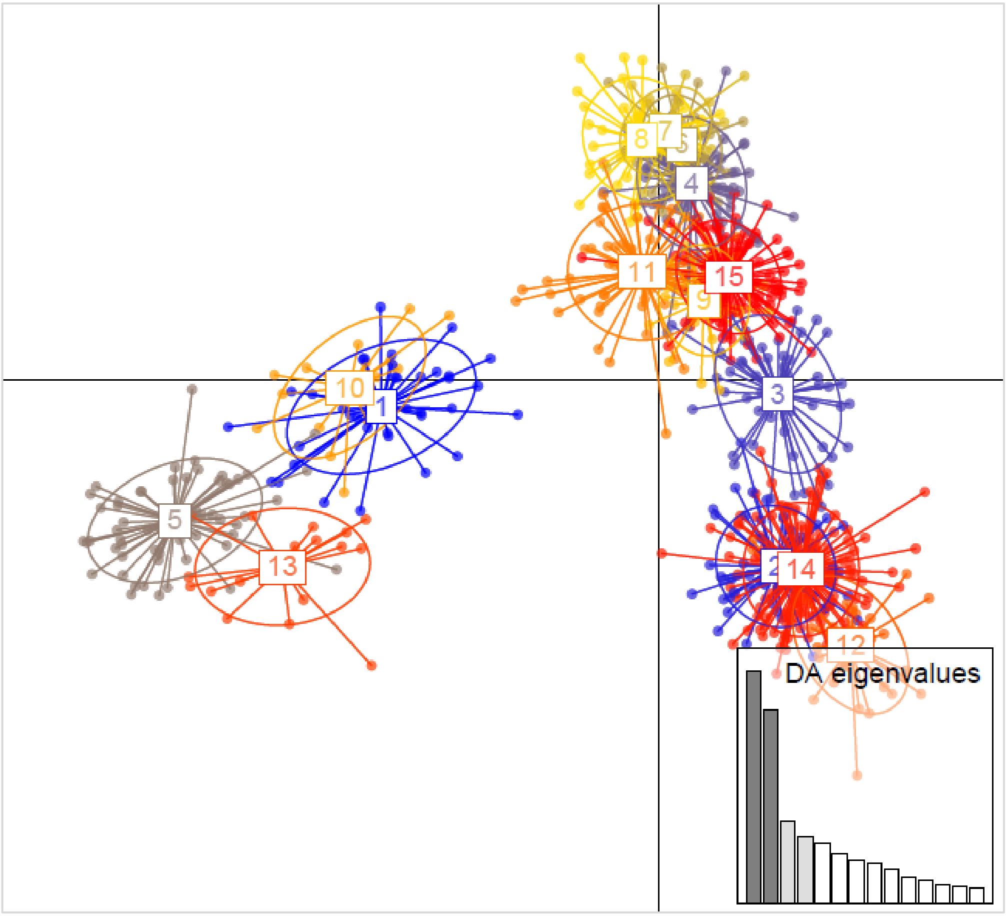

Figure 27. Genetic differentiation where the 15 groups are plotted (DAPC). In illustrated dimension Luleå populations (group 1, 5, 10 and 13) are clearly separated from other populations. In this dimension it might look like group 10 and 1 and 13 and 5 overlap, but when the graph is turned around, these populations are also clearly separated from each other.

The fact that Skielta group with Jokkmokk were not that farfetched either. Both these populations are within the Lilla Luleälven part of the river system. These populations also group with Kuouka and the genetic distance between Jokkmokk and Kuouka was very short. This is probably an effect of the fact that the turbine outlet from Letsi (lowest hydropower dam in Lilla Luleälven) flow into the Kuouka area. Thus, grayling can migrate down from Jokkmokk to Kuouka while migration back again is not possible.

More surprising was the great genetical distance between the populations in Görjeån and Flarkån (group 10 and 13). These tributaries both enter River Luleälven within only 35 kilometers, so they should group together and be closely related to each other. They should not be isolated from Kuouka and Jokkmokk either. The fact that these populations were alone in their groups might indicate that they might have gone through genetic depressions, lost genetic diversity, and drifted apart. Table 4.

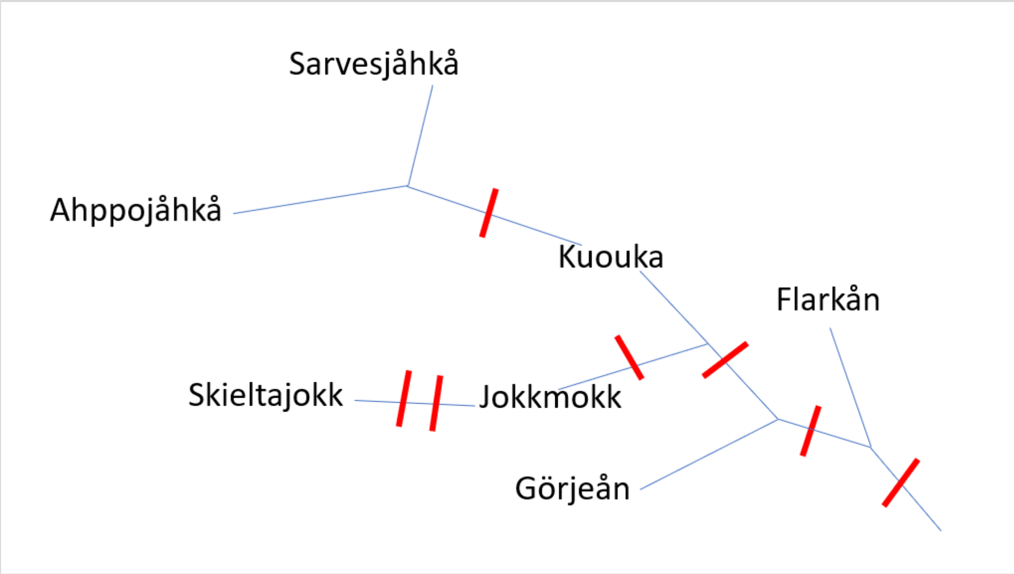

Figure 28. Schematic map of sample locations in River Luleälven and the connectivity between them. Hydropower dams are marked with red lines.

The populations in River Kemijoki don't show much correlation at all to the geography, except Marraskoski and Venejoki. Korkiamaanoja grouped with coastal grayling populations and the other populations were alone in their groups. The separation of populations might be an effect of hydropower dams, but it might also be an effect of the fact that sampling sites were located high up in tributaries where populations were more or less stationary, not migrating and having any exchange with populations in the main cannel. Korkiamaanoja is probably an effect of that coastal grayling have been stocked and released in some parts of Finland. Figure 29.

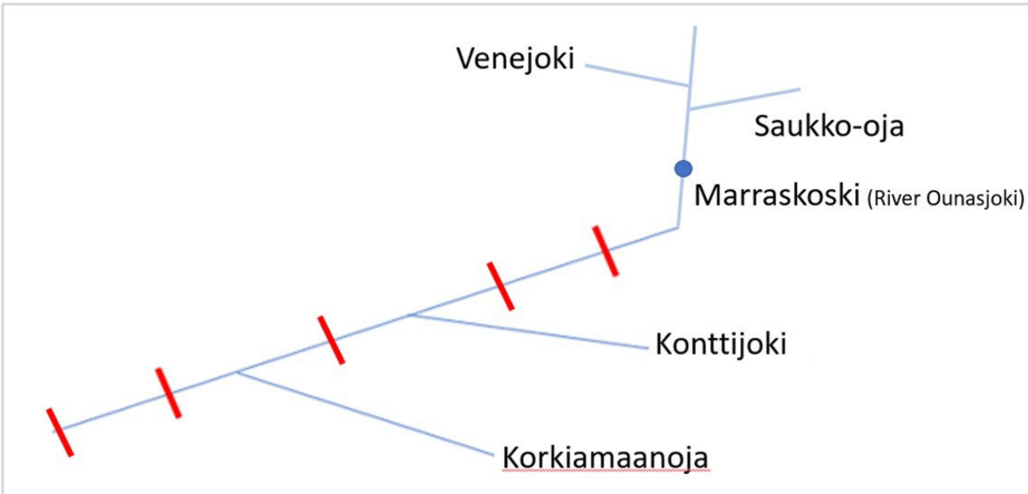

Figure 29. Schematic map of sample locations in River Kemijoki and the connectivity between them. Hydropower dams are marked with a red lines.

The genetical distance between grayling populations in the regulated rivers, River Luleälven and River Kemijoki, were greater than between the grayling populations within River Kalixälven. The distance between and the grouping of populations showed less correlation in the regulated rivers than in River Kalixälven. This indicate that there might be a direct effect on the genetics in grayling populations due to the regulation of River Luleälven, like the genetic effects found in fish in the upper parts of River Rhine (Gouskov et all. 2015).

Measures might be a need to maintain good genetic variation in the grayling populations over time, especially in the lower part of River Luleälven (Görjeån and Flarkån).

Brown trout *(Salmo trutta)*

The main goal for brown trout sampling in the present survey was for the genetic study, with typical sample size of 20-40 individuals per stream. Relatively small number of samples per stream did not allow reliable stream-specific analysis of growth and size at maturity of brown trout**.** However, samples pooled over streams revealed that brown trout showed typical growth patterns, and at least in the selection of headwater streams of River Kemijoki basin maturing schedule similar to stream-resident brown trout populations observed elsewhere (Koli 1990, Voellestad et al. 2002, Öhlund et al. 2008) and for example in an earlier study of brown trout populations in the River Kemihaara basin (Korhonen et al. 1996). However, there seemed to be variation both in growth and length/age of maturity of brown trout among streams, most probably due to differences in the characteristics of in-stream habitats as well as that of drainage areas (Jutila et al. 2001, Cattaneo et al. 2002, Almodovar et al. 2006, Rodger et al. 2020). As a next step to increase knowledge on local stream-specific brown trout populations in northern headwater streams, a monitoring project should be established covering a representative selection of headwater streams, where brown trout growth and length/age at maturity are examined, and population densities and size are estimated. The project should also include monitoring of brown trout movements between the target tributaries and the main channel of the river system. Methodically the latter could be conducted e,g. by using PIT (passive integrated transponder)-tagging of brown trout in streams and using a tag-reader array to monitor their movements (e.g. Cucherousset et al. 2005) and/or using a camera surveillance already applied in the studies described in chapter 'The tributaries benefit to the main river in River Luleå' in this report.

In this survey the genetic analyses of brown trout in free-flowing River Tornionjoki and River Kalix were based on a limited number of headwater tributary streams representing weakly the structure of brown trout genetic resources of the river basins. However, Palm et al. (2019) study gives a comprehensive view on the matter. According to Palm et al. (2019) in the River Tornionjoki basin, sea-migrating brown trout is the main form of brown trout in the main channel of the River Tornionjoki and in streams flowing into it up to the latitude of about 68 degrees north, with each of the streams flowing into the main channel having sea-migrating brown trout populations showing their own genetic diversity characteristics, which facilitates the stream-specific identifying of brown trout from a mixed sample of individuals ascending to the river from the sea as well of mixed sample of brown trout smolts descending to the sea. In addition, the study showed that there exists also resident brown trout form both in the main channel and in the streams flowing into the main channel, the conclusion based on the growth and the genetic characteristics of individual fishes sampled from both types of the habitats. It is noteworthy that in the small headwater tributaries of the streams flowing into the main channel and in the northern latitudes of the main channel brown trout populations were more distinct in their genetic profile than the populations from the lower reaches of the streams flowing into the main channel, suggesting that there are brown trout populations consisting only of resident individuals (Palm et al. 2019). The EMRA-samples from the smallest tributary streams, such as streams Kutuoja and Särkijoki were more clearly differentiated from brown trout from other sampling sites, while streams Ahmajoki, Alanen Kihlankijoki and Nivunkijoki, showed more genetic mixing and closer affinity to sea-migrating brown trout reference populations, which concurs with the results of Palm et al. (2019). Without any large genetic databases of the brown trout populations from the free-flowing River Kalix basin it can be assumed that the structure of genetic resources of brown trout in this river basin resembles that of River Tornionjoki basin. According to Bohlin (2001) and Cucherousset et al. (2005) there may be a continuum of life history tactics in brown trout populations in the river basins free for sea-migrating brown trout, the characteristics of the stream, such as altitude and distance from the sea of the tributary stream and foraging possibilities therein, determining the existence of migratory vs. residency of the population. Genetic analyses of brown trout populations in tributary streams of the regulated River Kemijoki catchment, as well in the River Luleå catchment, revealed that signs of sea- or lake-migrating brown trout forms in the genotypes of tributary stream populations were largely missing compared to that of the free-flowing river, such as River Tornionjoki basin (Palm et al. 2019). Closing the river by for example hydropower dams from sea-migrating brown trout populations fades out their populations and their genetic impact on the brown trout populations in the streams of the catchment. Within decades, the closure of the main river highlights the distribution and genetic diversity of local stream-specific brown trout populations that are still prevailing in the catchment. This is especially evident in the catchment where there are no large lakes to support adfluvial (lake-run) forms of brown trout. Local stream-specific populations showed variable genetic mixing between tributaries in different river basins of the river Kemijoki catchment, suggesting that tributary populations are at present either of resident or fluvial form. Resident forms are stream-specific or even stream-reach-specific, dwelling in a short stream reach of their whole life (e.g., Näsje 2008, Rodger et al. 2020), while fluvial forms probably move to some extent between tributaries and the main channel of the river basin and are not necessarily homing back to their natal stream for spawning, thus conditionally maintaining genetic mixing (e.g., Cucherousset et al. 2005). Interestingly, in the River Kemihaara basin, located in the uppermost part of the River Kemijoki catchment and having a free-flowing riverine main channel into which the tributary streams flow, tributary populations showed genetic mixing between the tributary streams and there appeared to be a mixed population in the main channel of the basin (see also Korhonen et al. 1996). In the lower and middle reaches of the River Kemijoki basin, where the main river channel is stepped by power stations and the channel sections between power stations are more or less of a lentic type, there appeared to be very little gene flow and mixing among the populations of the headwater tributary streams (see also Koskiniemi 2018).

As a compensatory management action for hydro power constructions, in the River Kemijoki catchment, about 60 000 brown trout, including both adfluvial (lake-run) form (typically fish from the Rautalampi hatchery stock, but also e.g. Lake Inari stock (River Juutuanjoki population)) and resident/fluvial form (River Kemihaara basin stock, and River Ounasjoki basin stock), have been released annually (Pylväs and Huttula 2018). The resident/fluvial forms are stocked mainly to the River Kemihaara, Ounasjoki and Luiro basins, while adfluvial forms are mostly released to the most constructed sections of the catchment, i.e., the lower and middle reaches of River Kemijoki and River Kitinen basin and Lake Kemijärvi (Pylväs and Huttula 2018, Keränen 2021). The analyses of genetic structure of the brown trout populations from the headwater tributary streams of the whole River Kemijoki catchment revealed no abundant signs of genotypes of either sea- or lake-migrating populations used here as reference samples. Stocked adfluvial brown trout do not seem to ascend for spawning into the tributary streams, and instead probably remain in the main channels of the basins (or e.g., Lake Kemijärvi) or suffer from low survival before reaching maturity and spawning-run (Heikinheimo and Huusko 1987, Kännö and Salonen 1989, Keränen 2021).

As a conclusion, at the present state where there is no access for sea-migrating brown trout to migrate into the River Kemijoki (compared to e.g. River Tornionjoki basin, see Palm et al. 2019) fishing and fisheries management in headwater tributary streams need to be based on the resources of local resident/fluvial brown trout populations. However, this is a demanding task because the genetic study indicated that majority of the tributary stream populations showed relatively small effective population size estimates and also high relatedness among the individuals. These characteristics seem to be typical for stream dwelling brown trout populations also elsewhere (e.g., Lemopoulos et al. 2017, Voellestad 2017). To this end, ecological and genetic premises for keeping the populations viable would not allow large stream-specific catches to be taken. Traditionally the fishing of resident brown trout in tributary streams has been small scale activity (see chapter 3. of this report) and based on the present results it will not affect negatively the potentially existing migratory populations in larger rivers.

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5. Fish migration survey with fish counter in Linabäcken and Harrijaurebäcken in the reservoir Letsi in Lilla Luleälven 2020 and 2021 and in Tsåkesjokk in lake Langas in Stora Luleälven 2021

Author: Stefan Stridsman, County Administration Board, Norrbotten

5.1. Summary

In order to obtain knowledge about the ecological significance of the tributary watercourses for the production of fish species present in hydropower plant reservoirs, fish counters were installed in Linabäcken and Harrijaurebäcken to control fish migration in 2020 and 2021 and in Tsåkesjokk in 2021. Fish counters were installed in Linabäcken and Harrijaurebäcken in early spring and dismantled in late autumn. In Tsåkesjokk, the grayling spawning migration was monitored in early spring in 2021 for 21 days. In Linabäcken, it was found that migration of breeding graylings occurred during the spring, however, the number was relatively low. In Harrijaruebäcken, no upstream migration of spawning graylings was recorded. In both Linabäcken and Harrijaruebäcken there was no spawning migration of trout. Downstream migration of trout of smaller size was registered in the fish counters, so-called smolt migration, in both Linabäcken and Harrijaurebäcken. In Tsåkesjokk, a large number of graylings were recorded. The spawning migration lasted for only six days when about 800 graylings migrated upstream from the lake Langas for spawning in Tsåkesjokk.

5.2. Introduction

The regulation of the Luleälven in Sweden and the Kemijoki in Finland has meant that the habitats for stream living fish species have changed negatively because previously flowing river areas have decreased or completely disappeared. In the majority of tributaries that are not directly affected by hydropower regulation, there are still habitats that current living fish can use. Understanding of how the tributaries in regulated watercourses are used by migratory fish stocks is largely lacking. Within the Interreg project EMRA (Environmental planning, Measures and Actions in Regulated water systems) under activity 5.2 “The tributaries contribution to the main watercourse” the up- and down migration of fish in tributaries of the Luleälven was studied using optical fish counter with camera. The fish migration control should increase knowledge about the ecological function of tributaries in regulated watercourses

5.3. Material and Methods

Fish migration survey was carried out in Linabäcken and Harrijaurebäcken, which enters into the reservoir Letsi in Lilla Luleälven, and in Tsåkesjokk, which enters into lake Langas in Stora Luleälven (figure 30). The reservoir Letsi and Langas have a water level amplitude of 4.7 meters and about 1 meter respectively (information Vattenfall AB).

Figure 30. Map of the survey sites (red circles) for the fish migration survey in Tsåkesjokk in the Stora Luleälven and in Linabäcken and Harrijaurebäcken in the Lilla Luleälven. Map from Norrbotten county's internal web GIS.

The fish counter consists of a photo tunnel with a stereo camera and with lighting tubes inside the tunnel (figure 31).

Figure 31. The fish counter consists of a photo tunnel (the white box) with a mounted camera (the gray box on the black side wall) and two lights tubes on the inside. Photo County Administrative Board in Norrbotten.

In order to save battery power and avoid the system being completely switched off, the lighting was not switched on during the survey in Tsåkesjokk and Harrijaurebäcken. In Linabäcken, 230 V was obtained up to the fish counter. Not having the light switched on during the night can mean that the image quality becomes somewhat worse during the evening, but since there are relatively good light conditions during the time of the survey, it was judged that the background light entering the photo tunnel was sufficient in Tsåkesjokk and Harrijaurebäcken.

