Report: Survey of unimplemented restoration plans in the Barents region

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Introduction

Freshwater ecosystems are home to a wide variety of organisms. However, there has been a significant decrease in their biodiversity globally due to, among other things, anthropogenic land use and extensive use of waterbodies (Tickner et al. 2020, Petsch et al. 2021).

Despite being relatively intact and sparsely populated, the Barents region has also faced land use that has had a detrimental effect on aquatic ecosystems. In the 20th century, rivers and streams were heavily modified for timber floating, and the impacts – cleared, straightened channels that lack retentive structures and habitats for fish and invertebrates – are still visible today (Muotka & Laasonen, 2002; Törnlund & Östlund, 2002). Other ongoing human activities such as building dams for hydropower and constructing road networks, have blocked fish migrations to large areas (Erkinaro et al. 2017; Karppinen et al. 2002). The mining industry and intensive wood production have caused habitat fragmentation, and peatland drainage has resulted in habitat degradation due to sedimentation and excessive leaching of nutrients (Kuglerová et al. 2021).

Attempts to restore degraded aquatic habitats have increased from the 1980s onwards (Eloranta, 2010). In the early years, the focus was on enhancing migratory fish breeding in channels that had undergone heavy modification for timber floating purposes. Since then, the methods have evolved, and the focus has widened to cover other compartments of biodiversity as well. In Finland, national strategies, The Strategy for Aquatic Restoration (Vesien kunnostusstrategia, 2013) and the Strategy for Preserving and Restoring Small Waterbodies (Pienvesien suojelu- ja kunnostusstrategia, 2015) guide the restoration of water bodies. Finland has also committed to improving the natural life cycle of threatened migratory fish stocks by The National Fish Passage Strategy (Kansallinen kalatiestrategia, 2012). In the future, there will be even more pressure on habitat restoration, since the biodiversity strategy by the European Union obligates EU countries to halt global species loss by 2030, and the proposed Nature Restoration Law will require active restoration efforts, also in aquatic environments.

Multiple aquatic restoration projects have been implemented in the Barents region in the past decades. Many plans have also been put aside due to a lack of funding. This report presents planned but unimplemented river and stream restorations in the Barents region, focusing on Lapland, Northern Ostrobothnia and Kainuu regions in Finland. Past, ongoing and future restoration projects in the Barents region of Sweden (Norrbotten and Västerbotten) and Norway (Troms og Finnmark and Nordland) are also reviewed, focusing on cooperation projects in the transboundary rivers.

Methods

The project started with a meeting where Finnish organizations working with aquatic restoration planning or research (the Lapland Centre for Economic Development, Transport and the Environment, the Finnish Environment Centre (SYKE), the Natural Resource Institute Finland (Luke), Metsähallitus Parks and Wildlife, the University of Oulu and the Finnish Ministry of Environment) were invited to discuss the topic of past and future restoration projects and to identify contact persons from each organization. The definition of the term 'restoration' was also discussed, and it was decided that a wide array of measures, such as habitat restorations, fish barrier removals, and eradication of invasive species could be included.

Interviews were then organized with the contact persons. The focus of the interviews was on identifying those restoration plans that have been produced in the organization's previous projects but have been left unimplemented and are available in archives. Stream inventories and fish migratory barrier inventories were also discussed. Another meeting was organized for authorities working with water management In Norway (The Norwegian Water Resources and Energy Directorate, the Troms and Finnmark County Governor) and Sweden (the County Administrative Board of Norrbotten). In this meeting, the state of restoration planning, ongoing projects and available data sources were discussed.

The restoration plans and other documents from Finland were obtained directly from the organizations responsible for them. From Sweden and Norway, information was gathered from

multiple sources, such as project websites and databases, with the help of contact persons. All plans and documents were read carefully, and key features were summarized.

The criteria for prioritization of Finnish restoration plans were discussed in a meeting with specialists from SYKE, Luke, ELY-centre of Lapland, and the University of Oulu. For the prioritization, additional spatial analyses were made in the ArcMap geospatial analysis tool and a web-based VALUE tool provided by the Finnish Environment Centre. VALUE was used to determine the catchment area for each restoration site, and to calculate the land use categories in the catchments from Corine 2012 land cover data. The percentage of ditched peatland in each catchment was calculated from the peatland ditching raster (SOJT_09b1, Finnish Environment Institute, 2011) in ArcMap. To estimate the intensity of forestry activities in the catchment areas, overall forest loss from 2000 to 2022 was calculated from the Global Forest Change dataset (Hansen et al. 2013). The state of habitat naturalness and ecological state of benthic invertebrate communities was evaluated using the PUROHELMI dataset (Aroviita et al., 2021) that provides modelled estimates of these variables in small streams. For headwater habitat naturalness, an average naturalness class (1-5) was calculated by weighing the classes with their occurrence (% of the combined headwater stream length) in the catchment. Web-based Vesikartta -map service, that contains data on the ecological status of all monitored surface and groundwaters, was used to gain information on the ecological status of larger river sections.

Unimplemented restoration plans in Finland

In the Barents region of Finland, restoration plans were received from three counties: Lapland, Northern Ostrobothnia, and Kainuu. Most of these restoration plans are targeted at rivers and streams that have already undergone some level of restoration after the end of the timber floating era. The measures taken back then, which were required by law after the timber floating permits were revoked, were often inadequate or have not lasted well. Hence, additional restoration measures are needed to improve habitat conditions for fish and other stream organisms.

Below are the restoration plans, listed by region. Lack of funding is the main reason for not implementing these plans. Reported restoration budgets are rough estimations.

Lapland

Raudanjonki (Metsähallitus, Wildlife Service Finland)

Raudanjoki is a tributary of the Kemijoki River. The targeted section is located northeast of Rovaniemi and includes three riffles (combined area of 5.5 ha) and one already restored riffle. The ecological state of Raudanjoki is classified as good. The river sections have undergone restoration after the timber floating era but are still lacking suitable spawning beds and nursery areas for brown trout (*Salmo trutta*) and grayling (*Thymallus thymallus*). The planned restoration activities include adding gravel of different sizes to create the spawning beds, as well as adding wood to the channel to create shade, and habitats for invertebrates and improve organic matter storage. The estimated budget for the restoration of the remaining sites is 297.000 €. The restoration plan was made in the Metsähallitus Wildlife Service Finland.

Vikajoki (Metsähallitus, Wildlife Service Finland)

Vikajoki, a tributary of the Kemijoki River, is located east of Rovaniemi. The ecological state of Vikajoki is classified as excellent. There are two restoration plans for this river section. The first one is targeted at four riffle sections (combined area of 5.62 ha) of which two have already been partly implemented in 2022. The other plan covers two riffles slightly upstream (combined area of 1.17 ha). After the timber floating period, the riffles of Vikajoki have been restored and currently, the river channel is reasonably heterogeneous. However, to allow spawning of brown trout and grayling, adding gravel beds is needed. In addition, the plan includes placing wood in the shore areas of the channel. The estimated budget for the first plan is 112.000 € and for the second 23.400 €. The restoration plans were made in the Metsähallitus Wildlife Service Finland.

Kalliojoki (Metsähallitus, Wildlife Service Finland)

Kalliojoki is another tributary of the Kemijoki River, situated to the west of Kemijärvi municipality. The ecological state of the river section is classified as excellent. The plan includes the restoration of six different riffles (area unknown), three of which have already been restored in 2022.

Kalliojoki was utilized in timber floating and was restored after that. Despite recent inventories revealing fairly heterogeneous channel morphology, all of the riffles lack sufficient spawning habitat for brown trout and grayling, requiring the addition of gravel beds of various sizes. The plan also involves the addition of wood to retain debris and create shelter and habitats for invertebrates. There is no budget estimation available for this project. The restoration plan was made in the Metsähallitus Wildlife Service Finland.

Sinettäjoki (The Lapland Centre for Economic Development, Transport and the Environment)

Sinettäjoki is a tributary of the Ounasjoki River which flows into the Kemijoki River in the city of Rovaniemi. The ecological state of Sinettäjoki is good. The restoration plan is targeted at two riffle sections (combined area of 1.1. ha) that were formerly used as timber floating channels. Despite restoration efforts made in the 1970s, remnants of timber floating are visible, and the riffles lack suitable gravel beds for fish spawning and nursery areas. The planned activities include adding gravel beds, improving pool-riffle-structures, adding large boulders, and digging deeper pools for adult fish. Water sampling and electrofishing have been conducted at the site. The density of salmonid fish detected in Sinettäjoki was lower than what would be expected in pristine rivers in Lapland, but comparable to other human-influenced insufficiently restored rivers. The budget estimation for the project is 50.000 €. The restoration plan was made in the Lapland Center for Economic Development.

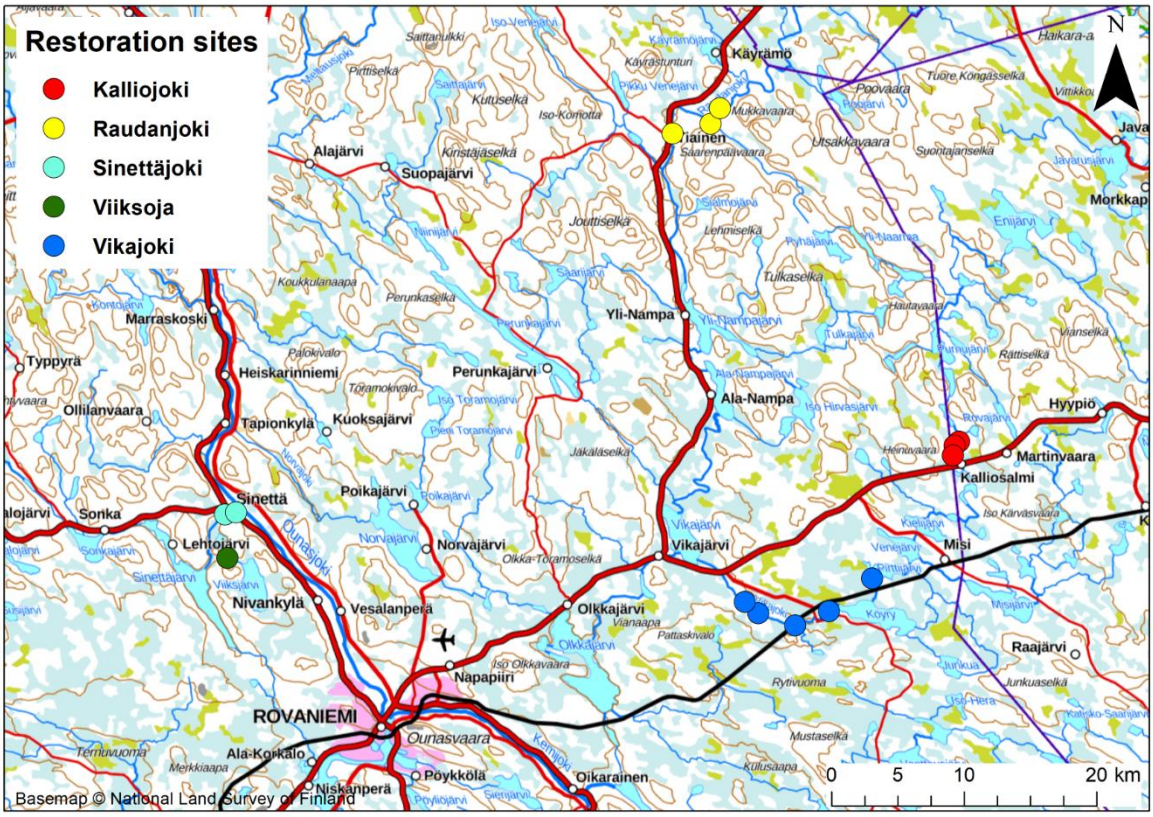

Figure 1. A map presenting the location of the proposed restoration sites in the tributaries of Kemijoki River, Lapland.

Viiksoja and Pessousjoki (Osuuskunta Seniorieksperttit)

Viiksoja is a small stream between two lakes, Viiksjärvi and Iso-Pessous in Rovaniemi. Pessousoja, located downstream from Iso-Pessous, flows into Sinettäjoki. Both stream sections were inventoried, and a restoration plan was created for Viiksoja. Both sections have been cleared and straightened and have remained like that after the end of timber floating in the stream. The needed restoration activities in Viiksoja are adding boulders, enhancing and building pool-riffle structures, and adding gravel beds and wood structures. There is also a fish barrier in the Viiksjärvi lake outlet that should be removed to allow free migration of fish. The total area that needs to be restored is 0.36 hectares. There is no budget estimation available for this project. The restoration plan of Viiksoja and inventory of Pessousoja have been developed in the Pienvesi-HELMI program by Jarmo Huhtala from Osuuskunta Seniorieksperttit.

Kirakkajoki, Ahvenjoki and Ronkajoki (The Lapland Centre for Economic Development, Transport and the Environment)

This restoration plan covers three river sections in the Pasvik River watershed in Inari municipality: Kirakkajoki (7 riffles with a combined area of 17.64 ha), Ahvenjoki (3 riffles with a combined area of 0.76 ha) and Ronkajoki (4 riffles with a combined area of 1.96 ha). The current ecological status of Kirakkajoki is classified as good. All three channels have undergone heavy modification for timber floating. In earlier restorations made in the 1980s, some old timber floating structures were removed, and boulders were added to the channel. Electrofishing conducted in the 1970s and 1980s caught brown trout, grayling, pike *(Esox Lucius)* and minnow *(Phoxinus phoxinus).*

In Kirakkajoki, the planned measures are adding boulders and strengthening the pool-riffle structures, rewetting dry parts of the channel and adding gravel beds for fish spawning and nursery areas. In Ahvenjoki, the only needed activity is adding gravel beds. In Ronkajoki, the plan is to rewet an old channel bypassed for timber floating and add gravel suitable for fish spawning. The plan also includes the removal of an old dam at the outlet of the lake Hammasjärvi, originally built to help with flood regulation. The dam has been partially dismantled but is still a migratory barrier for other organisms but brown trout.

By restoring these sites, it would be possible to increase the overall riffle area by 30 %. One practical difficulty in implementing the plan is the remote location of the sites and the lack of road networks. Some sites are only reachable by helicopter and where excavators are needed, those should be brought by a floating raft. The restoration plan was made in the Lapland Center for Economic Development. There is no budget estimation available for this project.