The fish counter is connected via signal cable to a computer where the software registers recognized fish movements both upstream and downstream based on set parameters for movement detection. The power supply to the equipment was obtained via Victron inverter phoenix 24/250V connected to two battery packs (battery á70 Ah) with four batteries each. These were charged with four serially connected solar panels of 160W. The equipment was remotely monitored with TeamViewer software through the Tp-link Archer MR 200 router with connection via Telia mobile data. To guide migrating fish into the photo tunnel fences were mounted on both the upstream and downstream sides. In Tsåkesjokk, steel mesh with 10 x 10 mm opening and rebar 8 mm was used as support legs. In Linabäcken and Harrijaurebäcken, grid strainers with a mesh size of 16 x 75 mm and steel pipes (60 mm in diameter) with haki-couplers were used.

Continuous video recording took place and files (.avi) are created for each hour of the day which are saved on the hard drive to be transferred to an external hard drive after each day. Detections of fish are saved as image (jpg), time of passage, length information, direction of movement, fish species and water temperature. Registration also takes place, depending on set variables for detection, for example on downstream drifting vegetation. Analysis of the auto-records was performed using Simsonar's FC software after the survey was finished to verify species, direction of movement, size and non-fish detections.

A logger (Onset Hobo MX2202) was installed at each fish counter to record water temperature (C°). Interval for the registration was set per hour.

5.4. Results

Tsåkesjokk

Tsåkesjokk flows into lake Langas, which has a regulation amplitude of about 1 meter which is regulated through Langas' outflow via Jaurekaska to Stora Lulejaure and which should be 27 m^3/s. The amount of water transferred is regulated by operation of Vietas hydropower plant. The average water flow in Tsåkesjokk is 0.2 m^3/s. In the project, an electronic fish counter, Simsonar FC (Simsonar Oy), was installed in the Tsåkesjokk estuary to primarily study the grayling (*Thymallus thymallus. L.*) spawning migration during the spring 2021 (figure 32).

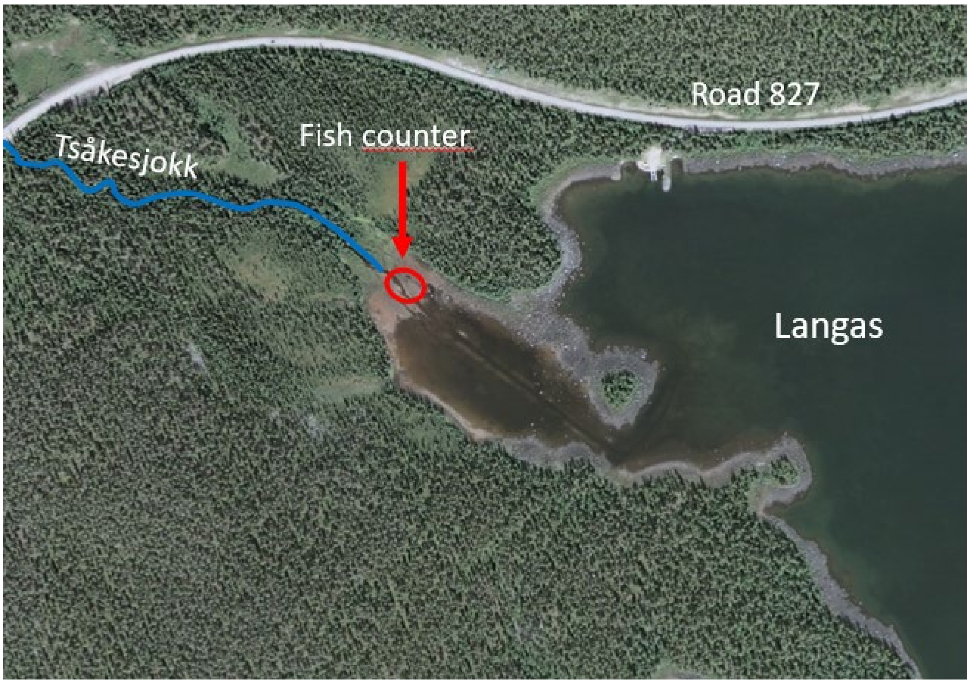

Figure 32. The red circle indicates the position where the fish counter was installed in Tsåkesjokk in 2021. Orthophoto from the County Administrative Board's web-GIS.
The fish counter was installed in Tsåkesjokk's estuary on 2021-05-26, at 17:00 and on 27/5 at 17:07 the photo tunnel had detached from its position and ended up on the shallow brink (figure 33).

Figure 33. Installed fish counter Simsonar FC with entry fence guiding fish into the fishcounter in Tsåkesjokk and solar panels for recharging batteries on May 26, 2021. Photo: Norrbotten County Board.

On 29/5 at 12:32, the phototunnel was restored to its position and back in operation with also guide fence for downstream migrating fish (figure 34). The interruption thus lasted for 43 hours and 30 minutes, after which there were no interruptions in the recording of video films until 15/6 at 14:40 when the fish counter was uninstalled.

Figure 34. The fish counter, Simsonar FC, reinstalled on 29 May because the counter was moved due to high water pressure. Guide nets were also installed to guide fish during downstream migration. Battery storage as well as PC and router for internet connection were stored in the light metal boxes on the back of the solar panels. Photo: County Administrative Board in Norrbotten.

No fish passed from 26/5 at 17:00 to 27/5 at 17:07. From 29/5 at 12:32 until 21:49 no fish were recorded. On 29/5 at 21:49 the first fish was recorded which was an upstream grayling with a length of 38 cm at a water temperature of 3.13 C°. Four species were recorded in the fish counter, grayling, trout (*Salmo trutta, L.*), pike (*Esoc lucius, L.*) and shoals of fry probably grayling or whitefish (*Coregonus lavaretus, L.*) (figure 35 and 36).

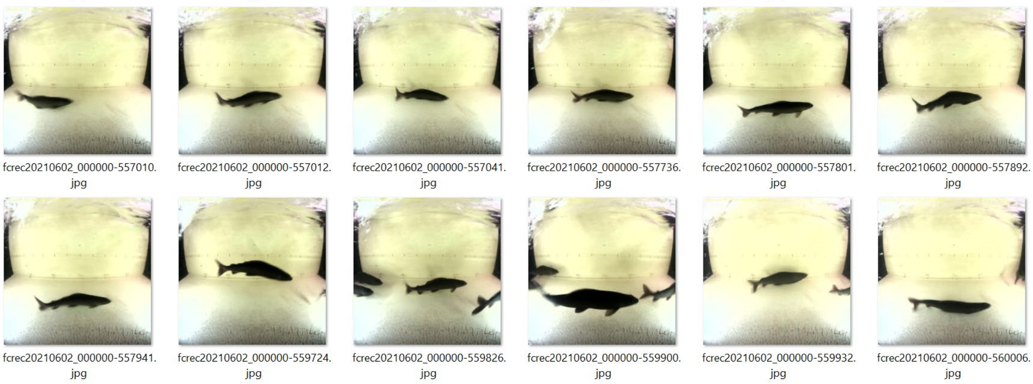

Figure 35. Example of auto-registered graylings in the fish counter in the Tsåkesjokk outlet in 2021. Photo: Administrative County in Norrbotten.

Figure 36. Example of auto-registered upstream and downstream passages of fish and downstream drifting vegetation in the fish counter in Tsåkesjokk's outlet in 2021. Photo: Administrative County in Norrbotten.

From 29/5 at 21:49 until 30/5 at 12:36, i.e., for 14 hours and 17 minutes, 150 graylings migrated upstream before the first grayling migrating downstream was recorded. A total of 1,882 grayling upstream passages and 1,300 downstream recordings were recorded between 29/5 and 15/6. Based on recorded grayling migrating up and down in Tsåkesjokk, an intensive migration continues for six days and then almost completely subsides until the fish counter was uninstalled (figure 37).

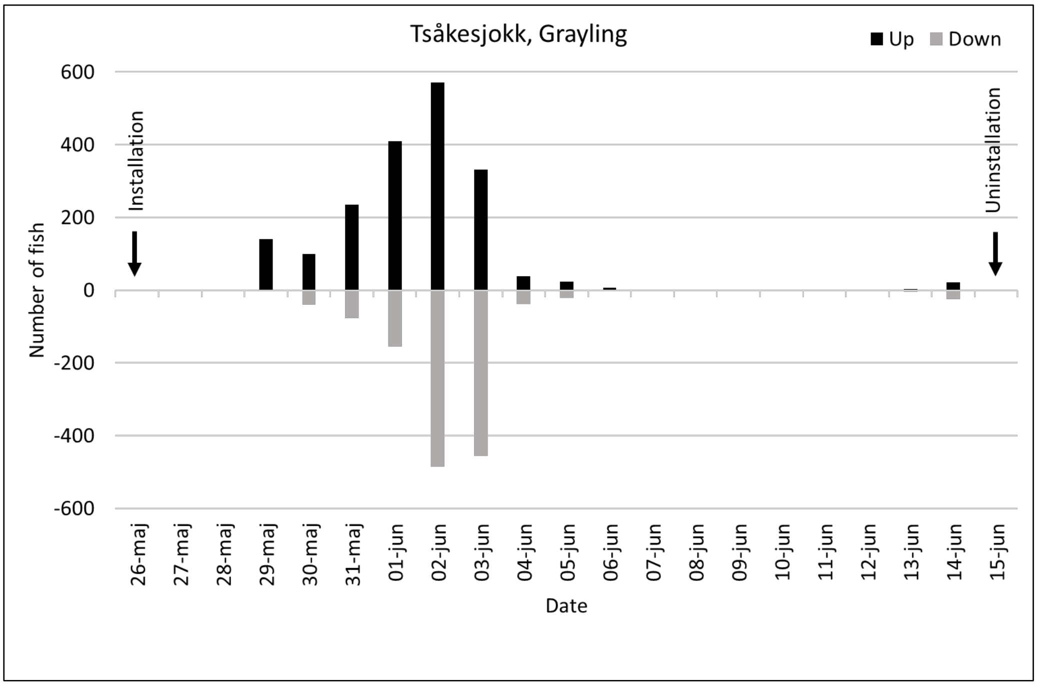

Figure 37. Number of graylings migrating upstream and downstream (positive numbers indicate upstream and negative numbers indicate downstream) that were registered in the fish counter in the Tsåkesjokk outlet in 2021.

In order to obtain an estimated number of graylings that migrate up to spawn in Tsåkesjokk, the number of graylings migrating up was accumulated reduced by those migrating down for each individual registration. At most 720 graylings were upstream of the fishcounter which was on June 8th. After the end of the fish migration control on 15/6 in the Tsåkesjokk outlet, 583 graylings were still upstream of the fishcounter (figure 38).

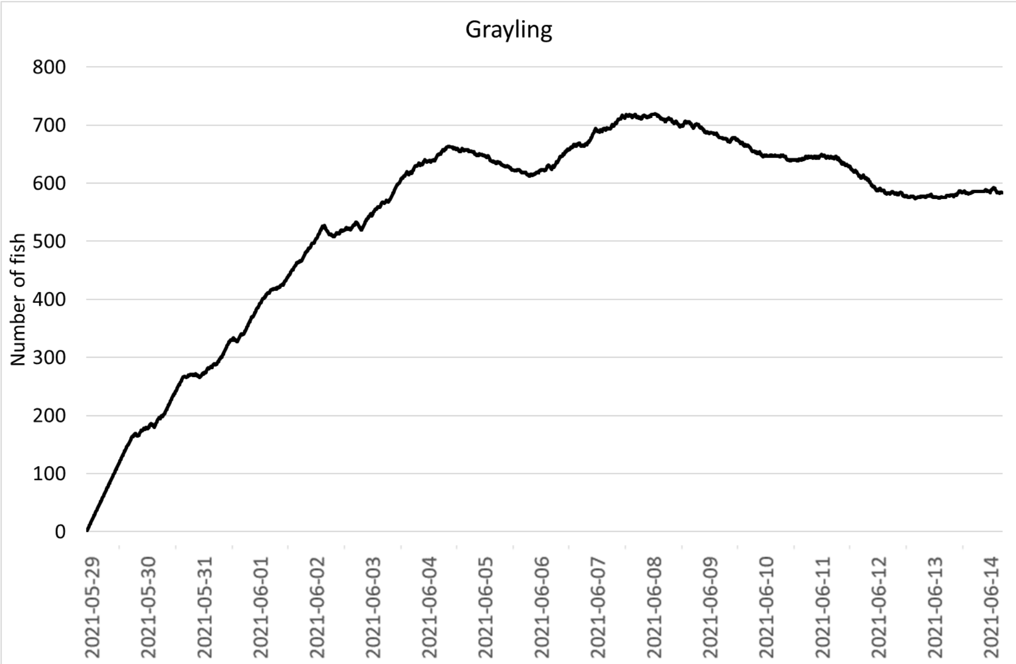

Figure 38. Accumulated number of graylings upstream of the fish counter in the Tsåkesjokk outlet in 2021.

The water temperature varies during the day by about 2 degrees during the first 7 days. After that, the temperature fluctuated more irregularly until 11/6 and then successively dropped by 5 degrees over the next two days (figure 39).

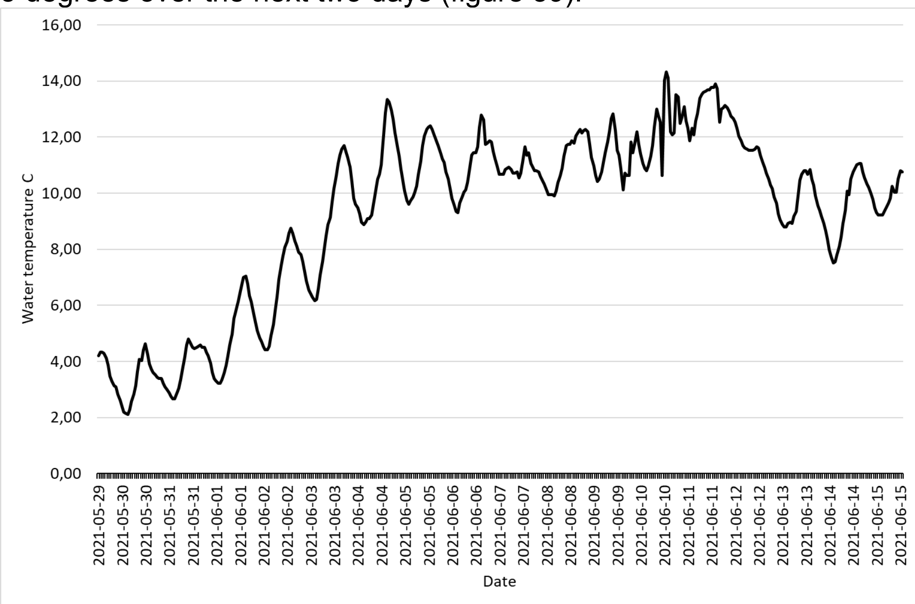

Figure 39. The water temperature (C˚) recorded with a temperature logger at hourly intervals in the Tsåkesjokk outlet in 2021.

The size distribution of migrating graylings was dominated by the size group 35-39 cm. Some individuals were found with lengths up to 51 cm (figure 40).

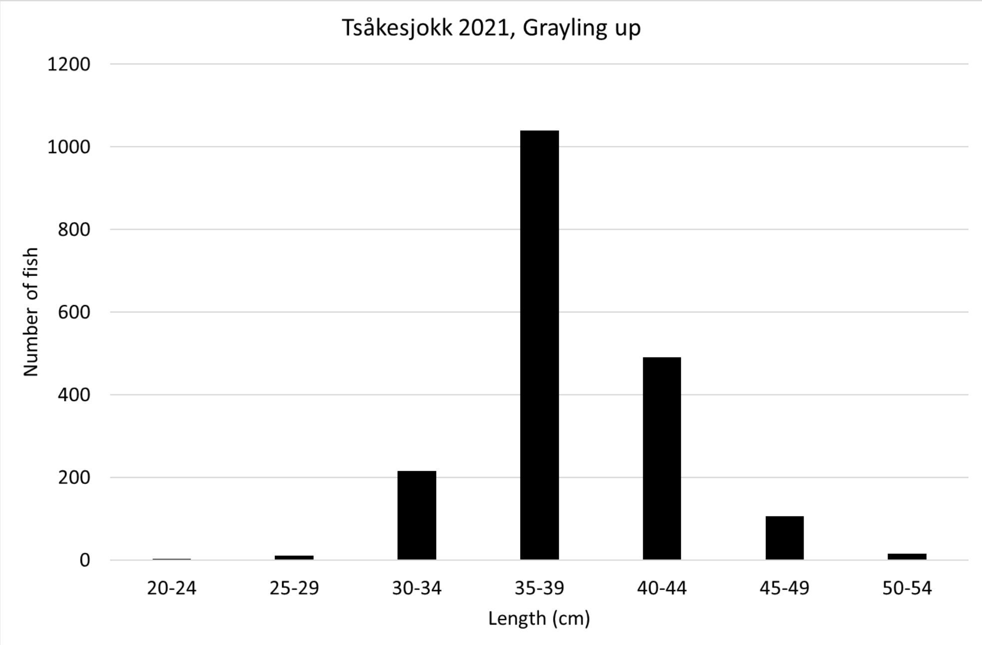

Figure 40. Number of migrating graylings recorded with the fish counter and grouped in 5 cm intervals in Tsåkesjokk in 2021.

From 21:00 until 02:59 activity increased with registrations of both ascending and descending graylings compared to daytime activity. However, an increased activity was registered in the middle of the day between 12:00 – 12:59 (figure 41).

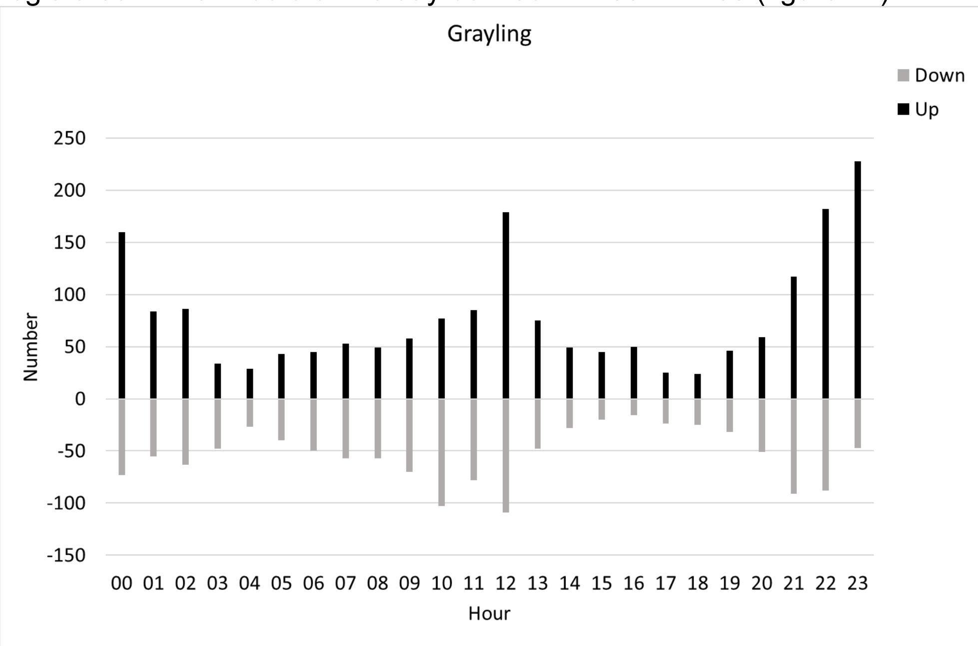

Figure 41. Number of migrating graylings upstream and downstream (minus value) combined for each hour from 29/5 to 15/6 2021 in Tsåkesjokk.

On 1/6, it was observed visually that spawning activity occurred in the Tsåkesjokk outlet area (figure 42). The water temperature varied on 1/6 between 3.4 to 7.0 C° and when the spawning activity was identified at 18:05 the water temperature was 6.7C°. On several occasions the surface of the water was broken by the grayling’s dorsal fins.