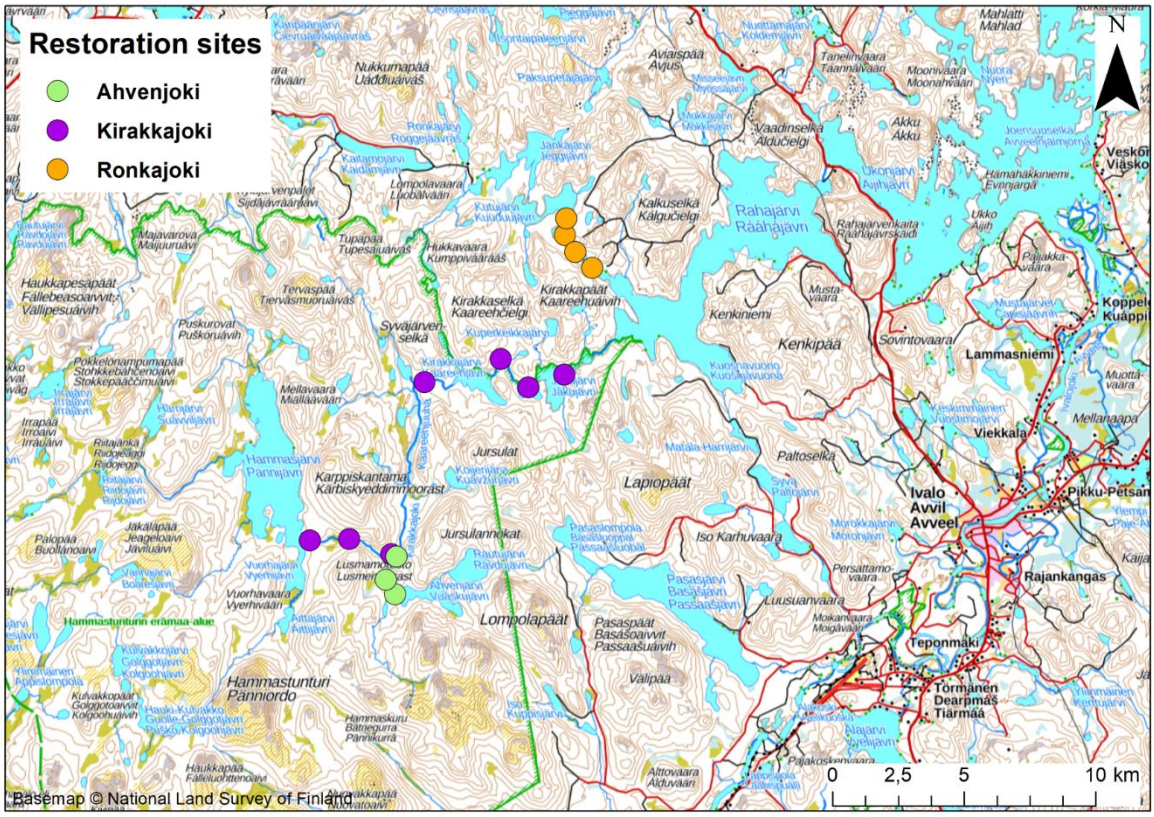

Figure 2. A map presenting the location of the proposed restoration sites in the Inarijärvi area, Lapland.

Northern Ostrobothnia

Pärjänjoki (Metsähallitus, Wildlife Service Finland)

The restoration plan covers 22 riffle sections (a combined area of 12.88 ha) in Pärjänjoki, located in the municipalities of Pudasjärvi and Taivalkoski in the Iijoki River watershed. The ecological status of Pärjänjoki is classified as excellent. The river was used for timber floating and was partly restored between 1988–1992. Restoration activities then were mainly returning boulders to the channel, but also adding gravel areas for fish spawning and fry to grow.

Despite this, most of the riffles still lack spawning beds and nursery areas and the plan is to add gravel of different sizes for brown trout and grayling. Relics of timber floating also still exist and need to be removed. The levees (in Finnish, 'uittomöljät'), were built from boulders taken from

river channels and used for dragging timber through riffle areas. The plan is to dismantle these banks and put the boulders back into the channel. The gravel and wood material found from the banks will also be used in the restoration. The addition of wood in the channel will provide shelter for fish and create habitats for invertebrates.

The estimated budget for implementing the plan is 89.000 €. The restoration plan was made in the Metsähallitus Wildlife Service Finland.

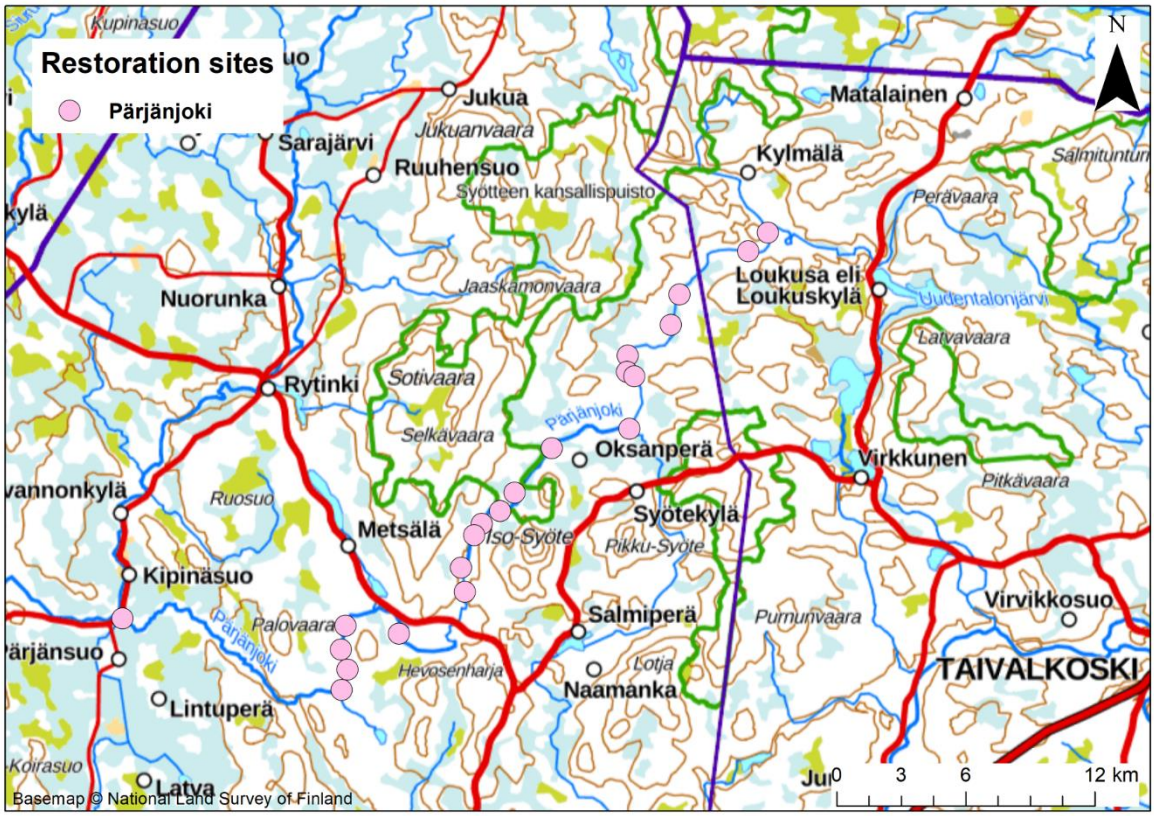

Figure 3. A map presenting the proposed restoration sites in Pärjänjoki, Northern Ostrobothnia.

Kainuu

Naamankajoki (Metsähallitus, Wildlife Service Finland)

The restoration plan covers three riffle sections (combined area of 4.57 ha) in Naamankajoki at the border of the municipalities Puolanka and Suomussalmi in the Iijoki watershed. The ecological state of Naamankajoki is classified as excellent. The river was used for timber floating in the 1950s and, to fix the damages, it was already partly restored between 1999 and 2000. Relics of timber floating are still present in the riffle areas and few gravel beds suitable for fish spawning exist.

Planned restoration activities are dismantling old levees and placing boulders and logs into the river channel. Gravel, suitable size for both brown trout and grayling, is to be added to create spawning beds and nursery areas for fish. The estimated budget for the plan is 25.000 €. The plan was made in the Metsähallitus Wildlife Service Finland.

Lylyjoki (Metsähallitus, Wildlife Service Finland)

The restoration plan for Lylyjoki in Puolanka targets three riffle sections (combined area of 3 ha). Lylyjoki belongs to the Iijoki watershed, and its ecological status is classified as good. The river was restored in 1994 as required after the end of timber floating. Back then, measures were mainly returning boulders to the river channel. In the current plan, restoration activities include removing old levees, adding gravel as spawning beds and nursery areas for brown trout and grayling, and adding wood structures to create shelter for fish and habitats for invertebrates. The estimated overall budget for the planned measures is 18.900 €. The restoration plan was made in Metsähallitus Wildlife Service Finland.

Näljänkäjoki (Metsähallitus, Wildlife Service Finland)

Näljänkäjoki is located on the border of Puolanka and Suomussalmi in the Iijoki watershed. The ecological state of the river is classified as excellent. The river was under construction for timber floating purposes in the 1950s. The permission to use the channel for timber floating was reversed in 1995 and required restorations were done in 1999-2000. Additional restoration measures are, however, still needed to enhance the spawning opportunities for fish.

The restoration plan of Näljänkäjoki covers nine riffles (combined area of 10.96 ha). To make the riffles suitable as spawning and nursery habitat for brown trout and grayling, gravel additions are needed at all nine riffles. The plan also includes removing the old timber floating banks and placing the boulders and wood material into the channel.

The estimated costs for implementing the plan are 55.000 €. The restoration plan was made in Metsähallitus Wildlife Service Finland.

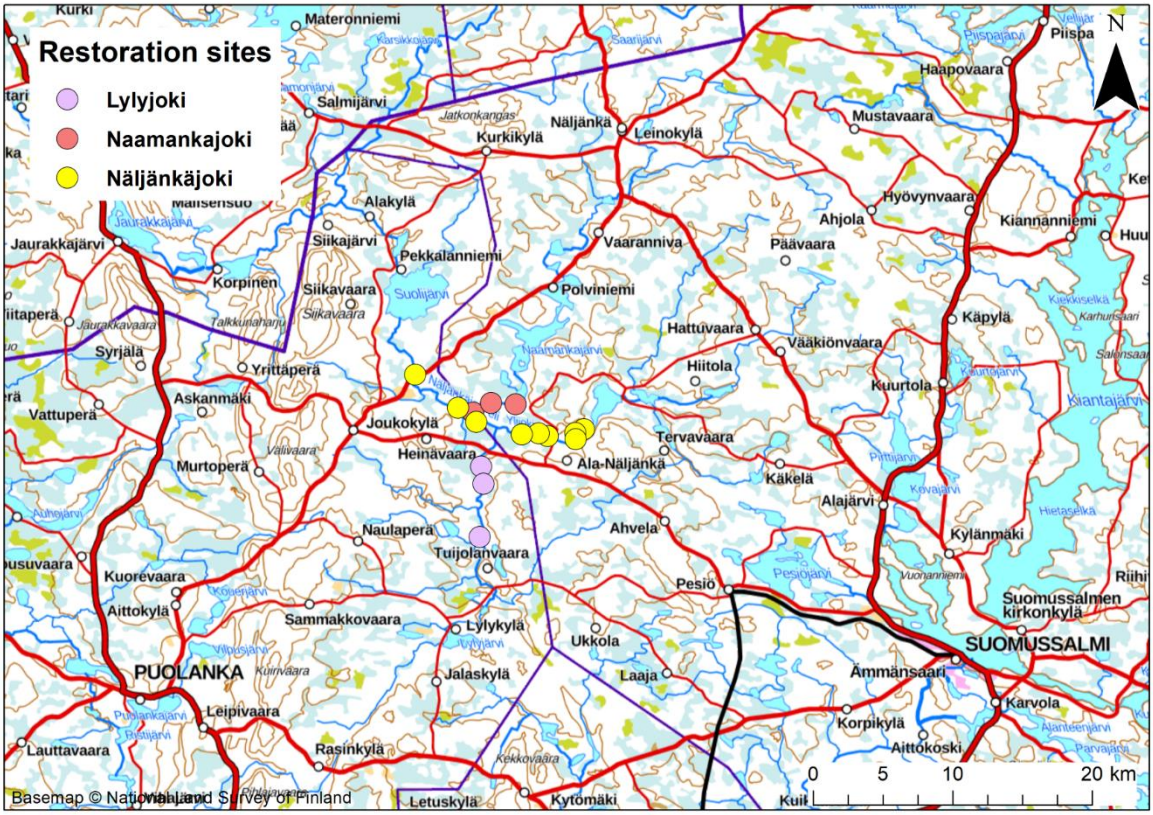

Figure 4. A map presenting the proposed restoration sites in Kainuu area.

Prioritization of restoration plans

As resources available for restoration projects will always be limited, it is necessary to assess where the greatest benefits can be obtained. The benefits gained from river restorations are linked to water quality and land use in the catchment, the existence of migratory barriers

downstream from the site to be restored and the selected restoration methods (Olin, 2013). In the past, restorations were mainly planned to improve breeding conditions for migratory fish species. Since the implementation of the EU's Water Framework Directive and the demand to improve the ecological and chemical status of all surface waters, other ecosystem components have been given more consideration.

All unimplemented restoration plans received for this survey focused mainly on migratory fish species. Restoration measures designed to improve fish conditions may also benefit other organisms. It is generally thought that increasing habitat heterogeneity by adding boulders, gravel and wood in stream channels will increase suitable habitat and foraging possibilities for benthic invertebrates, but there is little scientific evidence to support that assumption (Palmer et al. 2010, Louhi et al. 2011). Nevertheless, for species like freshwater pearl mussel (*Margaritifera margaritifera)*, which is dependent on Atlantic salmon (*Salmo salar*) or brown trout as a host, restoration measures that support fish presence are even vital (Geist et al. 2006). However, small headwater streams, while less important for fish, are critical hot spots for biodiversity (Meyer et al. 2007). These streams may also require restoration since land use (e.g. forestry) has often impacted these habitats heavily.

Another question is whether resources should be directed towards streams and rivers that are currently in relatively poor ecological condition, or towards those in relatively good condition. In the latter case, required restoration measures are potentially less extensive, and there is also a higher likelihood of having long-term benefits. Streams in poor condition, particularly when influenced by catchment land use, may not show positive responses to reach-scale restoration (Lorenz & Feld, 2013) and additional catchment-scale measures might be needed.

According to Finnish guidelines for water management planning (Vesienhoidon toimenpiteiden suunnittelun ohjeistus vuosille 2022–2027), stream restorations should aim to increase and improve habitat suitable for fish and other aquatic organisms, and to promote biodiversity. Restoration efforts have typically targeted riffle sections, but the new guideline emphasizes the

need for restoring pool sections and riparian habitats as well. Attention should also be paid to the load entering waterbodies from the catchment area.

Restoration plans received for this survey aim to improve habitat conditions for migratory fish, and the methods did not markedly differ. All these streams are former timber floating channels, and most have undergone some restoration activities before. The proposed measures most commonly include adding gravel beds, sometimes also wood and larger boulders, and creating more natural depth variation in the stream channel. Of the twelve sites included in this survey, ten are river-sized channels (catchment area > 100 km^2), and only two are smaller streams (Table 1a). The ecological status is good or excellent in all of the rivers where the status evaluation has been conducted.

Some differences arise when the catchment land use is examined. Peatland drainage intensity (%) is highest at the three sites located in the Kainuu region (Lylyjoki, Näljänkäjoki, Naamankajoki), and in the smallest stream, Viiksoja, in Rovaniemi (Table 1b). The intensity decreases northwards, and in the Kirakkajoki catchment, there is no peatland drainage. Forest loss in the catchment area (%), represents the amount of forest felling and is similarly highest in the southernmost sites and Viiksoja (Table 1c). In contrast, in the northernmost sites, there is practically no forestry. In line with the land use intensity, the southernmost headwaters have the lowest habitat naturalness (Table 1d). For the northernmost sites, naturalness status estimates were not available, but the sites in the Rovaniemi area have rather high estimates, indicating little human impact. The estimated change in the benthic macroinvertebrate communities in headwater sections reflected the pattern in habitat naturalness.

If valuing sites with minimal land use in the catchment, likely associated with lower nutrient and sediment loads, are considered most valuable, then the northern sites should be prioritized. According to the modelled estimates of habitat naturalness, the same sites have the most pristine headwaters, potentially offering habitats for fish also upstream of the restored site. Headwaters with undisturbed benthic macroinvertebrate communities can also serve as a rich source of invertebrates for downstream sections (Wipfli & Gregovich, 2002).

The only individual plan targeting a small stream (< 100 km^2) is the Viiksoja restoration plan which could be prioritized as having a potentially high value for biodiversity. However, in Viiksoja, some additional catchment scale restoration measures will likely be needed for long-term benefits, due to the impacts of drainage and forestry in the catchment. Additionally, the restoration plan of Kirakkajoki includes two smaller stream sections that have very intact catchments and could also be valuable for preserving biodiversity.

To enhance the state of migratory fish stocks, further prioritization should also consider the connectivity of the sites to other restored river sections, and to those spared from anthropogenic impacts. In the Kemijoki, Iijoki and Pasvik watersheds, multiple dams for hydroelectric energy production create migration barriers, and stocked fish populations have therefore limited possibilities for migration. In addition, smaller-scale barriers, such as improperly installed road culverts, further hinder the migration of fish and other organisms (Warren et al. 1998).