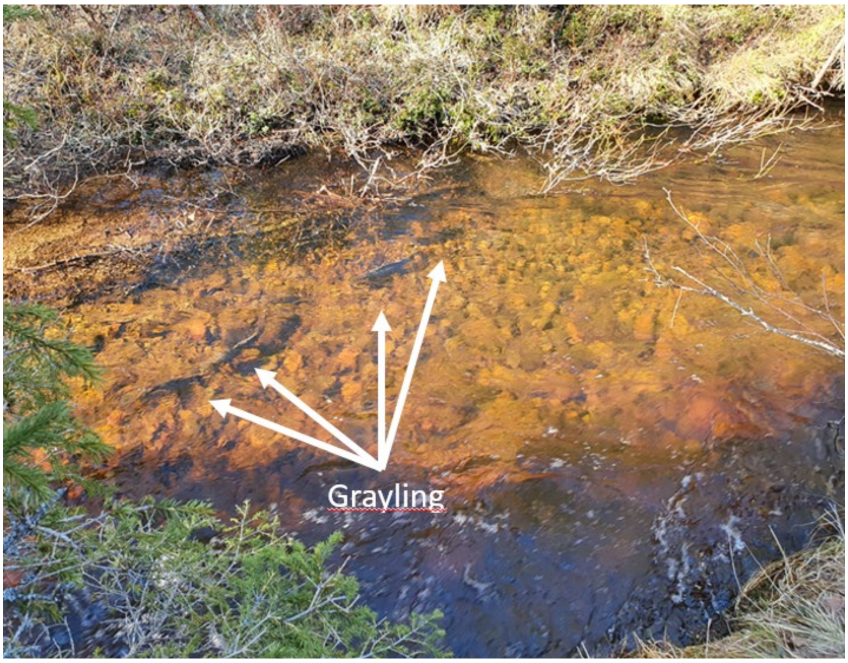

Figure 42. Four graylings showing spawning activity in the Tsåkesjokk outlet area on 1/6. Photo: Administrative County Board in Norrbotten.

A total of 95 pikes passed downstream and 31 upstream and they had a length between 29 – 84 cm (figure 43).

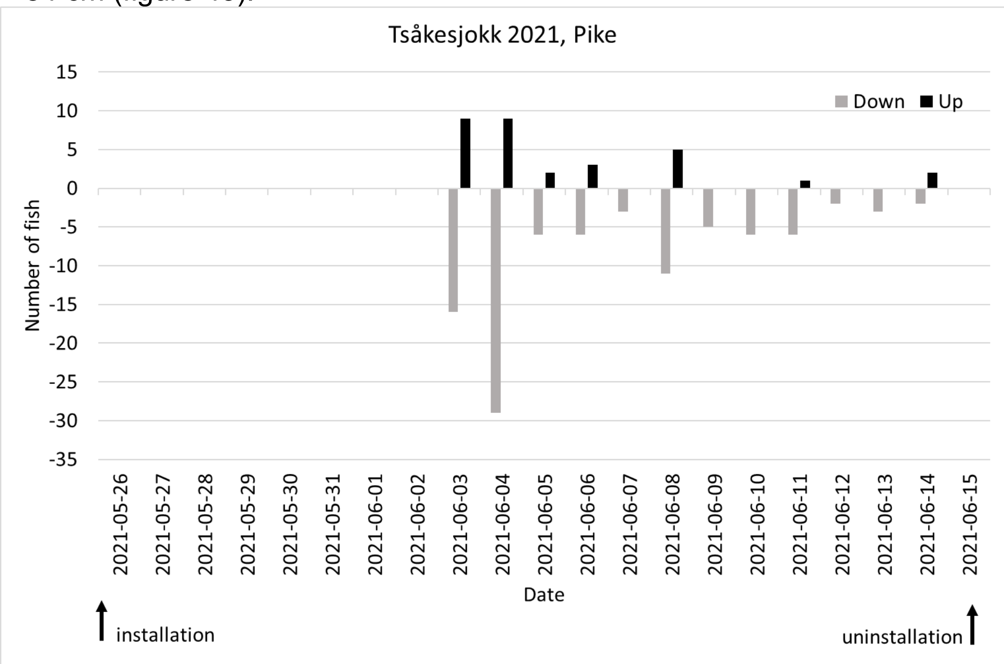

Figure 43. Number of upstream and downstream migrating (positive number indicates upstream migration and negative number indicates downstream migration) pikes that were registered in the fish counter in the Tsåkesjokk outlet in 2021.

Harrijaurebäcken

On 21 May 2020, the fish counter was installed in Harrijaurebäcken and the first fish to pass upstream was a perch on 22 May with a length of 34 cm (figure 44). The fishcounter was uninstalled on the 10th of October 2020.

Figure 44. Installation of fish counter in Harrijaruebäcken on May 21 (left) and May 27 (right image) 2020. Photo: Administrative County Board in Norrbotten.

On 18 May 2021, the fish counter was installed in Harrijaurebäcken and uninstalled on 8 September. On May 23, the first fish was recorded, which was a migrating wild trout.

In total, video recording was obtained for 123 days in 2020 during the survey period. Only 5 days were missing from video recording due to remote updating of windows and power supply to the equipment due to cloudy weather. In 2021, only 78 days of video recording are obtained due to very little solar radiation which meant low charging current to the batteries.

A total of 344 and 815 fish (up and down migration) were registered in the fish counter in 2020 and 2021, respectively (Table 6). The registrations were dominated by pike and perch. The largest trout (75 cm) that passed upstream in 2020 was of wild origin with adipose fin, exposed trout are adipose-fin clipped (Figure 43). Only one farmed trout was recorded as passing downstream in 2020. Of the total of 14 trout recorded downstream in 2020, 11 were single individuals as 3 turned upstream after registration. The number of migrating trout was a total of 7 of which 4 were individuals as three were registered downstream that turned upstream. Only one downstream grayling was recorded in 2020 and 2021 (Table 6). As the water level rises in the reservoir Letsi the clear current out of Harrujaurebäcken decreases and the number of passages of other species increases, such as for perch and pike (table 6). In addition to fish, a mink was recorded passing upstream.

Table 6. Registered fish species of up and down passages and length intervals (cm) in Harrijaurebäcken in 2020 and 2021.

Species 2020	**Up**	**cm**	**Down**	**cm**
Trout wild	7	20-75	14	20-35
Trout reared	0		1	37
Grayling	0		1	20
Pike	67	25-110	69	15-110
Perch	64	12-34	128	12-35
Whitefish	2	25	0	
Bream	0		1	15

Species 2021	**Up**	**cm**	**Down**	**cm**
Trout wild	5	40-56	35	14-30
Trout reared	0		0	
Grayling	0		0	
Pike	36	19-108	73	18-92
Perch	352	11-42	309	10-52
Whitefish	5	20-24	1	20
Bream	0		1	15
Roach	1	12	1	17

The fish counter automatically registers fish passages both upstream and downstream. Pike and perch frequently swam upstream and downstream through the phototunnel, generating multiple detections (Figure 45).

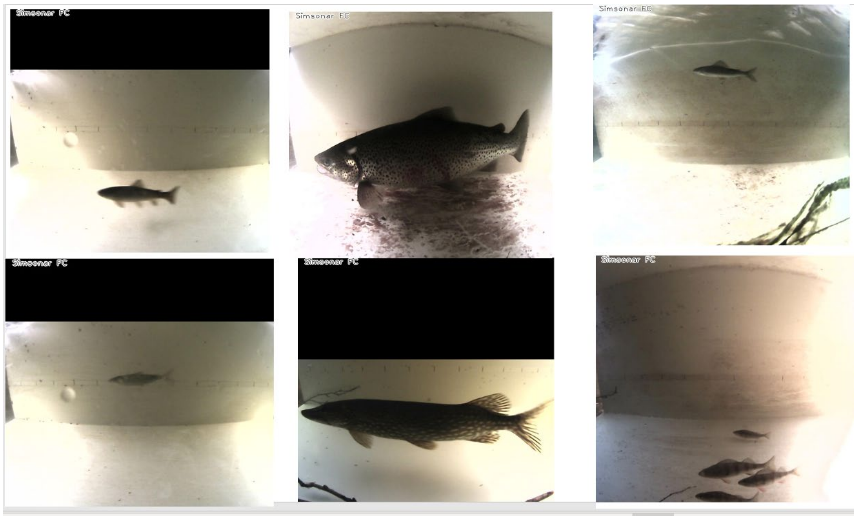

Figure 45. Example images of registered fish by the fish counter in Harrijaurebäcken in 2020. Photo: Administrative County Board in Norrbotten.

Highest activity of registered wild trout in 2020 occurred at the end of June and beginning of July and during September. Most of July and August no passage of trout was recorded. Downstream records were more than upstream and had size range of 20-35 cm (Figure 46).

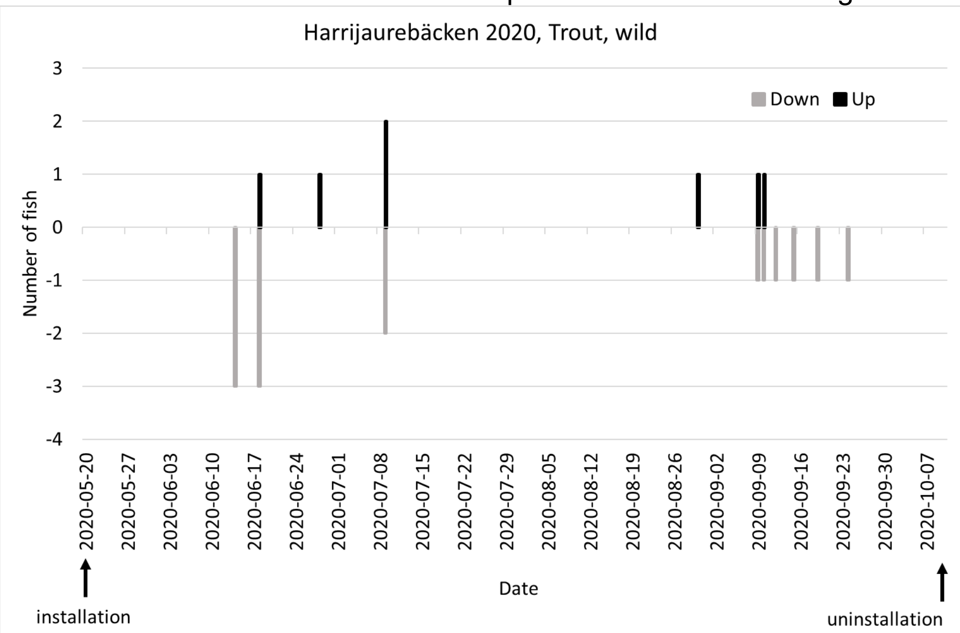

Figure 46. Number of registered up- and down-migrating (minus value) wild trout in Harrijaurebäcken in 2020 with indicated installation and uninstalling of the fish counter.

The 2021 records of upstream and downstream passages of wild trout were concentrated in late May and early June (figure 47).

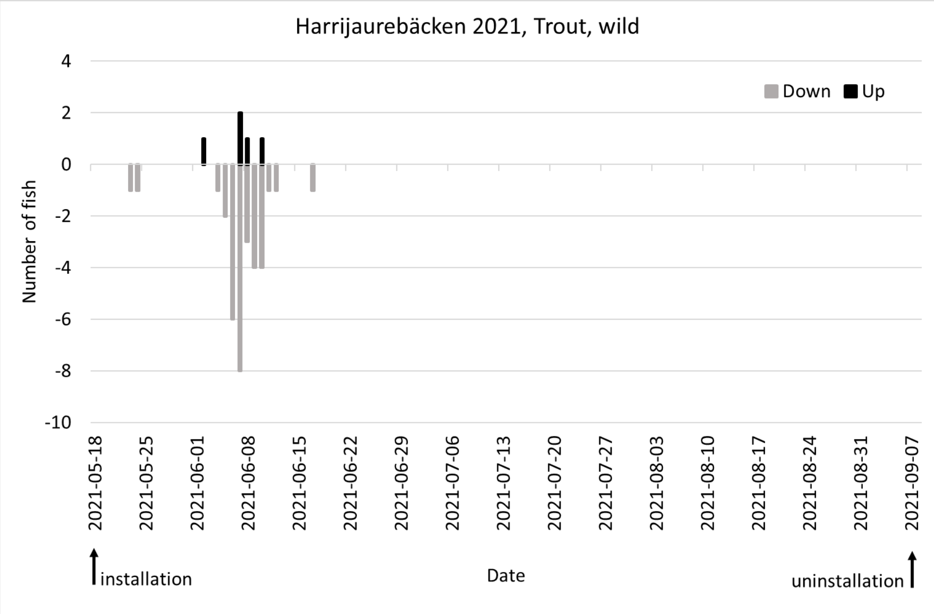

Figure 47. Number of registered up- and down-migrating (minus value) wild trout in Harrijaurebäcken in 2021 with indicated installation and uninstallation of the fish counter.

For the years 2020 and 2021 combined registrations for trout for each hour show some increased activity during the night for upstream migration. The downstream registrations show a relatively even activity throughout the day with a certain lower activity between 08:00 and 13:00 (figure 48).

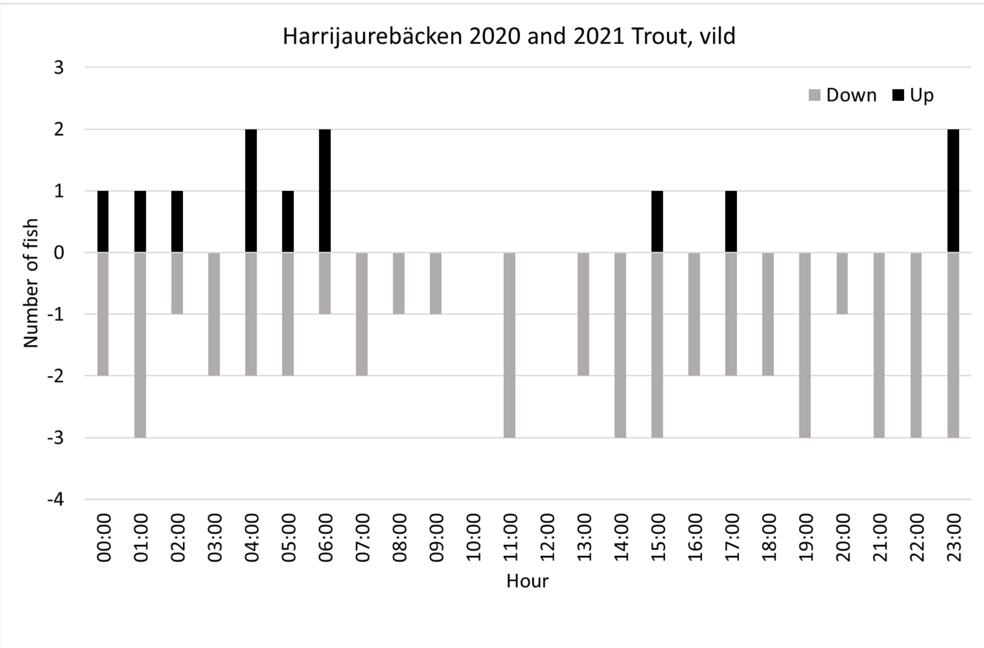

Figure 48. Number of registered up- and down-migrating (minus value) wild trout in Harrijaurebäcken combined for 2020 and 2021 for each hour.

Linabäcken

On May 21, 2020, the fish counter was installed in Linabäcken and later in the day a 22 cm wild trout passed downstream. On September 25, the fish counter was uninstalled. On 10 May 2021, the fish counter was installed in Linabäcken and uninstalled on 4 October. On May 10, the first fish was recorded, which was a migrating wild trout of 32 cm (figure 49).

Figure 49. Installation of the fish counter in Linabäcken 2021. Photo: Administrative County Board in Norrbotten.

A total of 183 and 355 fish (up and down migration) were registered in the fish counter in 2020 and 2021, respectively. The registrations in 2020 were dominated by trout and grayling (figure 50). In 2021, these species were also dominant, but also records of pike and perch were high. All trout were of wild origin (Table 7). In addition to fish, beaver, bird, mink and mouse were also registered.

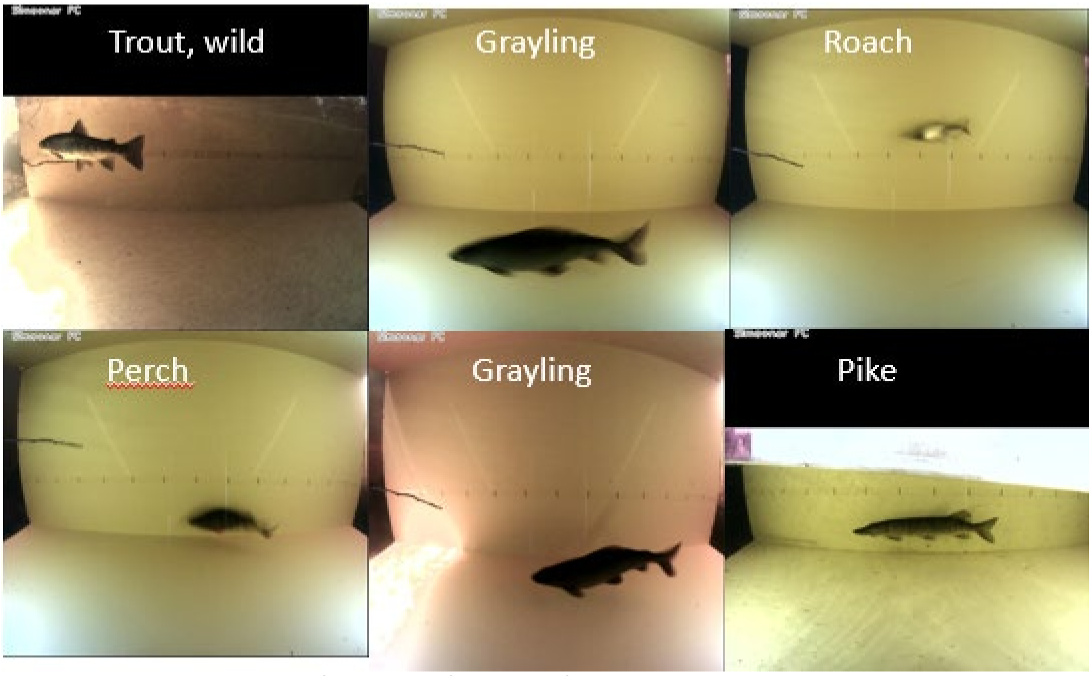

Figure 50. Example images of registered fish by the fish counter in Linabäcken in 2020. Photo: Administrative County Board in Norrbotten.

Table 7. Registered fish species of up and down passages and length intervals (cm) in Linabäcken in 2020 and 2021.

Species 2020	Up	cm	Down	cm
Trout wild	22	16-28	43	14-39
Trout reared	0		0	
Grayling	23	18-41	25	14-48
Pike	15	20-75	13	21-59
Perch	10	13-30	20	17-34
Whitefish	4	21-27	1	21
Roach	4	13-23	1	21
Burbut	0		2	22,34

Species 2021	Up	cm	Down	cm
Trout wild	11	16-37	23	20-40
Trout reared	0		0	
Grayling	47	15-49	50	19-49
Pike	57	22-81	65	18-81
Perch	37	13-42	56	6-42
Whitefish	0		0	
Roach	2	10,39	7	6-30

Highest activity of registered graylings in 2020 occurred immediately after installation of the fish counter at the end of May until the end of June. After 9 August, the upstream migration ceased, while the downstream migration continued until the beginning of September (Figure 49). Downstream migration of grayling began in mid-July and until mid-July the down-migration was the same in numbers as the early up-migration. The water temperature for when the first grayling passed upstream was 5.0 C°. The first 13 graylings migrated upstream when the water temperature was between 5.0 – 13.6 C°. The first downstream migrating grayling was on 10 June at a water temperature of 13.8 C° (figure 51).