Table 1. Catchment size (a), drainage intensity (b), forest loss (c) and habitat naturalness of headwater sections, sorted from smallest/lowest to largest/highest. Habitat naturalness can vary from one to five, five representing pristine and one critically altered stream habitat.

a

Site	Catchment area (km²)
Viiksoja	29.65
Ronkajoki	67.02
Kirakkajoki	279.00
Sinettäjoki	342.36
Kalliojoki	375.17
Naamankajoki	388.62
Lylyjoki	389.64
Pärjänjoki	409.75
Vikajoki #2	855.98
Vikajoki #1	908.65
Näljänkäjoki	1181.15
Raudanjoki	1270.01

b

Site	% Catchment drained
Kirakkajoki	0
Ronkajoki	0
Kalliojoki	2
Raudanjoki	10
Vikajoki #2	10
Vikajoki #1	11
Sinettäjoki	13
Pärjänjoki	19
Viiksoja	20
Naamankajoki	23
Näljänkäjoki	25
Lylyjoki	26

c

Site	% Catchment forest loss
Kirakkajoki	0
Ronkajoki	1
Kalliojoki	4
Vikajoki #1	7
Vikajoki #2	7
Raudanjoki	8
Pärjänjoki	9
Viiksoja	9
Lylyjoki	11
Sinettäjoki	12
Näljänkäjoki	12
Naamankajoki	12

d

Site	Naturalness of headwaters
Naamankajoki	3.12
Näljänkäjoki	3.18
Lylyjoki	3.30
Pärjänjoki	3.51
Viiksoja	3.63
Sinettäjoki	4.35
Vikajoki #1	4.41
Vikajoki #2	4.48
Raudanjoki	4.51
Kalliojoki	4.84
Ronkajoki	NA
Kirakkajoki	NA

Stream and migration barrier inventories in Finland

Inventories of small streams

During the 1990s, Metsähallitus and the Environmental Center of Northern Ostrobothnia created a method to conduct inventories in small streams. The main objective of this method was (i) to gather comprehensive and consistent data on the naturalness of stream habitats, (ii) identify factors that pose a threat to their natural state, and (iii) provide recommendations for restoration activities, if necessary (Hyvönen et al. 2005). The method has since been used by many organizations and consultants, as the interest towards the state of small streams has increased.

Since 1998, Metsähallitus has inventoried altogether 2107 km of streams in Lapland (898 km), Northern Ostrobothnia (1084 km), and the Kainuu region (126 km). In these inventories, a need for restoration has been detected in 80% of the inventoried stream length. Among the three areas, Lapland has the highest proportion of streams in a natural state with no need for restoration (43%), while in Northern Ostrobothnia, such streams are scarce (1%).

The most commonly suggested restoration measure is to block artificial ditches that carry water, sediments, and nutrients from the forested land to the stream. Also, structures to direct stream flow, large boulders, and gravel for spawning beds, as well as re-wetting of old channels have been frequently suggested. Restorations based on these inventories have also been implemented over the years. Recently, this has been done in the Helmi-habitats programme, which aims to restore around 600 km of small streams and their catchments within and outside conservation areas. A summary of the inventories, evaluation of the need for restoration and suggested restoration activities are presented in Tables 1 and 2. The inventory data were received from Metsähallitus Parks & Wildlife.

Table 2. The length and number of stream sections inventoried by Metsähallitus, and the detected restoration needs from the year 1998 onwards.

	The length of streams inventoried		The number of streams inventoried	
	Kilometers	Percentage	Number	Percentage
Northern Ostrobothnia				
No need for restoration	12.5	1.2	29	1.2
Minor need for restoration	514.7	47.5	1250	50.2
Clear need for restoration	430.7	39.7	869	34.9
Major need for restoration	125.7	11.6	343	13.8
Kainuu				
No need for restoration	13.3	10.6	30	7.4
Minor need for restoration	30.5	24.3	114	28.3
Clear need for restoration	72.1	57.3	231	57.3
Major need for restoration	9.9	7.9	28	6.9
Lapland				
No need for restoration	387.3	43.1	677	37.0
Minor need for restoration	116.3	13.0	220	12.0
Clear need for restoration	142.7	15.9	293	16.0
Major need for restoration	251.7	28.0	642	35.0
	898.0			
Altogether				
No need for restoration	413.1	19.6	736	15.6
Minor need for restoration	661.5	31.4	1584	33.5
Clear need for restoration	645.5	30.6	1393	29.5
Major need for restoration	387.3	18.4	1013	21.4
All streams inventoried	2107.4	-	4726	-

Data: Metsähallitus.

Table 1. The prevalence of different restoration measures in inventoried stream sections, presented by region.

Restoration activity	Northern Ostrobothnia (%)	Kainuu (%)	Lapland (%)
Blocking of forest ditches	20.9	27.1	13.8
Structures to direct flow	14.3	26.7	3.1
Adding boulder	14.1	13.1	11.9
Gravel for spawning	9.7	17.1	11.5
Re-wetting old channel	5.6	3.9	6.6
Adding meanders	2.4	1.8	2.4
Removing migration barriers	3.7	1.6	7.3
Increasing variation in depth	3.6	0.5	6.3
Lifting water level	6.3	2.1	1.6
Adding variation in channel ban	1.8	0.9	0.4
Removing vegetation	0.5	0	0.3
Re-foresting riparian zone	1.8	0.3	2.1
Dredging	4.4	0.5	6.7
Catchment restoration	0.1	2.2	7.4
Other*	10.8	2.2	18.7
Altogether	100	100	100

* A measure distinct from the previous. Can overlap with other activities. Data: Metsähallitus.

Fish migratory barriers

Kemijoki River tributaries, EMRA-project

The Lapland Centre for Economic Development, Transport and the Environment

The Lapland Centre for Economic Development Transport and the Environment (ELY) conducted an inventory of fish migratory barriers in the tributaries of Kemijoki River. The area under inventory was downstream of Rovaniemi and upstream of Isohaara, the lowest hydroelectric power station in Kemijoki. The inventories were conducted between 2020 and 2021 as part of the EMRA - Environmental Planning, Measures, and Restoration Actions in Regulated Water Systems-project, a Swedish-Finnish cross-border project lasting from 2019 to 2022. In total, 212 individual migratory barriers were located and described. The inventory report details the condition of road culverts and the severity of barriers. Several of the barriers are also classified as having no impact on fish. Removing or fixing others could have a significant impact on fish migration to spawning

areas in smaller tributaries. According to the ELY Centre of Lapland, currently, there is no active plan for the removal of the inventoried barriers. Locations of the inventoried sites are presented in a map (Figure 5).

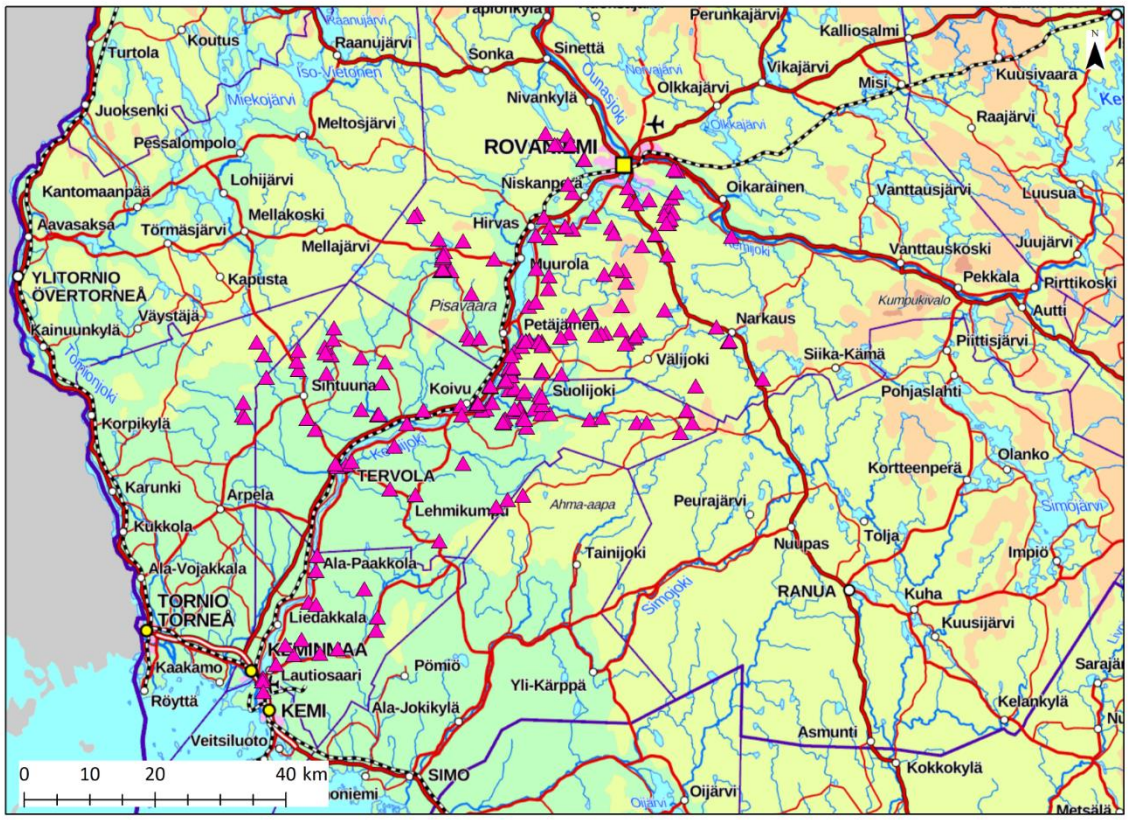

Figure 5. The locations of inventoried migration barriers in the tributaries of Kemijoki River.

Inarijärvi area, ReArc-project

The Lapland Centre for Economic Development, Transport and the Environment

The ELY Centre of Lapland inventoried migration barriers northwest and south of Inarijärvi in the Ecological Restoration of Arctic Rivers (ReArc)-project, which ran between 2019 and 2022. The ReArc project was a cooperation project targeting arctic river ecosystems in the northernmost parts of Finland, Sweden, Norway and Russia. Its objective was to survey human-impacted river ecosystems and return those to their natural state.

The inventories were conducted in 2019 and covered 108 migratory barriers. The inventoried barriers were located, the state of road culverts described and those having no value for fishery were identified. According to the ELY Centre of Lapland, there is currently no active plan for the removal of the inventoried barriers. Locations of the inventoried sites are presented in Figure 6.

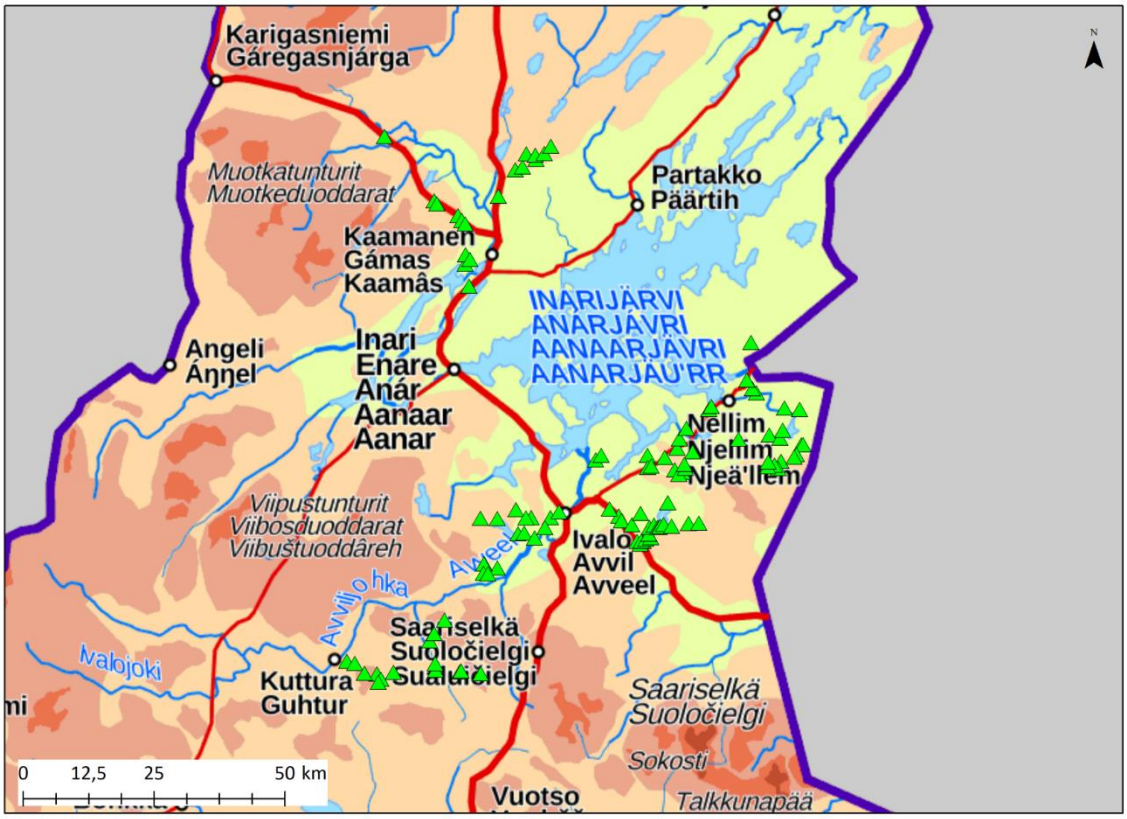

Figure 6. The locations of inventoried migration barriers in the Inarijärvi area.

River restoration measures in Sweden

Plans for future restoration measures in the Norrbotten region

Removing fish migration barriers

Fish migration barriers in rivers and streams of Norrbotten have been mapped for over a decade. More than one thousand dams and five thousand road crossings have been inventoried, of which around two thousand have been evaluated as causing a barrier for fish migration. Based on the evaluated ecological benefits, such as the presence of freshwater pearl mussel, Natura 2000

areas, and already allocated restoration efforts, 60 migration barriers have been selected for remediation.

Increasing spawning area for fish

In order to increase fish populations in the rivers of Norrbotten, a plan has been made to create approximately 5000 new spawning beds. Adding gravel beds to streams should improve their morphological quality and benefit Atlantic salmon and brown trout, but also freshwater pearl mussel and other organisms.

Environmental restorations

Alterälven

Alterälven north of Piteå municipality is a valuable river for fishing. However, the river channel has been cleared, and there are road culverts, dams, and a power plant that restrict fish migration. The plan is to create spawning and fry habitats for fish and increase the variability of habitats for all organisms, along approximately four kilometres of the stream. New habitat is also formed by rewetting old channels that were closed for timber floating purposes.

Bjurån and Forsträskå (Råneälven)

Bjurån and Forsträskå are tributaries of Råneälven, north of Luleå, that were previously used for timber floating. There is a plan to restore approximately 13 kilometres of stream length and create 15 new spawning areas, as well as to remove migration barriers caused by road culverts and dams in these streams. The planned measures will benefit, among other organisms, brown trout and freshwater pearl mussel, found in the area.

Teurajoki (Kalixälven)

Teurajoki is a tributary of Kalixälven in Pajala municipality. The river was previously used for timber floating and has not been completely restored since. There is a plan to create a more variable river habitat and increase the area suitable for fish spawning along four kilometres of the

river. A stone-built migration barrier to the upstream lake should also be modified to allow free passage for fish.

References:

The County Administrative Board of Norrbotten website - Restoration of lakes and watercourses: https://www.lansstyrelsen.se/norrbotten/miljo-och-vatten/atgarder-och-verksamheter-i-vatten/restaurering-av-sjoar-och-vattendrag.html. (accessed 21.12.2023)

On-going cross-border cooperation project: TRIWA LIFE (2023–2030)

The Torne River International Watershed LIFE (TRIWA LIFE) is a cross-border cooperation project between Sweden and Finland, aimed at restoring human-impacted aquatic environments in the Torne River watershed. The project is funded by the European Union from 2023 to 2030. The history of the Torne River, being used for timber floating, the ditching of wetlands for agriculture and forestry, as well as dense forest road network, have all deteriorated river ecosystems and created migration barriers. It is planned, that 96 kilometres of streams and 2500 hectares of wetlands will be restored, 399 migration barriers removed, and habitats of Atlantic salmon, otter *(Lutra lutra)*, green snaketail (*Ophiogomphus cecilia)*, freshwater pearl mussel and European bullhead (*Cottus gobio)* improved.