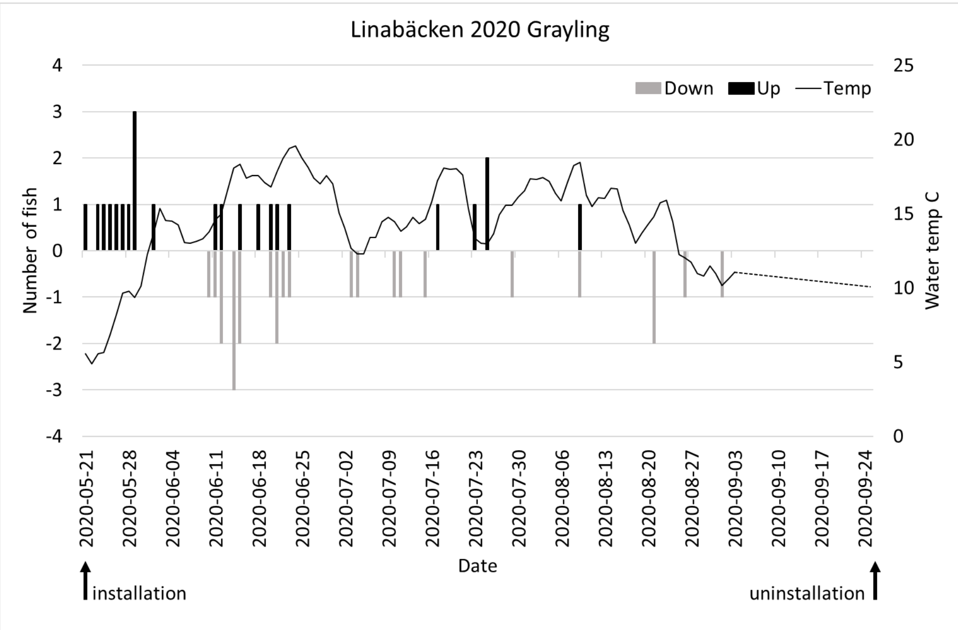

Figure 51. Number of registered graylings migrating up and down (minus value) in Linabäcken in 2020 with indicated installation and uninstalling of the fish counter and water temperature (solid line).

The highest activity of registered graylings in 2021 took place, similarly to 2020, immediately after the installation of the fish counter in mid-May until the beginning of June. At the end of July, increased activity was recorded both upstream and downstream for about a week. After that there was sporadic up- or downstreams detections (figure 49). From installation to June 29, the number of up and down migrations was 31 and 34, respectively. The water temperature when the first grayling passed upstream was 4.0 C°. The first 13 graylings that migrated upstream did it when the water temperature was between 3.25 – 5 C° (figure 52).

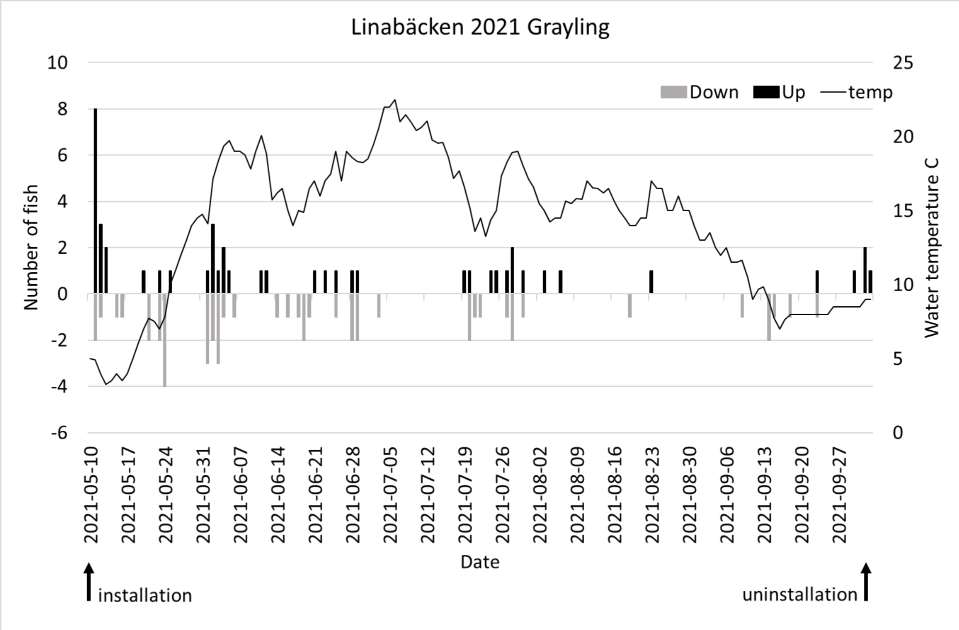

Figure 52. Number of registered graylings migrating up and down (minus value) in Linabäcken in 2021 with indicated installation and uninstallation of the fish counter and water temperature (solid line).

Peak activity of migrating wild trout lasted until June 21, after which it significantly decreased. The first migrating trout was recorded on 21 May at a water temperature of 5.5 C° and until 21 June when the migration was reduced, the water temperature was 17.8 C°. On June 12, when most (15) trout migrated downstream was the water temperature 14.9 C°. No upstream migration occurred during the end of the migration survey (figure 53).

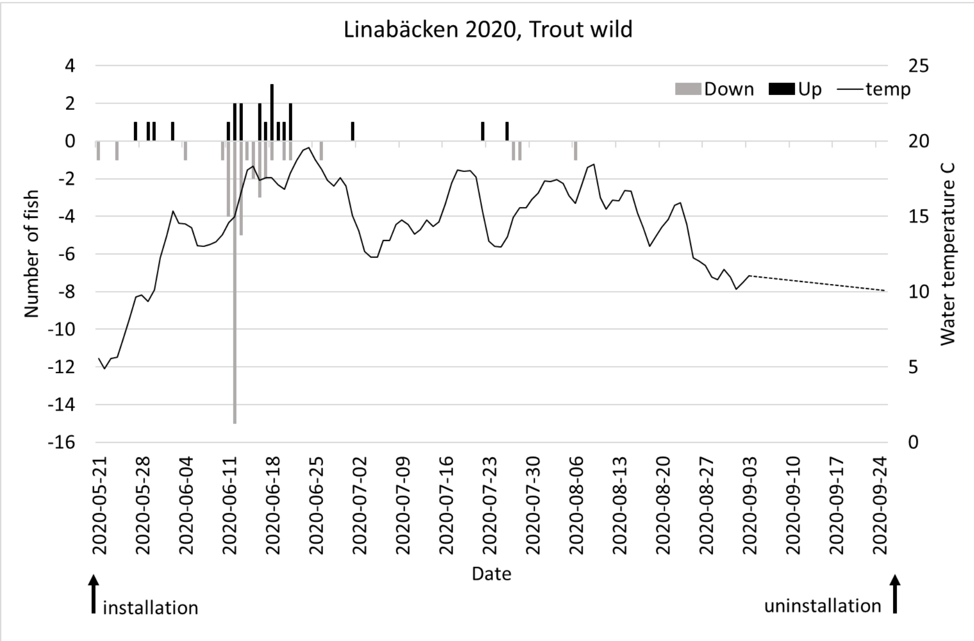

Figure 53. Number of registered up- and down-migrating (minus value) trout (wild) in Linabäcken in 2020 with indicated installation and uninstallation of the fish counter and water temperature (solid line).

Peak activity in 2021 of migrating wild trout lasted until June 13 and after that it significantly decreased. The first migrating trout was recorded on 10 May at a water temperature of 5.0 C° and until 13 June when the migration was reduced, the maximum water temperature was below 19.7 C°. No upstream migration occurred during the end of the migration control (Figure 54).

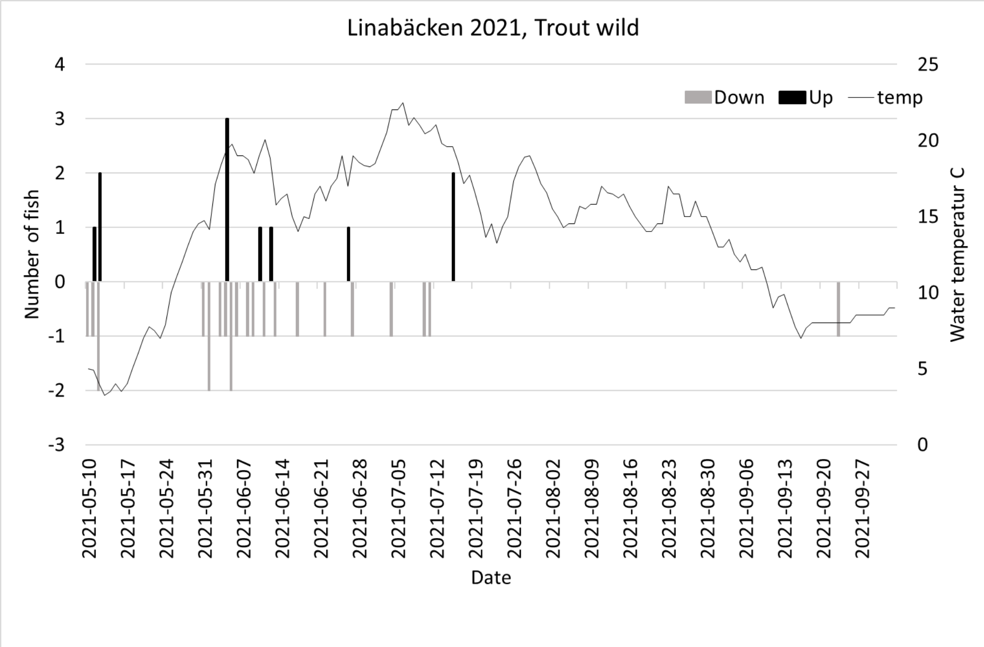

Figure 54. Number of registered up- and down-migrating (minus value) trout (wild) in Linabäcken in 2021 and water temperature (solid line).

5.5. Discussion

During the ice-free season, there is no problem with connectivity for migrating fish in Linabäcken, Harrijaurebäcken and Tsåkesjokk. There is no information on the connectivity during the winter, but it is likely that fish migration is also possible during the winter in Linabäcken and Harrijaurebäcken. It is likely that there is an opportunity for fish to migrate even during the winter in Tsåkesjokk thanks to the measure carried out by company Vattenfall AB in 2013 when the outflow of the stream channel to Langas was deepened and concentrated. However, the channel has been more shallow during years from the time for the measure.

The grayling spawns in the spring and thus differs from other Swedish salmonids, which all spawn in autumn or winter. Graylings that have overwintered in watercourses and lakes begin their spawning migration already under the ice or when it breaks and melts. Most adult graylings leave their wintering grounds, where they have been stationary over the winter, and seek out suitable parts of larger or smaller watercourses for spawning. The migrating distance to the spawning area can vary from 10 m to several km and is initiated at water temperatures between 3-5ºC (Mallet et al. 1999). In Tsåkesjokk, the first spawning graylings were recorded on 29 May at a water temperature during the day between 2.10 – 4.59 °C, which is slightly lower than that stated by Mallet 1999.

In Sweden, grayling usually spawn between April and June, at water temperatures between 4-12°C, however the optimal spawning temperature is between 5-7°C. Spawning can last up to four weeks provided that the water temperature does not suddenly drop below the optimal spawning temperature (Mallet et al. 1999). In the Tsåkesjokk outlet area and in the brook grayling spawning activity was identified on 1/6 at a prevailing water temperature of 6.7 C°, which is within the optimal spawning temperature specified by Mallet.

Grayling spawn in most types of running water, outlets, inlets and lakes and even in coastal areas. In rivers, it spawns on a relatively fine gravel bottom, but the substrate can vary from sand to larger stones. Spawning preferably takes place in such shallow water that the dorsal fin sticks up above the surface of the water (Nordwall, F. 2002). In the Tsåkesjokk outlet area on 1/6 2020, spawning activity of grayling was observed on shallow gravel beds whose dorsal fins protruded above the water surface, but also in slightly deeper areas where the entire fish was under water.

After installation in Tsåkesjokk's outlet in 2021 on May 26, the photo tunnel ended up out of position on May 27 due to high water pressure. On May 29, the photo tunnel was restored to its position. No fish were recorded until May 29 at 21:49 when the first grayling migrating upstream was recorded at a water temperature of 3.13 C° and then until May 30 for 14 hours and 17 minutes, 150 grayling migrated upstream before the first grayling migrating downstream was recorded. Assessment is made that no or very few graylings have passed upstream before 29/5 and that the entire grayling spawning migration has probably been recorded with the fish counter.

At most 720 graylings were upstream of the fish counter that occurred on June 8th. Since spawning areas were located downstream of the fish counter and observations of spawning were identified downstream of the fish counter, the spawning stock of grayling is estimated to amount to approx. 750-800 individuals. After the fish migration control was completed on 15/6 in the Tsåkesjokk outlet, 583 grayling were still upstream of the fish counter, which indicates that the migration of spawned fish takes place at a later time.

The majority of pike passed both downstream and upstream and 45 migrated downstream on June 3 and 4, which indicates that pike migrated up to Tsåkesjokk before the fish counter was installed or that pike overwintered in the stream. In total, more pike migrated downstream compared to upstream.

The majority of auto-registrations of drifting vegetation, for example small branches/twigs, give a high probability that fish did not pass the photo tunnel without registration. The recorded video material can be analyzed if, with changed settings for variables for auto-detection of movements in the phototunnel, there are doubts that fish were not auto-registered. In this case, it has been judged that no change of variables for autodetection is needed and thus no rescanning of the video material.

Grayling lack a clear body pattern like for example salmon and trout, which makes it very difficult to identify individual individuals to determine whether the same individual passed the fish counter in both directions. Even if external light was used by having the light tubes on, it would probably have been difficult to distinguish individuals in order to obtain the net migration in the number of graylings that passed the fish counter.

Tsåkesjokk lower part from road 827 "the road to the west" a stretch of about 500 meters constitutes a very important reproduction area for grayling where lake Langas forms the rearing area. The culvert under road 827 probably constitutes a partial migration barrier for grayling, as well as the steep part on the upstream side of the culvert.

In the fish counter in Harrijaurebäcken, migrating wild trout were registered during 2020 and 2021 with lengths between 14 -35 cm, which indicates that a so-called smolt migration occurs. However, there is no migration of spawning fish during late summer/autumn. The two trout recorded on September 9 and 10 were between 19-22 cm in size and were recorded as the same individuals passing both upstream and downstream. No upstream migration was recorded in 2021 during the autumn. Only one farmed trout of 37 cm was recorded in 2020 migrating downstream. In the Letsi reservoir the company Vattenfall AB releases annually 1000 trout that are adipose clippt. The stocked trout are of the Kaltis strain with a weight of over 160 grams reared at Vattenfall's hatchery in Heden, downstream of the Vittjärv power plant, in accordance with court decision 1994-12-28 appendix 301. The Kaltis trout originates from Kaltisbäcken in Lulejaure, Stora Luleälven and has its growth in Lulejaure and is a upstream migration population migrating for spawning into Kaltisbäcken.

Despite these annual releases, no upstream migrating trout were identified during the spawning period in Harrijaurebäcken in 2020 and 2021.

In the fish counter in Harrijaurebäcken, only one downstream migrating grayling of 20 cm was recorded during 2020 and 2021. This indicates that Harrijaurebäcken is not used by spawning migrating graylings from the Letsi reservoir for reproduction. Harrijaurebäcken is strongly affected by timber floating in the form of embankment, clearing and straightening of the brook, which may be a contributing reason for the few registrations of both grayling and trout.

The relatively large number of records of perch and pike is due to the rise of the water level in the Letsi reservoir which thus created a lower water velocity through the fish counter compared to spring and early summer when the water velocity was relatively high through the fish counter.

In Linabäcken during 2020 and 2021, a total of 66 migrating wild trout in size 14-40 cm were registered. Most of the registrations took place during spring and early summer, which is interpreted as a so-called smolt migration occurs. No upstream migration of trout was recorded during late summer and autumn, which indicates very low or no spawning return migration of previously trout smolt migration. No reared (adipose clipped) trout was registered in Linabäcken during 2020 and 2021. One reason for that can be that they are not originate from Linabäcken.

In Linabäcken, migrating graylings were recorded in the spring directly after the installation of the fish counter in 2020 and 2021. The sizes of the graylings varied between 15-49 cm. Since no so-called zero days were obtained, i.e. days without fish passages after installation of the fish counter, it can be assumed that the spawning migration of grayling had already started before the day of installation. The installation in 2021 took place on May 10 and the highest number of migrating graylings occurred on the same day, which reinforces that the migration started before the day of installation. Down migration of graylings took place in both years within the next 2 weeks after recorded migrating graylings, which is interpreted as spawned graylings returning to the Letsi reservoir. Some migration also occurs throughout the duration of the migration control. These passages of grayling are interpreted as feeding migrations. Of the other species, records of pike and perch dominated. Upstream migration of whitefish (4 pieces) occurred in 2020 but no registration in 2021. Most likely these are connected to feeding migration. The same also applies to registrations of pike, perch and roach, because these registrations are timed after the spawning migration period, which for these species occurs in early spring. Two downstream registrations of Burbut were recorded in 2020, one on the same day (21/5) as the fish counter was installed and the other on June 3. On June 10, 2021, fish of small size were recorded swimming both upstream and downstream in the fish counter. Species determination for these fish could not take place. Individual small fish of small size can pass the fish counter without being auto-registered and that these can also swim through the openings on the guidens fences. Other registrations in 2020 and 2021 were beaver (the majority of registrations both upstream and downstream), mink, mouse and bird

The following people employed at the Administrative County board in Norrbotten, Fisheries Unit, have participated with installation, dismantling and data analysis: Minna Brodin, Markku Kilpala, Erling Holmström, Andrew Holmes, Mikael Wallton och Stefan Stridsman.

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6. Mapping tributaries to the Kemijoki River

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6.1. Summary

A key measure was conducting an inventory of tributaries in the River Kemijoki waterway area between the City of Rovaniemi and the Isohaara power plant. The rivers or streams subject to inventories form an inventory period, the length of which is determined by a homogeneous section of the river with similar morphology. In practice, the length of the inventory section is formed, for example, by a homogeneous rapid water section, riffle section, or calm water section, and the section changes as the morphology changes. The length of the section is not determined in advance, rather the section length is formed when performing the inventory. Estimates of water depth, flow rate, bed quality, shore shadiness, vegetation coverage of shore zone, and forest type were performed during the inventories. In addition, the natural state status and factors altering the natural state were assessed, and the most important rehabilitation measures for the section were verified, if such were observed. Furthermore, the dominant particle size of riverbed material was assessed as well as the coverage of aquatic vegetation in the bottom of the watercourse. The catchment area was inspected in connection with the watercourse inventory, each inventoried according to the direction of the river, during which the ditch points loading the waterway and the loading factor of these were mapped by visual estimation, as well as the status of the water protection structures possibly identified. Prior to conducting fieldwork, geographical information systems were used for familiarisation with the area for assisting with the planning of tasks.

During 2020, a total of approximately 470 kilometres of the rivers located within the project area, including related catchment areas, were inventoried. The total inventoried area coverage, taking into account the waterway region of all tributary rivers, is approximately 344 thousand hectares. Measured by catchment area coverage, the Vähäjoki River is distinctly the largest of the tributaries in the project area, covering a total area of 734 km2. The largest tributary of the Vähäjoki River, Suolijoki River, has a catchment area covering 152.8 km2. Measured by catchment area coverage, the second-largest tributary is the Vaajoki River, covering 324 km2. The total area covered by Runkausjoki River catchment area is 315 km2, and for the River Louejoki, the catchment area is 283 km2.