The County Administrative Board of Norrbotten leads the project. Other participants are the Swedish Agency for Marine and Water Management, Luleå University of Technology, Sveaskog AB, the Lapland Centre for Economic Development, Transport and the Environment, the Finnish Forest Centre, Metsähallitus, the Natural Resources Institute Finland and the University of Oulu.

References:

The County Administrative Board of Norrbotten, TRIWA LIFE-project website: https://www.lansstyrelsen.se/norrbotten/om-oss/om-lansstyrelsen-i-norrbottens-lan/internationellt-samarbete/triwa-life.html. (accessed 21.12.2023)

The ELY-centre of Lapland, TRIWA LIFE-project website: https://www.ely-keskus.fi/triwa-life. (accessed 21.12.2023)

Completed projects in river restorations

ReArc (2019–2022)

Ecological Restoration of Arctic Rivers (ReArc) -project was a cross-border cooperation project in the northernmost parts of Sweden, Norway, Finland and Russia, covering several watersheds from Nordland to the Kola peninsula. The project was partly funded by the EU's Kolarctic CBC programme and ran between the years 2019 and 2022. The project aimed to map and restore arctic river ecosystems impacted by land use such as channel modification for erosion and flood protection, road network construction, and timber rafting. Measures included mapping and remediating migration barriers, river habitat restorations, and removing ecologically harmful erosion and flood protection structures.

ReArc was led by the County Administrative Board of Norrbotten. Other partners were the Pechenga Public Organization of Ecological Enlightenment, the Lapland Centre for Economic Development, Transport and Environment, Metsähallitus Parks and Wildlife and the Norwegian Water Resources and Energy Directorate.

References:

The ELY-centre of Lapland, ReArc -project website:
https://www.ely-keskus.fi/lappi-rearc. (accessed 21.12.2023)

Kolarctic CBC, ReArc -project website:
https://kolarctic.info/our-projects/ko1078-ecological-restoration-of-arctic-rivers/.
(accessed 21.12.2023)

EMRA (2019–2022)

The environmental planning, measures and restoration actions in regulated water systems (EMRA) -project was a shared, EU-Interreg Nord-funded project between Sweden and Finland. Between 2019 and 2022, inventories, restorations, development of restoration measures and research on the genetic variation of migratory fish as well as on the importance of fish for the

locals, were conducted in the lower parts of the Kemijoki River in Lapland, Finland and the Lule River in Norrbotten, Sweden.

As a result of the project, around 20 km of river habitat was restored, 19 side channels were opened, 27 spawning beds were created, and six migration barriers were removed in the Lule River watershed. In the Kemijoki watershed, 470 km of river channel was inventoried. Based on the inventories, riffle sections in four tributary rivers (Vähäjoki, Louejoki, Vaajoki, Runkausjoki) were chosen and restoration plans were created to improve conditions for the breeding of migratory fish. These restoration plans were not put into action within this project. Smaller-scale pilot restorations, such as spawning beds and remediation of migration barriers, were conducted in Kemijoki tributaries.

The project partners were the County Administration Board of Norrbotten, the Lapland Centre for Economic Development, Transport and the Environment, Metsähallitus, the Natural Resources Institute Finland, Vattenfall Vattenkraft AB and Kemijoki OY.

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EMRA -project report:
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The ELY-centre of Lapland, EMRA -project website:
https://www.ely-keskus.fi/ely-lappi/3890. (accessed 21.12.2023)

ReBorN LIFE (2016–2022)

In the Restoration of Boreal Nordic Rivers (ReBorN LIFE) -project, co-funded by the EU, six watercourses severely affected by timber floating were restored. Five of the rivers (Kalixälven, Råneälven, Piteälven, Åbyälven and Byskeälven) were located in Norrbotten and one (Lögdeälven)

in Västerbotten. As a result of the project, 243 kilometres of river length were restored, 14 679 spawning areas were created, and aquatic habitats were increased by 109 hectares. The project improved habitat conditions, especially for otter, freshwater pearl mussel and Atlantic salmon.

The County Administrative Board of Västerbotten coordinated the project. Project partners were The County Administrative Board of Norrbotten, The Swedish Forest Agency, Gällivare and Nordmalings municipalities and The Swedish Agency for Marine and Water Management.

References:

ReBorN LIFE -project website:
https://en.rebornlife.org/om-projektet. (accessed 21.12.2023)

Final report of the ReBorN LIFE -project:
https://en.rebornlife.org/_files/ugd/a179e9_1736e70ad1184cd084ed5c5857a3c413.pdf
(accessed 21.12.2023)

Remibar (2011–2016)

The Remediation of Migration Barriers in Streams (Remibar) was another EU-funded Life project in the Norrbotten and Västerbotten counties. The project was implemented in five catchments (Råneälven, Varjisån and Ängesån in Norrbotten and Lögdeälven and Sävarån in Västerbotten), where over 300 migration barriers were removed. The majority of the measures focused on remediating road culverts, but 30 dams were also removed. As a result, 1700 km of stream length was reconnected, opening new habitats for Atlantic salmon, brown trout and other animals.

The project partners were the Swedish Transport Administration, the County Administrative Board of Norrbotten, the County Administrative Board of Västerbotten, the Swedish Forest Agency, Sveaskog, Holmen Skog, SCA and the Swedish Agency for Marine and Water Management.

References:

Kestrup, Å. (2017). Report: The Impact of Migration Barrier Removal on Connectivity - Evaluation of Remibar. EC LIFE+ programme LIFE10 NAT/SE/045. https://bransch.trafikverket.se/contentassets/a9b565b7790f4109b9597beb434906ba/remibar_evaluation_report_170321.pdf. (accessed 21.12.2023)

River restoration measures in Norway

Land use impacts in northern Norway

The main anthropogenic threats to river ecosystems in Troms og Finnmark County are the generation of hydroelectric power, long-distance pollution, tourism and recreation, fish farming, introduced species and diseases, and channel modification for flood protection measures. In Nordland County, additional threats are agriculture, urban development, and mining, whereas long-distance pollution and tourism are less frequent issues (Vann-nett-portal).

Restoring rivers impacted by flood protection and erosion control measures

Unlike in Sweden and Finland, where forestry practices, including peatland drainage and timber floating, have altered fluvial ecosystems, Norway has experienced severe degradation of river habitats and a reduction in floodplain areas due to dredging and embankments of rivers for flood and erosion control. While the need for these structures still exists in densely populated areas, the Norwegian Water Resources and Energy Directorate (NVE) has successfully returned rivers to a more natural state at some sites. In these restorations, old embankments have been removed or relocated to return water flow into old, natural channels and to allow lateral connectivity between the river and the floodplain. NVE also has plans for future sites suitable for restoration. A challenge in the restoration of flood control structures is the reluctance of landowners to accept these measures, especially if they feel that their property might be under threat. In some areas, the threat may also be reasonable. Erosion and flood control constructions, as well as the projects where these have been reversed to restore river habitats, can be viewed in the Atlas.nve -map service.

References:

Interview of Senior Engineer Anders Björdal from the Norwegian Water Resources and Energy Directorate (NVE).

Vann-nett portal, The Norwegian Environment Agency: https://vann-nett.no/portal/. (accessed 21.12.2023)

NVE-Atlas 3.0, Norwegian Water Resources and Energy Directorate: https://atlas.nve.no/Html5Viewer/index.html?viewer=nveatlas#. (accessed 21.12.2023)

On-going cross-border cooperation projects

Our precious transboundary waters (2023–2026)

The EU Interreg Aurora project, Our Precious Transboundary Waters, is a cross-border cooperation project in the Pasvik, Neiden and Tana River watersheds. The project will run from 2023 to 2026. The overall goal is to resolve problems and threats the three transboundary rivers are facing, in cooperation between Norway and Finland.