Approximately 34 kilometres of rapid water sections, vital for the breeding of migratory fish species that spawn in fluvial waters, were found in all four chosen tributary rivers that were selected for preparation of the plans and were inventoried in more detail in 2021. Measured by total distance covered by rapid water sections, Vaajoki River was clearly the largest of the rivers included in the plan, where over ten kilometres of the river covering a total distance of close to 35 kilometres, were river sections classified as rapid water areas. Measured in hectares, the largest rapid water area was found in the Vaajoki River.

In summer 2020, there were eight fieldwork employees working for the Lapland ELY Centre, and the inventories were conducted in pairs using canoes or on foot along the riverbank. The inventory for the Kuolajoki River conducted by Metsähallitus was conducted by one person travelling along the banks of the river on foot. In addition, catchment area inventories for the sites specified for inventory were commenced in winter 2020, with an open map query made by the Lapland ELY Centre of loading ditches or migration obstacles in the project area using the ArcGis Geo Form application. The map query was distributed on the introductory

page for the EMRA project of the Lapland ELY Centre, and on the Facebook profile page for the EMRA project. The purpose of the query was to obtain advance information about the sites subject to inventory and the problems located in their catchment areas.
When conducting an inventory of migration obstacles, advance mapping was performed using a geographical information system and terrain map, which allowed the screening of sites travelling below roads for the inventory of natural waterways: rivulets, ditches, streams, and rivers.

The four rehabilitation plans compiled on the basis of the EMRA project findings are wide-ranging projects that would require a permit from the Regional State Administrative Agency for implementation, and the actual implementation of these would occur using separate projects or financing.

The downstream section of the Vähäjoki River through to Myllyköngäs and the largest tributary river of the Vähäjoki River, the Suolijoki River, were chosen for compiling the rehabilitation plans. Myllyköngäs and its dam form a complete migration obstacle in the Vähäjoki River. The second plan site is the Louejoki River with its source being the Louejärvi Lake, the third site is the Vaajoki River with its source being the Vaajärvi Lake, and the fourth site is the main forks of the Runkausjoki River, Ylempi-Runkausjoki River and Ala-Runkausjoki River. The main watercourse of the Runkausjoki River downstream from the confluence of the headwater forks was rehabilitated by private enterprises in summer 2021. The selection criteria used for the rivers chosen for a rehabilitation plan were the largest possible benefit of rehabilitation for the ecosystem and fisheries of fluvial waters, breeding grounds and nursery areas for migratory fish, as low as possible migration losses upon reintroduction of a migration route, and those that best support the businesses operating in the region, particularly nature-based tourism.
The nature management plans made for the catchment areas were focused on the same neighbouring river catchment areas as for the river rehabilitation plans for fishery rivers. The sites chosen for planning measures in line with the project plan were primarily the sites that satisfy the requirements of the Act on the Financing of Sustainable Forestry (KEMERA) (Temporary Act on the Financing of Sustainable Forestry (34/2015). Other sites were also included at a later date. Water protection plans were made for properties whose owners were in favour of the water protection projects and for which other characteristics for planning have been met.

6.2. Introduction

A key measure was conducting an inventory of tributaries in the River Kemijoki waterway area between Rovaniemi and the Isohaara hydropower plant dam. On the river section in question, there is a total of five power plants, from the upstream section of the river downstream; Valajaskoski, Petäjäskoski, Ossauskoski, Taivalkoski, and Isohaara at the southernmost boundary of the project area. There were twelve inventoried tributaries in total, the furthest upstream of which, Kuolajoki River, flows into the Valajaskoski impounded basin. The Ternujoki and Ropsajoki rivers flow into the Petäjäskoski impounded basin. The Leivejoki and Vähäjoki rivers flow into the Ossauskoski impounded basin. The rivers of Runkausjoki, Pisajoki, Louejoki, Vaajoki, Varejoki and Kaisajoki flow into the Taivalkoski impounded basin, and the Akkunusjoki River located further downstream flows into the Isohaara impounded basin. The tributary rivers of Kuolajoki, Ternujoki, Ropsajoki and Leivejoki are located in the City of Rovaniemi area. The rivers of Vähäjoki, Runkausjoki, Pisajoki, Louejoki, Vaajoki, Varejoki and Kaisajoki are located in the Municipality of Tervola, and further downstream, the Akkunusjoki River is located in the Municipality of Keminmaa. The inventories were conducted in the area in 2020 and 2021, with tasks concentrated on June, July, and August. The inventories were conducted by the Lapland ELY Centre, with the exception of Kuolajoki that was inventoried by Metsähallitus. The inventories conducted in 2020 assessed the river habitat, alterations caused by human activities, problems in the watercourse and neighbouring catchment area, as well as rehabilitation needs and rehabilitation possibilities.

The project also conducted monitoring of the water quality and biological status of the tributaries of the Ala-Kemijoki River (downstream section of the Kemijoki River from Rovaniemi to Gulf of Bothnia), which was used to supplement the monitoring data collected by Finland's Environmental Administration.

Obstacles for migration located in the area were also inventoried during both summers. The majority of inventoried migration obstacles were incorrectly installed road culverts and crossings of small fluvial waters. The inventories determined the type of migration obstacle and whether the migration obstacle was complete, incomplete, or intermittent. The inventories were conducted using the methods developed in the Esteet Pois! projects.

The intention for the inventories conducted in summer 2020 was to obtain comprehensive basic information about the tributary waterways of the Kemijoki River located within the project area, their baseline state, and the rehabilitation requirements and rehabilitation possibilities for the fluvial water areas, catchment areas and migration obstacles. On the basis of this information, four rivers were chosen for the making of more detailed rehabilitation plans, as well as the sites that will be rehabilitated as pilot sites for the project. The downstream section of the Vähäjoki River through to Myllyköngäs, and the largest tributary of the Vähäjoki River, Suolijoki River, Louejoki River, Vaajoki River, and the main forks of the upstream section of the Runkausjoki River, Ylempi-Runkausjoki and Ala-Runkausjoki. The main watercourse of the Runkausjoki River downstream from the confluence of the headwater forks was rehabilitated by private enterprises in summer 2021. The selection criteria chosen for the rehabilitation plan for the selected rivers were e.g., greatest possible benefit from rehabilitation for the ecosystems and fisheries of fluvial waters, and for the business in the region.

The nature management plans made for the catchment areas were focused on the same neighbouring river catchment areas as for the river rehabilitation plans for fishery rivers. The sites chosen for planning measures in line with the project plan were primarily the sites that satisfy the requirements of the Act on the Financing of Sustainable Forestry (KEMERA) (Temporary Act on the Financing of Sustainable Forestry (34/2015). Other sites were also included at a later date.

6.3. Material and methods

The employees working in the EMRA project started work in the beginning of March 2020. As soon as work commenced, preparations were made for the inventory of the catchment areas specified in the project decision and for making project plans. In line with the project decision, a total of twelve rivers where subject to inventory, Kuolajoki, Ternujoki, Leivejoki, Ropsajoki, Vähäjoki, Pisajoki, Louejoki, Vaajoki, Varejoki, Runkausjoki, Kaisajoki, and Akkunusjoki. On the Vähäjoki River, its largest tributary, the Suolijoki River, was also inventoried, as well as the largest Vaajoki River tributary, the Sivakkajoki River, and Sihtuunajoki River, which is a tributary of the Varejoki River. In respect to the Suolijoki and Sivakkajoki rivers, the grounds for the inventories were the size of the tributary and its estimated significance on fish stocks and load, and in respect to the Sihtuunajoki River, its significance on the trout populations in the downstream section of the Kemijoki River. On the basis of research conducted in earlier years, the Sihtuunajoki River was known to still have a trout population that may have been isolated from the original trout population of the Kemijoki River. Before summer and its planned fieldwork, the tributaries within the project area and their catchment areas were studied using maps, and earlier research conducted on twelve of the tributaries, in respect to fish populations, current state of watercourses, and history was examined, in addition to the forestry practices in the catchment areas and other related human activity. On the basis of this data, efforts were also made to assess the significance of the various tributary waterways within the project area on the ecosystem of the Kemijoki River downstream from Rovaniemi, on its fish populations, as well as for local people and businesses. Prior to commencing the actual inventories, geographical information systems were used to identify any navigable roads that could be used to approach the watercourse, and any other possible factors that could potentially affect the actual carrying out of the inventories.

On the basis of the material obtained, a decision was made to arrange tasks for 2020 so that all twelve of the tributaries would be primarily inventoried during the first summer. The inventories would specify the current state of each river, the factors affecting water quality, the condition of the watercourse, particularly considering migratory fish that spawn in rapid waters, the current load incurred by the catchment area, a preliminary rehabilitation requirement and rehabilitation possibilities in both watercourses and catchment areas. Possible migration obstacles located in the project area would also be mapped. On the basis of preliminary inventories, as stipulated in the project decision, four rivers would be selected for the making of more detailed rehabilitation plans and the sites of the project for the implementation of biotope-enhancing measures. It is vital that the results of the inventories conducted during the first summer are also available for utilisation in the planning and implementation of future measures for enhancing the natural state of the project area, also for the eight tributary waterways for which there are no rehabilitation plans made by the project, or that are not sites designated for biotope-enhancing measures.

The distribution of tasks among the Finnish operators was also agreed in spring 2020. In respect to the mapping work for the tributaries and biotope-enhancing measures, the ELY Centre operated the land and water areas under private ownership, and Metsähallitus would concentrate its measures on state-owned areas. For the purpose of ensuring the fluency of tasks and management of entireties, it was agreed that Metsähallitus would conduct the inventory for the Kuolajoki River located closer to the City of Rovaniemi, and the ELY Centre would be responsible for the remaining eleven.

Catchment area inventories conducted for assisting with inventories were commenced with an open map query made by the Lapland ELY Centre of loading ditches or migration obstacles in the project area using the ArcGis Geo Form application. The map query was distributed on the introductory page for the EMRA project of the Lapland ELY Centre, and on the Facebook profile page for the EMRA project.

The basis for the planning of the inventory method were the methods and inventory forms developed for the rehabilitation needs analysis of the TRIWA III – Assessment of forestry impacts and water management in the international waterway areas of the Tornionjoki River project (Alanne, Bergman, Johansson, Kangas & Rydström 2014). The inventory manual for the TRIWA III project was not used. In addition, influence was also obtained from the ditch area inventory forms of the Finnish Forest Centre and from the water protection measure inventory form of Metsähallitus. In the inventories conducted in summer 2020, observations were collected into the mobile application ArcGis Collector, to which site-specific inventory forms had been made for watercourse inventories, catchment area inventories, and for migration obstacles. The inventory method and registration method were actively developed during the course of the project.

Project fieldwork commenced as soon as the floods receded. Inventories on the Kuolajoki River were mainly focused on July, during average water and low water periods. The inventory was conducted by one person travelling along the banks of the river on foot. Five trainees and one watercourse inventory stocktaker started work on 1 June for the inventories conducted by the ELY Centre. In total there were eight ELY Centre employees conducting the inventories. As soon as work commenced, during the first two weeks, the employees were thoroughly familiarised with the filling in of inventory forms, and with all other factors that must be observed during the inventories.

The actual inventories were conducted using four pairs, and work started from the headwaters of the rivers. Travel in the inventory area was done either using canoes, or on foot, depending on the size and water conditions of the river. The persons conducting the inventory usually walked through rapid water sections in order to make more detailed observations and inventory entries. The same procedure was followed whenever a ditch flowing into and loading the waterway was observed. The waterways subject to inventories form an inventory section, the length of which is determined by a homogeneous section of the river or stream with similar morphology. In practice, the length of the inventory section was formed, for example, by a homogeneous rapid water section, riffle section, or calm water section, and the section changed as the morphology changed. The length of the section is not has been specified in advance, rather the section length was formed while performing the inventory. The inventories paid attention to water depth, flow rate, bottom quality, shore shade coverage, coverage of shore zone vegetation and forest type, and assessments were made of natural state, factors altering the natural state, and the most important rehabilitation measures for the section were verified, if such were verified as being required. Furthermore, the dominant particle size of the riverbed was assessed as well as the coverage of aquatic vegetation in the bottom of the watercourse. In addition to the assessment of the watercourse, the loading of the ditches flowing into the watercourse or other adverse impacts on the watercourse itself were also assessed.

Following completion of the fieldwork for 2020, the data received from the inventories were gathered and the results were analysed. On the basis of the obtained findings, four rivers were chosen for the compiling of the actual rehabilitation plans. The downstream section of the Vähäjoki River through to Myllyköngäs that acts as a perfect migration obstacle and further downstream lower in the largest tributary river of the Vähäjoki River, the Suolijoki River. The second river chosen for planning was Louejoki, and the third was Vaajoki. The fourth plan site was the Runkausjoki river, for which rehabilitation plans were made for its upstream section, for Ylä-Runkausjoki and Ala-Runkausjoki. The main channel of the Runkausjoki River was restored in 2020.

The grounds for this selection were the maximum possible benefits that could be achieved by rehabilitation for the entire aquatic ecosystem, the need for rehabilitation and the impacts it would have, as few migration losses of sea migrating migratory fish as possible upon restoration of the migration connection, and those rehabilitation measures that would best support local businesses, especially nature-based tourism. Selection of the rivers was also influenced by location. Of the tributaries selected for rehabilitation planning, three flow into the second-most downstream impounded basin of the Kemijoki River, Taivalkoski, and one flows into the next impounded basin, Ossauskoski. All rivers are located within the Municipality of Tervola. All four rivers flow into the main watercourse of the Kemijoki River at locations rather close to one another.

The management plans made for the catchment areas were focused on the same neighbouring river catchment areas as for the river rehabilitation plans for fishery rivers. Used to assist planning in the former winter season, geographical information systems were used, the most important of which were the nature management spatial datasets provided by the Finnish Forest Centre, the Uljas spatial dataset system planning and monitoring system for protected areas maintained by Metsähallitus, the catchment area demarcation tool of the Finnish Environment Institute, and the spatial dataset for acid sulphate soils maintained by the Geological Survey of Finland. The sites chosen for planning measures in line with the project plan were primarily the sites that satisfy the requirements of the Act on the Financing of Sustainable Forestry (KEMERA) (Temporary Act on the Financing of Sustainable Forestry (34/2015). Other sites were also included at a later date. The property owners of properties preliminarily considered as being suitable for catchment area planning were contacted by telephone. In support of the rehabilitation plans for the catchment areas, a thesis required for becoming a forestry engineer was also made. In connection with the calls made to property owners, the owners participated in a questionnaire conducted with in the scope of the thesis that evaluated the interest of private landowners in the water protection solutions. In connection with the questionnaire, the preliminary attitudes of property owners on water protection projects were received. Water protection plans were made for properties whose owners were in favour of the water protection projects and for which other characteristics for planning have been met.

Three more trainees and one more experienced planner were employed for the project for performing fieldwork. As with the previous summer, the employees were divided into four different teams. The permanent employees of the project worked alone, and the others in four pairs. At the sites to be inventoried, those with forestry industry-related training concentrated on inventories conducted for catchment areas, and those with fisheries sector or biological training concentrated on the inventories conducted on watercourses. All employees took part in conducting inventories of migration obstacles.
The inventories conducted in 2021 undertook to specify the baseline state, rehabilitation need, and rehabilitation measures of the planning areas as accurately as possible. As with the previous summer, inventory data were gathered using a mobile application form template. The earlier ArcGIS Collector was replaced by the service provider with the more reliable and better suited application for telephone connections, and more streamlined ArcGIS Field Maps.

In line with the preliminary inventories conducted during the previous summer, the waterway forms an inventory section, the length of which is determined by a homogeneous section of the river or stream with similar morphology. In practice, the length of the inventory section was formed, for example, by a homogeneous rapid water section, riffle section, or calm water section, and the section changed as the morphology changed. Using the application used in the 2021 inventories, the upstream and downstream boundaries were precisely determined, and as with the earlier inventory, attention was paid to water depth, flow rate, bottom quality, shore shade coverage, coverage of shore zone vegetation and forest type, and assessments were made of natural state, factors altering the natural state, and the most important rehabilitation measures for the section were verified, if such were verified as being required. Furthermore, the dominant particle size of the riverbed was assessed as well as the coverage of aquatic vegetation in the bottom of the watercourse. On the basis of the observations made, the application was used for entering a preliminary proposal and instructions for rehabilitation measures to be implemented by rapid water section, such as the making of spawning grounds, increasing the flow of tributary streams, the making of protective sites, the adding of wood material, and other measures that enhance biotope diversity. For the sections proposed for rehabilitation, the application was also used for entering information about and quantities of potential on-site rehabilitation materials, such as rocks on the shores that had been removed from the river, and any possible gravel located in the watercourse. The application was also used to enter the materials required for conducting the rehabilitation measures, an estimate as to the required quantities, and whether the rehabilitation will be done using machinery or manually.

The ditches that were recorded in the 2021 inventories for the previous summer as loading waterways were subject to a repeat inventory, and the reason for and source of the load was investigated. The inventory was conducted on foot and extended out to the upstream drainage area. In connection with the inventory, a preliminary proposal for water protection structures suitable for the site, its location was issued, and the benefits of the structure for reducing load were estimated. The proposed measures are planned for nearby catchment areas of drained rivers used for forestry purposes that have shown to incur active water loading. The most commonly observed load type was solid loading caused by erosion. The water protection plans made for the EMRA project primarily proposed the water protection means eligible for finance according to KEMERA (Temporary Act on the Financing of Sustainable Forestry (34/2015). The starting point for water protection plans is the continuation of feasible forestry activities following the implementation of the water protection measures. On the privately-owned properties of the nearby catchment areas of rivers, the Lapland ELY Centre did not handle wide-ranging water protection measures in the plans compiled in the EMRA project, such as bog restoration or the building of wetlands. Standard methods of Finland's Environmental Administration were used for waterway monitoring. Water samples were analysed in accredited laboratories. Benthic fauna was collected from the same rapid water sections using four 30-second kick-net sampler. Periphyton samples were collected off stone surfaces in the same rapid water sections. All findings were recorded in registers maintained by Finland's Environmental Administration. The project continued the mapping of possible migration obstacles that was commenced in 2020. Mapping was performed throughout the open water season, until snow and the freezing of the waterways prevented mapping. With a few exceptions, mapping inspected all sites within the project area marked on the map where the waterway flows below a road. In addition, the migration obstacles were also assessed in connection with the watercourse inventories, where attention was given to migration obstacles caused by nature, such as waterfalls, as well as human-made structures, and other changes in the watercourse. Obstacles such as these could be e.g., the remains of dams built for the purpose of log driving.

The guide produced by the Esteet Pois II project was used for the mapping of migration obstacles. The purpose of the guide was to promote the need for information for the fieldworkers and fluvial water rehabilitation workers about identifying the obstacles caused by waterway culverts, increase expertise into the implementation of rehabilitation measures, and using examples to illustrate the costs of various rehabilitation tasks. In the mapping, characteristics and harm were assessed visually and using measurement. The mapping measured the head from the culvert to the surface of the water and the water bottom, flow rate and the depth of the water in the culvert, installation gradient and the bottom of the culvert. In addition, possible migration obstacles upstream and downstream from the culvert were assessed, such as the depth of the water in the approaching basin and tightness, possible obstacles existing in the approach area, such as vegetation and material carried with the current. In addition, the culvert itself was assessed for condition, diameters and lengths were measured, and the number of culverts recorded. For each culvert, estimates were made pertaining to the duration of the migration obstacle it forms and its significance, i.e. if the obstacle is definitive, occasional, or partial.. In connection with the mapping, entries were also made in the inventory form for a proposal for the rectification of the culvert obstacle.

6.4. Results

The aim of the task of the Lapland ELY Centre to conduct the inventory and make plans for the river channels and catchment areas for twelve tributaries was to develop an inventory method, create new working procedures, produce fishery restoration plans for four rivers, and 30 nature management plans for the project region in cooperation with owners of the land and water areas. This means support for the main principles of the EMRA project to enhance the state of the natural environment and to restore the living environment of the aquatic organisms of the river environment.

The goal of the EMRA project was to develop the mapping method for the TRIWA III project for the forestry impact assessment and water management for the river Tornionjoki' s international watercourse area and to combine mapping methods suitable for the fishery restoration planning of rapid water sections and nature management planning with the watercourse and shore zone mapping. The mapping methods were developed by exploring and making compatible the methods and recording details used by other organisations. For the purpose of nature management planning, an ArcGIS Field Maps application form was developed primarily for supporting the planning of water protection. At the same time, the already existing form templates were developed to become more suitable for supporting the restoration planning for the fluvial areas of the rivers to become more suitable for the fry production of fish that spawn in the rivers. The forms are also easily edited for the planning of nature restoration measures and the collection of information. The method speeds up the travel of information by combining the observations made in the terrain and the plans with the ArcGIS Online geographic information system. It is possible to add a number of users in the ArcGIS Online workspaces, which means that the sharing of information is effective and up to date. The method provides a means for increasing cooperation and information exchange in working communities and between organisations. In addition, this is a congruent method of recording and measuring things that enhances the reliability and comparability of the information.

The Lapland ELY Centre and Metsähallitus mapped a total of twelve tributaries on the Kemijoki River on the river section between Rovaniemi and Isohaara. The mapped rivers starting from Rovaniemi travelling downstream are Kuolajoki, Ternujoki, Ropsajoki, Leivejoki, Vähäjoki, Runkausjoki, Pisajoki, Louejoki, Vaajoki, Varejoki, Kaisajoki, and Akkunusjoki. In addition, the larger tributaries of these rivers that were considered to have significant impact on the load coming from the catchment area or possibly significant as the breeding grounds for migratory fish were also mapped. The tributaries chosen for mapping were the upstream sections of the River Ternujoki; Mustijoki and Tiskijoki, Reutujoki of the Ropsajoki River, the Suolijoki River on the Vähäjoki River that has also been selected for restoration planning, the Purnuoja Stream of the Pisajoki River, the Sivakkajoki River of the Vaajoki River, and the Sihtuunajoki River of the Varejoki River. The total coverage of riverbeds mapped was approximately 470 kilometres. The mapping identified around 1,350 ditches, of which approximately 600 were estimated to receive load. A total of 649 potential migration obstacles were mapped, of which 211 acted as some degree of migratory obstacle. The number of migration obstacles is similar to those indicated in earlier studies, where approximately one-third of all road culverts were established as being obstacles for migration. All in all, the Lapland ELY Centre made fluvial area restoration plans for six tributary rivers, particularly taking into consideration the habitat requirements of trout. When choosing the sites for restoration planning, it was considered appropriate to expand the four plans required by the project plan into six, in order to ensure that the plans would form sufficiently effective entireties. Two of the plans – Yli-Runkausjoki river and Ala-Runkausjoki river – are focused on the upstream section of the Runkausjoki River. The mainstream of the Runkausjoki River was earlier restored in 2021. In addition to the largest tributary of the Vähäjoki River, the Suolijoki River, it was also necessary to extend restoration measures to the Vähäjoki River and its section located downstream from the Myllyköngäs dam, into which the Suolijoki River flows. Myllyköngäs on the Vähäjoki River is an absolute migratory obstacle due to the decommissioned dam located on the site. Other restoration plans were made for the Louejoki and Vaajoki rivers. All rivers and most of their catchment areas are located in the Municipality of Tervola, and, with the exception of the Vähäjoki River, flow into the Taivalkoski impounded basin. The Vähäjoki River flows into the Ossauskoski dam basin. The rapid water sections to be restored according to the restoration plan covered a total of 34.4 kilometres and 32.3 hectares. There are 204 biotopes, i.e., rapid water sections, planned for restoration that are divided into 69 restoration areas. Of the restoration areas, 13 are located on the Suolijoki River, 4 on the Vähäjoki River, 18 on the Louejoki River, 17 on the Vaajoki River, 12 on the Yli-Runkausjoki River, and 5 on the Ala-Runkausjoki River. Measured by total rapid water area, the Vaajoki River was distinctly the largest, with the total rapid water area coverage of approximately 8.6 hectares. The Vaajoki River also differed from all the other mapped rivers, including that in respect to the fact that the rapid water areas comprised nearly 40 per cent of the total distance of the mapped river sections. Particularly in the upstream section of the Vaajoki River, the distances covered by rapid water sections were up to a number of kilometres in length. The area covered by rapid water was also significant on the Louejoki River. The total rapid water area coverage of the mapped areas was 7.3 hectares. The rapid water area coverage for the Suolijoki River totally 5.7 hectares, 4.0 hectares for the Yli-Runkausjoki River, and 1.5 hectares for the Ala-Runkausjoki River. In the restoration plans, at least some degree of restoration is proposed for nearly all the rapid water sections. The most commonly proposed restoration measure is adding of spawning gravel.

Figure 55. Mapping of the riverbed in the river Vaajoki in the summer of 2021. Photo: Timo Lettijeff, Lapland ELY-centres.

In accordance with the project plan, 11 nature management plans were also implemented that primarily deal with the protection of water bodies. These entireties differ from one another, involve a versatile range of different water protection measures, and have varying scope. In order to enhance the effectiveness of the water protection measures, the plans were located in the same nearby catchment areas of rivers as those for the river restoration plans made by the Lapland ELY Centre. The water protection measures support river restoration plans by reducing the solids washed along ditches. In addition, the travel of metals and organic materials into the watercourses is reduced. In order to achieve long-term benefit from the river restoration, the load site for each catchment area of the river must first be actively addressed.

The nature management plans are mainly focused on privately owned properties that, based on the inventories conducted in the EMRA Project, have the need to reduce the watercourse loading caused by forestry. In accordance with the project plan, the selection of sites for planning highlights the sites that are suitable for KEMERA financing. Prior to planning, the position of the property owner on the water protection projects was clarified. Due to the restrictions imposed by the COVID-19 pandemic, it was impossible to organise meetings, so all communication was handled by telephone and email. The number of nature management plans had to be reduced but this was compensated for by expanding the plans wherever possible. Due to there not being any information briefing events that are normally organised in connection with river restoration plans, valuable information about the experiences of the people who use the rivers subject to planning, and information about the state of the rivers from local people, some having lived in the area for decades, was not received.

As a result of mapping related to the restoration and nature management planning for fisheries, information was produced in the EMRA Project about the state of the Ala-Kemijoki rivers and their catchment areas, and about the need for water protection.

Fine soil is typical for the area that can easily be washed along forest ditches to access the watercourse. The bogs of the catchment area are almost entirely ditched, which means that there is insufficient natural water retention in the catchment area and the precipitation and thaw water flow along the ditches to quickly access the watercourse. The flow rate in the ditches can occasionally rise to high levels with dramatic fluctuations in water height, which plays its own part in the erosion and washing of soils. Due to natural retention, floods in the area are also quick and powerful, and during the low-water times of the summer months, especially during hot summers, the rapid water sections almost run dry. All of the rivers in the area have once been used for timber floating, which means that all of the rivers have been dredged using machinery or by manual labour for the purpose of timber floating. Following the cessation of timber floating, the rivers were restored in the 1990s. The restoration was conducted to the best of the knowledge available at the time, and therefore does not conform to today's requirements. The restoration measures mainly involved the demolition of structures made for the purpose of timber floating, such as dams, and returning individual rocks into the river. With the dredging of the rivers, the spawning gravel and stony areas comprising stones with a small diameter that are important for young fish have been washed away entirely in some places. Despite the restoration implemented earlier, also the rocks that are above the surface of the water are missing or their numbers are too few. The lack of surface rocks complicates the winter freezing of the river. Due to the lack of rocks breaking the surface of the water, the forming of ice cover in rapid water sections of the river is slow and often the rapids will freeze on the bottom first. In some rapid water sections this is evident with almost complete lack of the river bottom flora and the freezing of the riverbed also destroys any possible fish eggs laid on the river bottom. The Ala-Kemijoki catchment area is the former seabed and in places acidic sulphate soils are found. This has been taken into account in the water protection measures by emphasising alternatives that do not further dry the soil and those that require as little excavation as possible.

Figure 56. River Vaajoki, whose rapids areas lack stones reaching the surface and the river is frozen at the bottom. The lack of bottom vegetation in Vaajoki is probably due to the freezing of the bottom of the rapids. Photo: Timo Lettijeff, Lapland ELY-centres.

The nature protection plans have addressed eight different water protection means or combinations of such. The plans include a total of 30 sites. The extent of individual plans varies according to requirements and possibilities. The EMRA project area’s erosion-sensitive, finely grained soil type and acidic sulphate soils affected the selection of water protection methods to favour natural solutions to avoid excavating. In addition, planning was affected by the typically small and narrow spaces along the riversides. The narrow properties posed some challenges for the placement of water protection structures. The most popularly proposed measure, altogether 38 times, was adding of wood material into the forest ditches or water storage structure. The second-most popular proposal was a base dam, altogether 26 times. Other water protection methods, such as flow rate regulating dams, sedimentation basins, overland runoff areas, stream restoration, and ditch blocking was suggested 2–20 times. When operating in nearby catchment areas, the possibilities for the management of nutrients and solids using effective surface runoff areas are limited because of the gradients of terrain forms close to the river and a dense network of ditches.

Figure 57. A new forest ditch in the upper part of the Suolijoki river. Photo: Jere Jääskeläinen, Lapland ELY-centres.

In the restoration plan for the rivers, emphasis is placed on the restoration of the breeding and spawning areas for fish. Almost every restoration area will receive deliveries of gravel with a grain diameter suitable for trout to make spawning gravel areas. In some areas, it is also necessary to add small stones that are suitable for juvenile fish. Rocks are added to the rapid water sections, either by excavating the bottom or using rock material available from the river shores. The shores of the rapid water sections often still have the rocks and boulders that were removed from the river for the purpose of timber floating. The available rock material is used to construct or strengthen existing rapid steps. Rocks and boulders that break the surface of the water will also be added to the river for promoting the formation of the ice cover. If there are, for example, vegetation-covered rocks already in the vicinity of the areas for restoration in tributary streams and ditches, these will be transferred to the areas to be restored to speed up the formation of bottom vegetation. The adding of wood material to the areas for restoration in addition to adding rocks is a good way of increasing flow rate and directions. The added wood material also provides shelter and nutrition for various aquatic organisms. The wood material to be added is sourced from the shores of the areas for restoration if the landowners provide their consent for such.

6.5. Discussion

The main principles of the EMRA project were to enhance the state of the natural environment and to restore the living environment of the aquatic organisms of the river environment. In order to achieve this goal, it is important to start work from the river catchment areas. The benefits of river restoration can remain temporary, if loading from the catchment area continues. On the Finnish side of the EMRA project area, land use is forestry-dominated, with less agriculture, peat production and a less heavily built environment. The water loading caused by agriculture is emphasised in the River Kemijoki watercourse as the seashore is approached. In all the six areas for restoration, the load in the river was almost entirely caused by forestry.

The Lapland ELY Centre developed a nature management-suitable mapping method to be used in the ArcGIS Fields Maps application. The developed mapping method requires fine-tuning, which will succeed in the future through experience of using the system. It would be good to gather opinions and development suggestions from different organisations and users so that the method serves as many requirements as possible. In addition, it is necessary to synchronise the method between different users, in order for inventory data and plans follow the same principles and usability improves.

The COVID-19 pandemic prevented public events and meetings from being organised, which significantly impacted the possibilities for working in cooperation with the locals. River restoration plans and nature restoration plans were taken forward without any real interaction with the owners of land and water areas, which affected the geographical placement of plans, the extent of content, and the exchange and communication of information to the landowners of the project area. The landowners of the river shores chosen for restoration in the river restoration plans of the EMRA project were reached by telephone in connection with the telephone questionnaire that was carried out as thesis work. Getting contact information from private individuals is challenging, which plays its own part in reducing the sample size. Phone conversations were seen as a limited means of cooperation when the issue discussed was not previously familiar to both parties. The number of people reached by telephone was unfortunately small, although the cooperation with the contacted landowners was fluent, and the discussions provided valuable information, such as about the fish stocks in the area. As part of the questionnaire, the respondents' preliminary interest in water protection projects on their own properties was investigated.

Adding wood material to forest ditches and water protection structures is a new water protection method that has shown promising research results (Huotari 2021). The Finnish Environment Institute has studied the water-cleaning impacts of wood material, and the results show that wood material reduces flood-related watercourse loading, reduces nutrients and suspended solids that end up in watercourses, and increases the number of benthic fauna, thereby increasing biodiversity. The Lapland ELY Centre included the method in the planning from the beginning of the project and also arranged a pilot site in the summer of 2022 to test the method in practice. The sites were selected based on information obtained from the catchment area inventory.

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7. Pilot measures in the tributaries of the Kemijoki River

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7.1. Summary

On the basis of inventories conducted in summer 2020, sites were also selected for the rehabilitation of pilot sites performed by the project.
The Lapland ELY Centre chose the pilot areas as spawning gravel beds for the Ropsajoki River, the water protection structures for implementing in the catchment area for the Suolijoki River, and replacement of the road culvert that acts as a migration obstacle on the Sihtuunajoki River that is a tributary of the Varejoki River. As pilot sites in the Raudanjoki River waterway area, Metsähallitus rehabilitates the Silmäjoki River, Vaattunkijoki River, and the Raudanjoki River at Vikaköngäs with spawning gravel laying, adding of rocks in the watercourse, and adding wood material. Of the selected pilot sites, the rehabilitation measures to be conducted on the Silmäjoki and Vaattunkijoki rivers, and the water protection structures to be installed in the Suolijoki River area are performed manually, while the rehabilitation of Vikaköngäs, Sihtuunajoki River and Ropsajoki River is done using machinery.
The Ropsajoki waterway's source is the Tervajärvi Lake, from which starts the Tervajoki River that flows into the Venejärvi Lake. The Venejoki River starts from the Venejärvi Lake, and its name changes to Ropsajoki River approximately six kilometres downstream from the Venejärvi Lake. The Ropsajoki River runs from the east into the Kemijoki River close to the village of Muurola. The total area covered by the Ropsajoki River waterway catchment area is 89 km2 and the lake coverage is 3.6%. The length of the Ropsajoki River is 19 kilometres. By type, the river is a small peatland river, the ecological state of which has been classed as 'good' (Water bodies data system VEMU of Finland's Environmental Administration).
The Ropsajoki River waterway was used for log driving, with the last log driving on the Ropsajoki River being in 1955. For the log driving implemented, almost every rapid water section of the Ropsajoki River has been cleared. In addition, a number of log driving dams have been made for enabling log driving, guiding walls made using the rocks removed from the constructed watercourse, and straightening of the watercourse had been done using excavation.

The log driving rule for the Ropsajoki River was overturned in 1980 and the removal of log driving structures in accordance with a Water Court ruling was conducted in 1990. The laying of spawning gravel beds within the scope of the EMRA project for the currently planned rapid sections, and rehabilitation measures in line with the ruling issued by the Northern Finland Water Court, were conducted by Lapin Vesipiiri in a number of areas, but a number of rapid water sections have not experienced any rehabilitation at all. One of the rivers mapped by the EMRA project in 2020 was River Ropsajoki. The mapping of the Ropsajoki River assessed the river habitat (current type, quality of riverbed, vegetation, impact of human activity, need for rehabilitation). the neighbouring watershed was assessed for vegetation and soil, impact of human activities, loading quality, and the need for rehabilitation. According to an inventory carried out in summer 2020, a number of structures made to facilitate log driving could still be seen in the terrain, but the rapids on the Ropsajoki River were considered as having been naturally adapted rather well. As usual for dredged river waterways, no gravel spawning grounds for trout were observed in the rapid water sections of the river. The Ropsajoki River was selected as the pilot area for the project, and the laying of spawning gravel will be implemented for the river. It was decided that the laying

of gravel for spawning should focus on a single river, in order to achieve as big a fisheries benefit as possible.

The Metsähallitus sites of the Silmäjoki, Vaattunkijoki, and Raudanjoki rivers are located in the Kemijoki River catchment area and form a uniform network with the tributaries of the Kemijoki River. The Raudanjoki River flows into the Kemijoki River in the village of Oikarainen and its downstream sections have been substantially altered for use in hydropower production. Olkkajärvi, the most downstream lake of the Raudanjoki River, operates as a regulated basin for the Permantokoski hydropower plant. Otherwise, the Raudanjoki River waterway is in an unharnessed river ecosystem, with the largest lakes listed downstream to upstream being Olkkajärvi, Vikajärvi, Ala-Nampajärvi, and Ylä-Nampajärvi. The lakes or the fluvial waters running between these form a possible habitat for the lake-migratory trout, providing that spawning is achieved using supplementary rehabilitation. The largest tributary of the Raudanjoki River is Vikajoki River that has plenty of lakes. The most downstream lake of the Vikajoki River is Köyryjärvi, followed by Pirttijärvi, Venejärvi, Kielijärvi, Karvatit, Kalliojärvi, Alajärvi, Keskijärvi, Purnujärvi, the Naarmajärvi lakes, Majavajärvi, and Enijärvi. By Perä-Pohjola (Southern Lapland) standards, the Raudanjoki waterway area has a significant number of lakes. The Silmäjoki and Vaattunkijoki rivers are tributary channels of the Raudanjoki River that flow into the downstream section of the Raudanjoki river, in a section of the river located between the Olkkajärvi Lake and Vikajärvi Lake. The Vaattunkijoki River does not have any larger lake basins and the river represents a typical large stream waterway for peatlands. The Vaattunkijoki River has been cleared for log driving purposes, and possibly also for the drainage of forest land in the area. The Silmäjoki River waterway has a number of lake and pond extensions, the furthest downstream of which is the Apukkajärvi Lake. Upstream from the Apukkajärvi Lake, the lake basins are Toramojärvi, Latvajärvi, Tammilampi, and Perälampi. The name of the Silmäjoki River changes a number of times, but the actual Silmäjoki River is located in the central section of the river ecosystem. In the areas further upstream, the Silmäjoki River is called Otsuoja, with the names of the river changing downstream to Latvajoki and Toramojoki. Waterway arrangements related to directing water to fish farm ponds were implemented on the upstream sections of the Silmäjoki River in the 1970s, which means that the upstream section of the Silmäjoki River is not in its natural state either. The Silmäjoki River has been also cleared for log driving purposes, and possibly also for the drainage of forest land in the area.

The Silmäjoki and Vaattunkijoki rivers are watercourses that have been cleared for the purpose of log driving, with the average width of the areas for rehabilitation being approximately 4–6 metres. In accordance with the Water Act, despite being named as rivers, both sites are classified as being streams, with catchment areas covering less than 100 km2. Being small fluvial sites, these are suitable for manual rehabilitation measures. Sacks of natural gravel (average diameter of 30–60 mm) have already been transported to the sites. The purchasing of spawning gravel and haulage to the worksites were implemented by earlier Metsähallitus projects, which meant that these activities did not cause any costs for the EMRA project. The costs related to actual rehabilitation measures were paid by the cost centres of the EMRA project.

The Raudanjoki River is clearly larger than the other two Metsähallitus pilot sites. In respect to fisheries, following the cessation of log driving the Raudanjoki River has been rehabilitated, but the riverbed of the river area mainly comprises boulders and finer soil material, and despite rehabilitation measures, the area has no naturally spawning trout stocks. There is also no certainty that grayling naturally breeds in the area, but the stock can be considered to be rather weak. It was verified that as supplementary rehabilitation measures in the area, there is a need for laying spawning gravel and adding wood material. The implementation of tasks was put through a tender procedure specifying tasks to be implemented using forestry tractors modified for handling rehabilitation tasks.

Of the rehabilitation sites, the sites located in the Silmäjoki and Vaattunkijoki rivers had already been rehabilitated in the upstream rapid sections during earlier years. Employing EMRA project resources, the streams were rehabilitated to completion in terms of fisheries, and conditions can be assumed to improve by strengthening the lifecycle of migratory fish. The methods chosen by the Lapland ELY Centre for piloting water protection structures for installation in the catchment areas were the adding of wood material in forest ditches and water protection structures. The method was developed in the "Making water protection and waterway rehabilitation more effective using new wood-based materials" project, and the continuation project "Catchment area level piloting of wood cleaners for the water management of agriculture and forestry". The method primarily uses softwood, from which the trunk bundles, treetops, or branched small trees are installed in forest ditches and water protection structures. The pilot sites chosen for catchment area piloting are on two privately-owned properties located on the banks of the Suolijoki River in Rovaniemi.
For the final pilot site, the grounds for the replacement of the road culvert that acted as a migration obstacle on the Sihtuunajoki River, a tributary of the Varejoki River, was the existence of a trout population that had become isolated from the original population, which had been verified in earlier studies. The removal of the migration obstacle significantly increases the rapid surface area potentially suitable for trout and facilitates the migration of trout.

7.2. Introduction

On the basis of inventories conducted in summer 2020, sites were selected for the rehabilitation of pilot sites performed by the project. A total of twenty pilot sites were subject to rehabilitation. The rehabilitation measures performed were restoring gravel beds for spawning grounds, water protection structures, and the removal of migration obstacles. The restoration of gravel beds for spawning grounds were performed in the Ropsajoki River located in the City of Rovaniemi area, water protection structures in the catchment area of the Suolijoki River, and the removal of a fish migration obstacle in Sihtuunajoki River that is a tributary of the Varejoki River. In respect to the restoration of gravel beds for spawning grounds in the Ropsajoki River that acted as the selection criterion for the selected sites, by centralising these gravel beds on a single river, the achievable benefit would be as large as possible. For the same reason, the water protection structures to be constructed in the catchment areas were concentrated on a single river. The reasoning for the removal of the migration obstacle was that the road culvert for rehabilitation acted as a full migration obstacle on the Sihtuunajoki River that, on the basis of earlier studies, the other one of these in the tributary water of the downstream section of the Kemijoki River still has the occurrence of trout indigenous to the Kemijoki River.

Metsähallitus conducted rehabilitation on the pilot areas on the Silmäjoki River, Vaattunkijoki River, and Raudanjoki River waterways. These sites are located in the catchment area for the Kemijoki River and form a network of tributary rivers. The Raudanjoki River flows into the Kemijoki River in the village of Oikarainen located upstream from Rovaniemi and its downstream sections have been substantially altered for use in hydropower production. Otherwise, the Raudanjoki River in an unharnessed river ecosystem. The lakes located in the waterway region form a possible habitat for the lake-migratory trout, providing that spawning is achieved using supplementary rehabilitation. The Silmäjoki River and Vaattunkijoki River sites located in the catchment area for the Raudanjoki River were partly streams and partly rivers that were suitable for manual rehabilitation measures. At the Vikaköngäs site on the Raudanjoki River, supplementary rehabilitation is performed using a forestry tractor. The rehabilitation measures to be conducted are mainly restoration of gravel beds for spawning grounds, placing rocks in the watercourse, and by increasing wood material.

7.3. Material and methods

The pilot sites for biodiversity-enhancing measures were chosen on the basis of earlier data gathered from the project area and the inventories carried out in summer 2020. With the selection of sites, efforts were made to focus measures on a versatile manner and as broadly as possible throughout the project area. The grounds for selection were the overall benefits achievable with limited resources for the ecosystems of the river areas, the improvement of the habitats for migratory fish, and the promotion of their migration and breeding possibilities. Efforts were also made to make selections in such a way that their type would be present in the project area and widely available throughout North Finland, and the need is distinct. Wherever possible, individual measures were focused by size on such areas where the achievable benefit would be as big as possible and the monitoring of measures possible.

The measures chosen in respect to the water protection structures to be implemented in the catchment areas were the adding of wood material into the forest ditches and water protection structures. The measures decided to be conducted in the tributary watercourses within the project area were primarily adding rocks and spawning gravel that can either be implemented manually or using light machinery. The third biodiversity-enhancing measure was the removal of migration obstacles. The Metsähallitus sites chosen for implementing measures were the fluvial water sites that were subject to rehabilitation measures during earlier projects. As an outcome of the EMRA project, the fisheries rehabilitation measures for the sites in question were completed in the sections that were not possible to rehabilitate in earlier projects. The Metsähallitus sites were stream and river sections, the inventory and rehabilitation requirements of such were determined in earlier Metsähallitus projects, such as the ‘Valuma-alue’ (Catchment Area) project.

In respect to the migration obstacle removal, the measure chosen was the removal of the culvert that functioned as a definitive migration obstacle and replacement using a new culvert. The replacement of the culvert facilitates the migration of trout in the Varejoki River tributary, the Sihtuunajoki River, which in earlier studies has been verified as being one of two tributaries of the Ala-Kemijoki River that is home to a trout population that has been isolated from the original trout stock in the Kemijoki River. The Sihtuunajoki River and its trout population is important when considering the revival of the entire trout population of the Ala-Kemijoki River as the sea migration connection is opened. The road culvert that acted as a definitive migration obstacle completely prevented the migration of all aquatic fauna for a distance of a number of kilometres in the section of the river upstream from the culvert and the lake basins. The road culvert site running beneath the road and forming a migration obstacle had a total of seven iron pipes of varying diameters, and from the lower end the head fall to the water surface was approximately one metre. With the rehabilitation of the site and the removal of the migration barrier, the culvert was replaced by a steel culvert with a diameter of two metres and length of ten metres. In order to facilitate the upstream migration, pools were made for the river sections downstream from the culvert and thresholds were made in such a way that a natural bed of gravel and rocks was set inside the culvert with a thickness of approximately 40 centimetres, and the water level was raised by a minimum of twenty centimetres during low flow rate times. The flow rate was set to a suitable level using the length and gradient of the culvert, which facilitates the upstream migration for the majority of aquatic fauna. The landowner of the forestry vehicle road running over the road culvert and the site, Tornator Oy, issued permission for implementing rehabilitation measures. Tornator Oy also participated in the purchasing of the culvert and the costs of replacement.

The replacement of the road culvert was put out to tender as a joint contract with the laying of spawning gravel in the Ropsajoki River in spring 2022. The tender included all the necessary materials and work. In respect to the Ropsajoki River, the acquisition of gravel material to be used was put out to tender and the gravel was already delivered in 2021.

For the implementation of water protection structures made in the catchment areas, the manual adding of wood material was chosen. The method was developed in the “Making water protection and waterway rehabilitation more effective using new wood-based materials” project, and the continuation project “Catchment area level piloting of wood cleaners for the water management of agriculture and forestry”. The method primarily uses softwood, from which the trunk bundles, treetops, or branched small trees are installed in forest ditches and water protection structures. The pilot sites chosen for catchment area piloting are on two privately-owned properties located on the banks of the Suolijoki River in Rovaniemi. (Huotari et al. 2021.) The adding of wood material in the forest ditches and water protection structures mimics nature’s own means by binding the solids and nutrients washed by the water and increasing natural diversity. The wood material added to the forest ditch and water protection structure reduces the finely grained soil ending up in the waterway. A thin biofilm of periphyton forms on the surface of wood materials submerged in water that comprises bacteria, algae, and fungus. The waterway loading of the forest ditch is reduced, as the biofilm and the organisms benefiting from this filter impurities from the ditch water and consume nutrients. (Huotari et al. 2021.) The method has low costs and can be implemented in connection with forest management measures or as own activities conducted by the forest owner. The necessary tools were hand-operated tools, such as e.g., brush cutters, chainsaws, and axes. Water protection structures were implemented in the catchment area of the Suolijoki River. The task was conducted by the ELY Centre and project employees, with a 3–4-person group working at any one time. A rehabilitation plan was made for the Suolijoki River within the EMRA project for the fisheries rehabilitation of fluvial areas. The water protection structures implemented as pilot work, and the reduction of loading received by the main watercourse as a result also benefits any fishery rehabilitation measures to be implemented at a later date and improves the ecological status of the river.

In respect to the ELY Centre, the site intended for rehabilitation measures in the river watercourses of the project area was the Ropsajoki River that is located close to the City of Rovaniemi. In the inventories, the Ropsajoki River was verified by rapid sections as having a fast flow and having a bottom been primarily cleared of rocks and boulders, which is typical for rivers cleared for the purpose of log driving. Small stones and gravel suitable for spawning and trout nursery grounds was not observed in the inventories. By its condition, the Ropsajoki River had already almost achieved natural status that the rehabilitation measure chosen was the laying of spawning gravel beds in the suitable rapid water sections. The delivery of gravel was put out to tender and the gravel was delivered to the areas intended for the laying of gravel in spring 2021. 200 tons of gravel was acquired. The actual laying of the gravel was implemented during July of the following summer. Work was conducted using a forestry tractor fitted with a clamshell bucket, using which the gravel was transported from the stockpiling areas to the gravel bed sites and laid on the riverbed. The gravel used in the tasks had an average diameter of 60 mm, with the fluctuation margin being 20–150 mm. Travel to sites intended for the laying of spawning gravel were marked and cleared in advance, and the gravel sites in the river were either marked in advance or indicated during the execution of tasks by a fisheries expert who was responsible for directing work.

In respect to Metsähallitus, pilot sites for rehabilitation were selected from the Silmäjoki, Vaattunkijoki and Raudanjoki waterways. These sites are located in the catchment area for the Kemijoki River and form a network of waterway tributary rivers of the Raudanjoki River waterway area. The Raudanjoki River flows into the Kemijoki River in the village of Oikarainen and its downstream sections have been substantially altered for use in hydropower production. Olkkajärvi, the most downstream lake of the Raudanjoki River, operates as a regulated basin for the Permantokoski hydropower plant. Otherwise, the Raudanjoki River waterway is in an unharnessed river ecosystem. The selected sites have been cleared for log driving purposes, and possibly also for the drainage of forest land in the area. Waterway arrangements related to guiding water to fish farming ponds had also been done for some of the waterways. The selected sites partly represent streams and partly rivers.

Being small fluvial sites, the Silmäjoki and Vaattunkijoki rivers are suitable for manual rehabilitation measures. Sacks of natural gravel (average diameter of 30–60 mm) were delivered to the sites during earlier projects of Metsähallitus. The purchasing of spawning gravel and haulage to the worksites belonged to earlier Metsähallitus projects, which meant that these activities did not incur any costs for the EMRA project. The actual manual rehabilitation measures and related costs were paid by the cost centres of the EMRA project. The actual rehabilitation planning for the Silmäjoki and Vaattunkijoki rivers was implemented in earlier Metsähallitus projects.

The Raudanjoki River is clearly larger than the other two Metsähallitus pilot sites. In respect to fisheries, following the cessation of log driving the Raudanjoki River has been rehabilitated, but the riverbed of the river area mainly comprises boulders and finer soil material, and despite rehabilitation measures, the area has no naturally spawning trout stocks. There is also no certainty that grayling naturally breeds in the area, but the stock can be considered to be rather weak. It was noticed that as supplementary rehabilitation measures in the area, there is a need for laying spawning gravel and adding wood material. The implementation of tasks was put through a tender procedure specifying tasks to be implemented using forestry tractors modified for handling rehabilitation tasks. Of the rehabilitation sites of the Ruonajoki River, some were already rehabilitated in earlier years. The most common rehabilitation measures were the adding of rocks, gravel, and wood. These measures were performed on each rehabilitation section. The required spawning gravel was delivered in sacks to the sites along the watercourse by snowmobiles in the previous winter season. Gravel was transported by trucks to the sites close to streams, where the gravel was placed in sacks using a clamshell bucket and lifted onto a snowmobile trailer. The sacks of gravel were taken by snowmobile to places that were as close as possible to the watercourse to partially advance-marked sites.

The Vikaköngäs rapid water section in the main watercourse of the Raudanjoki River was subject to inventory in April 2021 during the low water period. The rapid water section was rehabilitated during the fishery rehabilitation period for the Raudanjoki River, and the rapids form a heterogeneous and diverse rapid section. The rapid water section itself has a boulder bottom, which is typical for rapids along this watercourse that have been cleared for log driving and already before been rehabilitated. The structure of the bottom itself was good and diverse, but the most important element for the natural lifecycle of fish spawning in fluvial waters, spawning gravel, was missing almost entirely. The required rock and gravel material was brought to the area and stockpiled on private land close to main road no. 82 at the start of a forestry vehicle route. The travel of the forestry tractor to the upstream sections of the area for rehabilitation was done using the existing old routes in the area. These routes were mainly the foundations of wintertime snowmobile routes. Trout spawning grounds were made in the upstream, central, and downstream sections of the area by delivering spawning gravel (30–60 mm) to the area. In addition, smaller-scale spawning grounds suitable for grayling were made in areas of calmer flow rates using finer gravel of 8–16 mm. The rock material intended for the area was driven to the area using a forestry tractor, and the spawning gravel was laid using a clamshell bucket and utilising the extended beam of the forestry tractor. The necessary preparatory tasks were conducted using hand tools. The gravel beds formed mattresses with a minimum thickness of 25–30 cm for the fluvial sections with suitable flow rates and protective rocks. When laying the gravel beds, the gravel must be related to the flow rate, protective properties, and water depth, and should undertake to achieve a diverse breeding and nursery ground. Driving in the watercourse was avoided whenever possible, which avoided minimal harm to aquatic mosses and other aquatic fauna and ensured that the river bottom would be restored as quickly as possible following the completion of the tasks. Work was scheduled for the low-water season in July–

August 2022. Gravel beds were placed in such a way that even during low flow rate seasons, the water current would be sufficient for retaining the gravel beds and the fish eggs buried in the gravel in the current. The requirement for spawning gravel and nursery rocks in the rapid water sections totalled approximately 200 tons. Wood material was submerged in small scale for the shore areas of rapids in such a way that the wood material was anchored to the river bottom and/or shore using natural materials. The majority of the wood material was placed along the current for diversifying current conditions, retaining litterfall, creating protective sites, and for making nutrient binding and circulation more effective. In principle, the branches of wood material were left in place. Wood material was not removed from the shore zone, rather this was sourced from adequately distant forestry land, which avoided causing the reduction in the shadiness of the shore zone or the litterfall from ending up in the watercourse. The use of wood material in the main watercourse of the Raudanjoki River also took into consideration the needs of water traffic and no wood material was placed in the central sections of the watercourse. In the neck of the rapid water section, measures were implemented in a such a way that no changes were made to the average water level of the upstream lake.

Figure 58. A forestry tractor laying spawning gravel in the Vikaköngäs rapid water sections. Photo: Antero Mölläri, Metsähallitus

The competitive bidding related to procurement for the EMRA project was done in two stages. The machinery work part was put out to tender as a two-year contract agreement in 2021. The contract agreement in question was used in the open water season of 2021 in connection with other work conducted by Metsähallitus, and when the agreement was extended for 2022, the agreement in question used the machine tasks for the EMRA project sites. Machine tasks are mainly the adding of spawning gravel and nursery rocks for the already rehabilitated rapid water sections of the Raudanjoki River waterway area. In addition, the heavy goods vehicle in question was used for the placement of wood material in the rapid water areas. For implementing manual rehabilitation measures in the smaller sites, a tender bidding competition was organised in spring 2022. The acquisition of manual rehabilitation included a 3-person work group that mainly used the Hartijoki River methods and tools (figure 59), but also an ATV for transporting to the area the advance brought gravel sacks that held spawning gravel and nursery rocks mixed together with approximate shares of 70% and 30% respectively.

Figure 59. Restoration group in Vaattunkijoki and Silmäjoki was using Hartijoki method and hand tools for restoration actions. Photo: Sihveri Ervasti, Metsähallitus

Figure 60. ATV winch can be used for moving bigger boulders. Photo: Markku Vierelä, Metsähallitus

7.4. Results

With the goal of the EMRA Project being small-scale restoration, during the summer of 2022, the Lapland ELY-Centres implemented a catchment pilot project to add wood material to forest ditches. The method is new and has only been applied in a few places in Lapland. Adding wood material to forest ditches is based on the research and development projects PuuMaVesi and PuuValuVesi by the Finnish Environment Institute, which have yielded good results using wood material as a means of water protection. According to the study, wood material increases solids retention in the sedimentation basin by about 60%, humus retention by about 20%, during flooding by 40%, nutrient retention by 20%, during flooding by 60%. (Huotari et al. 2021).

The selected sites were based on the results of the 2021 catchment area inventory of the EMRA project. The Suolijoki River joins the Vähäjoki River a little before the Kemijoki River and is one river for which the Lapland ELY Centre has made a river restoration plan under the EMRA Project. The forest ditches are located on two properties where cooperation was arranged with the owners to obtain permission to construct and place bundle of tree trunks in the forest ditches. The bundles of tree trunks support the river restoration plan by reducing the amount of sand and nutrients that end up in the watercourses from the forest ditches. Sand can clog and even cover the riverbed gravel, making it difficult for trout and grayling to dig spawning nests. In addition, the compacted gravel bed can pose a problem for fish eggs because of the excessively low oxygen content. Nutrients cause eutrophication in watercourses, which can lead to overgrowth of plants, changes in flow rate conditions, darkening of the water colour, lack of oxygen on the riverbed, and changes in the chemical properties of the water. Excess travel of nutrients into the watercourse changes the aquatic environment, which means that the fish and other species living in the watercourse will have to give way to other species because of living conditions, the relations between species groups change, or species can also completely disappear.

The areas chosen for the pilot sites were the collector ditches that flow into the Suoli River, which have different properties. The selected forest ditches and their catchment areas have different characteristics, including varying in size, soil type, and loading type, and fluctuate in respect to flow rate strength and water depth. The total calculated catchment area of ditches is 120 hectares. In the forest ditches of peatlands, the water depth was the most stable and the flow rate the slowest. However, a ditch located in mineral soil appeared to be more sensitive to changes in water levels, but the flow rate remains moderate even during times of low water. In peatland forest ditches, no immediate observations of changes in the watercourse load were seen during the installation. To the surprise of the researchers, a group of minnows (Phoxinus phoxinus) sought refuge near the bundle of tree trunks, indicating that the bundles are beneficial to aquatic organisms as a place of shelter. Fine particulate matter began to accumulate around the bundle of tree trunks installed in the mineral soil areas. Since particulate matter was released from the ditches during the installation, it was difficult to determine the cause of this accumulation. The bundle of tree trunks was installed as a summer job by the Lapland ELY Centre in June. During a site visit in mid-August, the bundles were found to be in place, but due to the dry season, some of the bundles were partially above the water level. The subject of the bundle of tree trunks site has been communicated within and outside the Lapland ELY Centre in natural encounters. The topic has generated interest due to its timeliness, and the method itself has been of interest from the perspective of practical implementation.

Building and installing a bundle of tree trunks was found to be easy and fast. The method can be recommended for active forest owners for implementation by their own effort. Installation of a bundle of tree trunks requires the permission of the property owner, and in case of waterlogging-related harm, the permission of the owners of other properties related to the ditch is also required. The method is not intended to dam water, so the bundles should be monitored after installation to prevent unexpected damming that may hinder forestry use. An indicative cost estimate has been calculated for a bundle of tree trunks, assuming the work of two forestry workers at an hourly wage including a portion for planning and management. The final total cost of the work is determined by several factors, so the cost estimate presented herein should be considered indicative. The cost estimate can be used by forestry service entrepreneurs for bidding.

The pilot site arranged in the EMRA project in the summer of 2022 included five ditches that flow into Suolijoki River over a distance of 4.4 kilometres as the crow flies. The team travelled from one ditch to another by car, then on foot to the work site. A total of 35 bundles of trimmed spruce tied with sisal rope were placed in the ditches. The cost estimate includes labour costs and the price of sisal rope. The cost of the used timber has not been taken into account due to the low cost of small-diameter timber. The approximate joint cost for the site is 773 euros (VAT 0%). The cost per bundle in this case would be about 22 euros (VAT 0%).

Figure 61. For the tree trunk bundles, spruces were felled from the side of the ditch with a clearing saw. Photo: Reeta Peteri, Lapland ELY-centres.

Figure 62. At the bottom dam, the water level in the shallow ditch was raised so that the tree trunk bundles stay below the water level. Photo: Reeta Peteri, Lapland ELY-centres.

The removal of the migration obstacle was carried out in the summer of 2022 as part of the EMRA project objectives. The project involved removing a fish migration barrier, a road culvert on the Sihtuunajoki River in Tervola. The small Sihtuunajoki river, 2–3 metres wide, originates from Lake Jyröjärvi and then meanders through the lakes of Iso-Ruuhijärvi and Pikku-Ruuhijärvi towards the Varejoki River, which flows into the Kemijoki river at the Taivalkoski power plant reservoir. A fish ladder is planned for the Taivalkoski power plant dam according to Finland's fish ladder strategy, which enables migratory fish to reach the Kemijoki River and its tributaries up to the Ossauskoski power plant dam. The culvert is

located halfway up the Sihtuunajoki River on an unnamed road between Valkolantie and Isolehdontie, about 20 kilometres north of Tervola. The culvert, which was an obstacle for fish and other aquatic life, consisted of seven metal pipes with a diameter of approximately 40 cm. Measuring from the lower point, there was a drop of 30 cm to the water surface and 80 cm to the riverbed. The drop was so significant that fish and other aquatic life were unable to migrate upstream in the river. The choice of migratory obstacle to be removed was influenced by the results of migratory obstacle and river inventory carried out in the EMRA project, which indicated that the Sihtuunajoki River is suitable for trout and has natural breeding and juvenile production areas. Based on the results of electrofishing surveys, Sihtuunajoki has a natural population of trout and suitable spawning areas (Huhtala 2018). In the EMRA project, the river channel and crossing structures of the River Sihtuunajoki were surveyed in the summer of 2020. The culvert in question is the only absolute fish migration passage barrier in the Sihtuunajoki River. The culvert structure project for the Sihtuunajoki River was selected as a pilot project in 2021 when pilot work site planning began. In spring 2022, the Lapland ELY Centre identified the ownership of the property and acquired the necessary permits for replacing the culvert in Sihtuunajoki River. The property and water area in question is owned by Tornator Oy. Tornator Oy also participated in the cost of the work site. The culvert replacement was carried out as a turnkey project, including all work phases and materials. The Lapland ELY Centre not only obtained the necessary permits but also guided the work to enable unobstructed passage for fish and other aquatic life upstream. The owners of the property within the impact zone of the road were informed about the culvert replacement. The property owners were also told about the valuable aquatic environment, obstacles to fish migration, and the EMRA project in Sihtuunajoki River. The subject of the culvert replacement and migration obstacle has been communicated within and outside the Lapland ELY Centre in natural encounters.
The culvert installation was carried out according to the instructions for installing culverts in water bodies developed in the “Esteet Pois! II” project by the Finnish state-owned enterprise Metsähallitus (Jänkälä et al. 2020). The new culvert is a plastic-coated steel culvert with a diameter of 2 metres. The bottom of the culvert is sunk 25% below the bed of the channel, and the culvert is filled with natural gravel and stones to create a natural effect. The location was challenging because the culvert was placed in the steepest part of the rapids. If the drum had been placed in a new location, the costs would have risen significantly. The steepness of the rapids at the culvert and downstream from it required significant threshold structures for about 50 metres downstream from the culvert. The natural thresholds built below the culvert drum adjusted the flow conditions inside the culvert according to the guidelines. The water level in the Sihtuunajoki River was average at the time of installation. After installation, the measured water level in the culvert was 30 cm, with a target depth of at least 20 cm. The water flow rate was measured at 32 cm/s, with a target of less than 50 cm/s. The natural conditions of the river are maintained in the culvert, allowing unobstructed passage for fish and aquatic organisms in the Sihtuunajoki River.

As an immediate result of the culvert replacement, we observed a 25 cm trout and small trout or grayling fry swimming in the culvert. In the future, the Sihtuunajoki River will provide unobstructed passage for fish and other aquatic organisms, expanding the diversity of the river environment. The removal of the obstruction enables an increase in the available spawning and nursery areas, expanding the habitat for fish and other aquatic organisms. In the long term, obstacle removal increases genetic diversity, which acts as a buffer against environmental changes.

Figure 63. Sihtunajoki's seven-pipe culvert structure viewed from the downstream direction before culvert replacement. Photo: Timo Lettijeff, Lapland ELY-centres.

Figure 64. Sihtunajoki culvert after changing. A rapid was also built below to slow down the water flow and raise the water level in the road culvert. Photo: Lapland ELY-centres.

The Lapland ELY-centres and Metsähallitus also carried out small-scale river restorations as pilot projects. The Lapland ELY Centre restored fish spawning areas in the Ropsajoki River in Rovaniemi by adding gravel of suitable diameter for trout spawning. The gravel was delivered to the Ropsajoki River restoration areas as close to the shores as possible in 2021, and the actual renovation work was carried out in August 2022. Gravel was added to three long rapids sections, and a total of 200 tons of gravel was used for these. A forestry tractor and its bucket were used to transport and spread the gravel, but the equipment used did not allow for modification of the riverbed at the sites for restoration, so pre-existing areas suitable in bottom topography and water depth were used for gravelling.
The rapids to be gravelled were the Mukkakoski, which was downstream from the Lake Tervajärvi outlet, with a length of approximately 1,000 metres and an area of approximately one hectare. Approximately 30 tons (20 m3) of gravel were brought to Mukkakoski. The

other gravelling area was Viitaköngäs. The length covered in this area was approximately 2.9 kilometres and an area coverage of approximately 2.9 hectares. At Viitaköngäs, the gravel had been brought to two different locations the previous summer, from where it was transported to the areas being restored. A total of approximately 90 tons (60 m3) of gravel was used at Viitaköngäs. The third and furthest downstream rapids area for restoration was Pitkäkoski – Suukoski, which had a total length of approximately 1.2 kilometres and an area of approximately 1.4 hectares. Gravel had also been transported to two different storage locations near the river the previous summer, from where it was transported to the areas for restoration. Approximately 80 tons (55 m3) of gravel was used for restoration in this area. Gravel was spread to several tens of different locations on each restoration site, and the areas to be restored varied greatly in size. Spawning grounds were attempted to be made at a depth of approximately 0.5–1 metre. The goal was for at least 1–2% of the rapids areas to be suitable spawning grounds for trout. There was little fine material in the spawning gravel, so water turbidity during the work was minimal. The goal was for at least 1–2% of the rapids areas to be suitable spawning grounds for trout. The total area of the rapids to be gravelled on Ropsajoki River was approximately 5.3 hectares. The cost of gravelling per unit area of rapids was 0.3 €/m2.
The finishing work on the gravelled areas was done manually using hand tools. The work was scheduled for the summer low-flow season in July.

Figure 65. Laying of spawning gravel with a forest tractor in Ropsajoki in the summer of 2022. Photo: Piia Sonkajärvi, Lapland ELY-centres.

Figure 66. New spawning gravel in Ropsajoki. The color of gravel will darken in a few years. Photo: Piia Sonkajärvi, Lapland ELY-centres.

In Metsähallitus pilot sites, spawing grounds and juvenile habitat we arranged, primarily for trout, but also for grayling. The total length of restored river habitat in the Silmäjoki was 600 meters, and in the Vaattunkijoki 335 meters. In the bigger river Vikaköngäs totally 1.04 hectars of riverbed was restored by adding gravel and reinstalling stones and boulders.

Totally, 50 spawning beds and juvenile habitats were arranged in the Silmäjoki area and 32 – in the Vaattunkijoki area. In the area of Vikaköngäs, the total number of spawning beds was approximately 100. The estimated area of restored juvenile habitats in the Silmäjoki amounted to 2,900 m2, in the Vaattunkijoki 1,500 m2, and in the Vikaköngäs 3,500 m2.

Table 8. Metsähallitus and Laplands ELY-Centres restoration sites; length of restoration sites, estimation of restored surface and number of spanwning habitats as a result of restoration measures.

	Längd, restaurerad yta (meter)	Yta (hektar)	Antal lekbottnar	Yta lekområden (m^2).
Silmäjoki	600	-	50	2 900
Vaattunkijoki	335	-	32	1 500
Viikaköngäs	-	1,04	100	3 500
Ropsajoki	5 100	5,30	150	450

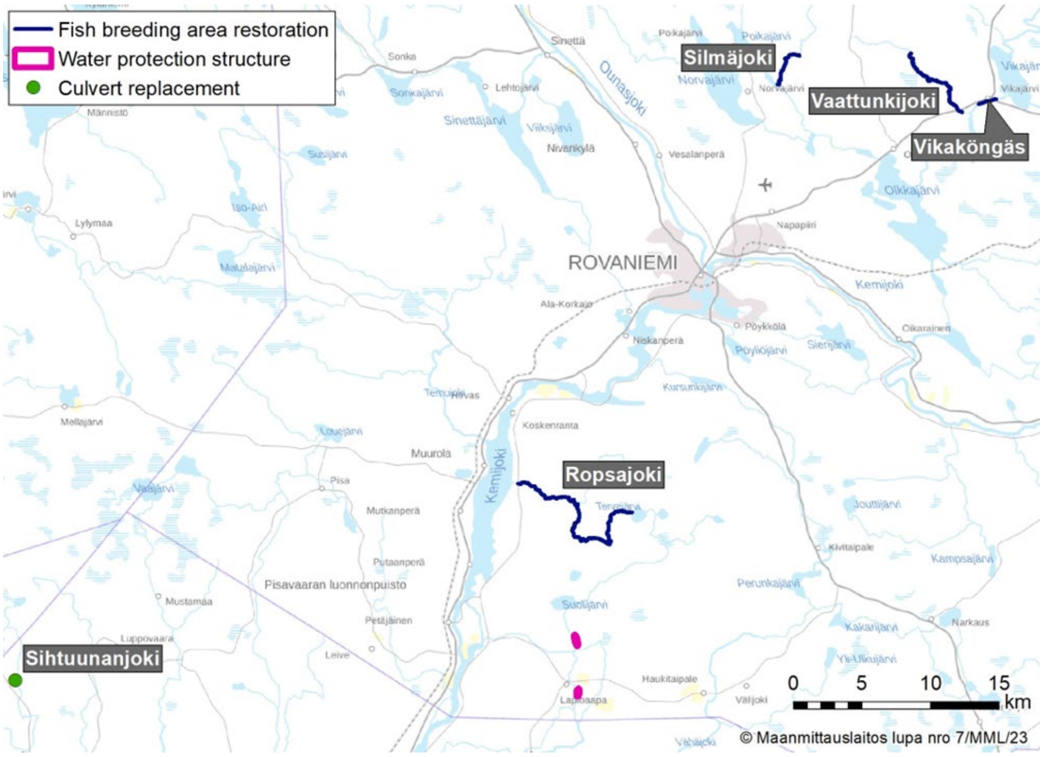

Figure 67. Location of Ely center in Lapland and Metsähallitus restoration sites in the Kemijoki catchment area. Photo: Riku Elo, Laplands ELY-Centres

7.5. Discussion

The use of wood material in forestry for water protection appears to be a promising new method. The EMRA project pilot restoration site found the method relatively easy to implement, for example, as a private project of an active forest owner. In terms of cost-effectiveness for forest service providers, the method needs to be further developed to be implemented with machinery in connection with other forestry measures. Further research is needed for the evaluation of achievable watercourse benefits as well as to find sufficient wood and the most effective installation method.

Removing fish migration obstacles from watercourses where fish movement is possible is a quick and immediately beneficial way to increase the size and quality of habitats for migratory fish and other aquatic organisms. It is important to continue mapping fish migration obstacles to identify problematic sites. The greatest benefit is achieved by prioritising fish migration obstacle removal in watercourses where there is the greatest potential to increase spawning and nursery areas and improve fish and other aquatic organism movements. There are so many different types of watercourse structures that impede fish migration, so the most important thing is to start working on unobstructed watercourses. There are many fish migration barriers that are not difficult or expensive to remove. Responsibility for maintaining crossing structures, such as culverts and bridges, lies with either the property or the road right-of-way owner. Information about the obstructive structure should be communicated to the property or right-of-way owner. Metsähallitus has produced guidelines for identifying and removing obstructive crossings that are available for everyone. The Sihtuunajoki culvert replacement project directed by Lapland ELY Centre, was inventoried and replaced according to the guidelines produced by the Metsähallitus Esteet Pois! II project.

Removing fish migration obstacles on a larger scale without cooperation between different actors is slow and costly. In Lapland, several actors have identified obstructive crossings and communicated the need to act for the benefit of migratory fish. There is a need to develop a cost-effective model for practically removing migration obstacles, especially in

cases of privately owned or small road associations where removing a crossing can be a challenging operation in many ways or the need to remove a migration obstacle is not recognised. Currently, obstructive crossings are removed in connection with road renovations when there is a need to renew the culvert or bridge.
In the implementation of the Ropsajoki River spawning gravel by the ELY Centre, it would have been good to have an excavator available on the site. Using an excavator, all areas to be covered with gravel could have been shaped so that the thickness of the gravel layer would have been 40–70 cm in every restoration site. Additionally, a few boulders could have been placed downstream from the gravel beds to keep the gravel in place. The environmental protection unit of the Lapland ELY Centre was consulted in advance on the permit requirements for the restoration measures, and if an excavator had been used to modify the bottom or shores of the restoration areas on the Ropsajoki River, the restoration measures would have required a permit from the Regional State Administrative Agency (AVI). Obtaining such a permit would have taken at least a year, so the gravel beds could not have been implemented as part of the EMRA project's pilot work.
Special attention should also be paid to the training of the machine operator used in the restoration measures, in relation to creating gravel spawning beds and rehabilitating fish habitats.

In Metsähallitus pilot sites one of the most important factor for natural reproduction, suitable gravel for spawning beds, has been washed away during the early years while cleaning river channels for timber running. Clearing the channels by excavators and bulldozers has also cleared the natural gravel from the river into the riverbanks, or the water current has increased so much that the gravel was washed away from the rapids. The cleared riverbeds no longer have the structure that holds the gravel still.
By adding gravel for suitable sites, spawning beds for trout and grayling can be created. Gravel itself is a relatively cheap material and can be used in a big amount. From literature it can be found that spawning areas should amount to 5-10% of the total bottom areas in the rapids. In the course of restoration, there also needs be understanding of juvenile habitats and needs, to avoid a bottle neck effect during the transition between the spawning and juvenile stages. More or less, river and stream habitats need to be diverse after restoration actions, so that they should be suitable for fish of all sizes and stages of natural reproduction. Diverse river habitat also is important for other water species than fish and diverse rivers will form entire connectivity by water and land.
Transporting gravel by trucks and forest tractor will raise the total costs. The price of fuel has been growing a lot during the global crisis and needs to be taken into consideration in the projects. EMRA project was in between Covid-19 and Ukrainian war and increasing of common costs has been rapid. Nevertheless, all planned actions were performed at the pilot sites of Kemijoki.

During the EMRA project there were also other projects going on in Metsähallitus. Sharing information between the projects is a way to carry out cost-effective work and reaching goals has been successful. Metsähallitus' pilot sites were chosen by results of the Valuma-alue -project. The EMRA work package of DNA sampling was used. DNA sampling in the small rivers such as the Silmäjoki and the Vaattunkijoki confirmed that these two streams need to be part of EMRA's restoration actions.

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8. Knowledge exchange about fish farms

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8.1. Introduction

Fish farming and stockings of juvenile fish are widely used in both Sweden and Finland. Both Kemijoki Oy and Vattenfall are obligated to stock fish as compensation of the negative impact on fisheries from hydropower production. Especially the commercial fishing of salmon in the Baltic Sea has been diminishing for a long time as the stocks of Atlantic Salmon have been regressing. The professional fisheries is administrated in multinational co-operation, but the experiences from fish farming is quite scarce. There are multiple similarities in Sweden and Finland when it comes to fish farming. For instance, the species and the reasons for compensatory fish farming are the same.

In recent years fish diseases and the rise of mortality have caused challenges for compensatory stockings. Precautionary methods must be developed continuously. The strategies for stocking of fish and the methods used and developed are important topics to ensure the biggest benefit of fish farming. Knowledge exchange between Sweden and Finland can offer significant synergy benefits.

8.2. Material and Methods

With this work package, the project created co-operation and knowledge exchange between the fish farming and hydropower companies as well as authorities with several physical meetings and visits to create personnel network for the methods and techniques to improve.

Kemijoki Oy and Vattenfall have held several teams -meetings in the spring 2022 to catch up with current issues in fish farming and to plan visits in both countries.

Personnel from Vattenfall visited Voimalohi Oy’s fish farm in Ossauskoski during the EMRA working group meeting held in Juopperin kartano at 29.-30.3.2022. Reciprocally, the personnel of Voimalohi Oy visited Bodens hydropower plant and Hedens fish farm in 29.6.-1.7.2022.

8.3. Results

The most significant result of this action of knowledge exchange is the network established for personnel from fish farms. Getting to know co-workers and visiting the fish farms has made real co-operation possible.

The experiences learned and the good co-operation started in EMRA-project will be continued also after the project has finished. In particular methods and strategies for handling disease, rearing strategies and ensuring genetical integrity with breeding programs are important topics.

8.4. Discussion

Nowadays the surveillance of compensatory stockings is undergoing a regeneration phase and a target for finding better methods has been set. For an example the use of Carlin-tags has been left out in both countries and a better, more reliable, and more ethical methods has been taken in use.

Also, the actual fish farms gain from knowledge exchange and co-operation. Feeding, temperature, management and handling of the fish have challenges in both countries. Compensatory stocking is an essential part of hydropower production. In addition, the changes in hydropower and electricity supply business and the expectations on the production environment must be taken into account. Sweden and Finland are obliged to manage the compensatory stockings and the management of the Baltic Sea Fisheries in co-operation also in the future, so the start of the work in this Interreg project has been a good start.

The whole action of knowledge exchange in fish farming has been of utter importance. It has been good to know that the challenges faced in fish farming and compensatory stocking of the juvenile fish are very similar in both countries and that the effects of global warming brings similar challenges to the fish farms situated in the polar circle area. Knowledge of the efforts to fight several similar issues with fish farming has become clear especially with the visits to the fish farms. Challenges with the catchment and transportation and storage of the adult fishes have been discussed at the visit to the Bodens hydropower plant where Vattenfall has the special equipment for the catching of the upstream migrating mature fish. Another area where we see a need for continued cooperation is methods for evaluation the effects of compensatory stocking and the gaining more knowledge about the lifestages after stocking. Today all stocked salmonids are identified through removing the adipose fin in the juvenile stage. Other methods discussed are pit-tag marking and telemetry to track the movement pattern and condition of specific individuals.

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