There are four objectives in the project. The first is to document the changes in the Pasvik River, arising from the closing of the smelting plant on the Russian side of the border. The second is to develop genetic methods in the monitoring of human impacts on brown trout populations of the Pasvik River and Inarijärvi area. Third, new data on Atlantic salmon in the Neiden River is collected, and a database for future monitoring is created. Finally, a plan to prevent the spread of the salmon fluke (*Gyrodactylus salaris)* to the Neiden and Tana Rivers is created, along with the development of an eDNA-based method for parasite detection.

The Lapland Centre for Economic Development, Transport and the Environment and the County Governor of Troms and Finnmark lead the project. Other partners include the Natural Resources Institute Finland, the Finnish Food Authority, NILU, Akvaplan-Niva, The Norwegian Institute for Bioeconomy, The Norwegian Institute of Natural Research, the Norwegian Veterinary Institute, the Norwegian Food Safety Authority and the Swedish National Veterinary Institute.

References:

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Completed cross-border cooperation projects

Joint Environmental Management of the River Tana (2017–2020)

The project Joint Environmental Management of the River Tana ran from 2017 to 2020. This EU Interreg Nord-funded project aimed at compiling environmental data from Norway and Finland and developing the protection of biodiversity in the Teno River watershed.

The project had several outcomes. Firstly, a database of the surveys of Atlantic salmon, brown trout and Arctic char (*Salvelinus alpinus*) in the tributaries of Teno was formed. Secondly, a survey of migration barriers was conducted, and the data were combined with earlier inventories from the year 1999. In Finland, 84 sites were inventoried, and 26 migration barriers (road culverts) were detected. In Norway, out of 16 inventoried sites, 11 had migration barriers. The restoration potential of the barriers was evaluated, and three sites (one in Finland, and two in Norway) were remediated in 2018-2019. Additionally, shared water quality monitoring according to the EU's water framework directory was developed. Lastly, endangered species and habitats in the Teno River valley were surveyed and existing data were combined across the border.

The project partners were The Lapland Centre for Economic Development, Tana and Karasjok municipalities, the Natural Resources Institute Finland, the Norwegian Water Resources and Energy Directorate and the County Governor of Troms and Finnmark.

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The ELY-centre Lapland, project website: https://www.ely-keskus.fi/ely-lappi/joint-environmental-management-of-the-river-tana-tenojoen-interreg-hanke-. (accessed 21.12.2023)

Saving Our Northern Freshwater Pearl Mussel Populations (2019–2022)

In the Saving Our Northern Freshwater Pearl Mussel Populations (SALMUS) project, partners from Finland, Norway, Sweden and Russia combined forces to map northern habitats and populations of the freshwater pearl mussel. The project was partly funded by the EU's ENI Kolarctic Cross Border Cooperation programme and ran between 2019-2022. The target area was the cross-border river systems in the Green Belt of Fennoscandia.

In the SALMUS project, occurrences of freshwater pearl mussels were mapped, and the viability of newly found populations was evaluated. The survival of the majority of the populations would require large-scale restorations, covering both river channels and catchment areas, as well as allowing access for the host fish brown trout and Atlantic salmon. Two restoration methods were tested to increase oxygen-rich interstitial spaces in the stream bottom: the Hartijoki method and wooden deflectors, which together provided good results. Captive breeding of the freshwater pearl mussel was also successfully tested in the Lutto River, which has no host fish due to Tuloma River hydroelectric power plants that prevent fish migration to upstream tributaries. The ecosystem services provided by the freshwater pearl mussel and host fish were also studied and it was discovered that stakeholders and locals do recognize the value of healthy river ecosystems.

Metsähallitus Parks and Wildlife, the University of Jyväskylä, the Natural Resources Institute Finland, Alleco Ltd, the Karelian Research Centre of the Russian Academy of Science and the Institute of North Industrial Ecology Problems, The Norwegian Institute for Bioeconomy and The County Administrative Board of Norrbotten conducted the project. Russian contribution was omitted after the start of the war in Ukraine.

References:

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https://julkaisutmetsa-ss4.focusflow.net/assets/pdf/lp/Asarja/a243.pdf. (accessed 21.12.2023)

Past cooperation with Russia

Barents cooperation with Russia has been suspended. Nevertheless, there are several shared watersheds between Russia and other Barents countries, and collaborative projects in river management have been conducted in the past. One project, especially important for cooperation in fishery matters, is the Tuloma River project which is presented below.

Cross-border cooperation project: The Tuloma River Project

The Tuloma River basin covers an area of 21500 square kilometres and is situated in the Kola peninsula. Most of the catchment area falls within Russia's territory, but several tributary rivers, including Nuorttijoki, Luttojoki, Anterijoki, Jaurujoki, and Hirvasjoki, flow from the Finnish side of the border. There are two hydroelectric power dams in the main channel of the Tuloma River, the Lower Tuloma dam (built in 1936) and the Upper Tuloma dam (built in 1963), located on the Russian side of the river. The lower Tuloma dam has a functioning fish ladder. A fish pass was constructed also at the upper Tuloma dam, but it was later (1970) closed, and since then, the dam has been a barrier to fish migration.

The river has been historically significant for fishing. Before the construction of two hydroelectric dams, Atlantic salmon inhabited the whole river system and the tributaries on the Finnish side were important spawning habitats. Today, Atlantic salmon cannot migrate in the river, but the upstream tributaries harbor a unique naturally breeding migratory brown trout stock and the extremely rare freshwater pearl mussels.

During the end of the 1990s and early 2000s, an EU-funded research project aimed to restore Atlantic salmon populations in the Tuloma River system. In this project, Russian, Finnish, Irish and American researchers investigated the past and current migration routes of Atlantic salmon and their behaviour in the dam and upstream areas. Several options to open new migration routes and increase the functioning of existing fish passages were evaluated.

The following was suggested. The fish pass at the Lower Tuloma dam should be realigned and refined, to allow more fish to ascend the dam. Also, fish migration through the natural migration barrier in the tributary river Pecha, which flows into Tuloma River between the two dams, should be improved. This is because Pecha River has existing spawning areas for Atlantic salmon. Third, a new fish pass should be constructed in the Upper Tuloma dam, to allow Atlantic salmon migration into the vast upstream catchment. This would also require the introduction of salmon to upstream areas, to create a fish population with a tendency to migrate upstream in the future.

The plans made in the Tuloma-river project have not been implemented. There are multiple reasons behind this, including lack of funding, the discovery of salmon fluke in the lower parts of Tuloma River in the 2010s, and impaired possibility for cooperation between Finland and Russia.

References:

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Summary and conclusions

The purpose of this survey was to collect unimplemented river restoration plans, with a focus on restoring biodiversity and enhancing fish migration possibilities, from the Barents region. In this report, the found restoration plans, stream inventories and migration barrier inventories from the Finnish Barents region have been presented. Past and ongoing projects, as well as needs for restoration measures in the future in other Barents countries, Sweden and Norway, have also been reviewed.

The river restoration plans compiled from Finland reflect the period when timber floating modified Finnish river systems. Traces of timber floating persist, and supplementary restorations are still needed, to improve the state of the threatened migratory fish species. The restoration plans presented in this report mainly targeted middle-sized rivers, but inventories in small streams indicate a great need for restoration activities in these habitats as well. Migratory fish barriers have also been inventoried in several watersheds, revealing that road networks have severely deteriorated connectivity in stream networks. There is work to be done to remediate these barriers and improve fish migration.

Restoration projects in Sweden and Norway, and cooperation projects between the three countries, have addressed similar issues. On many occasions, the focus of the projects has been to enhance free migration and breeding opportunities for migratory fish species, such as Atlantic salmon and brown trout. Several projects have also improved, or aim to improve, conditions for other threatened species, like the freshwater pearl mussel. In the future, the shared demand to halt and reverse biodiversity loss will increase the need for national and cooperative measures in restoring all components of aquatic ecosystems within the river systems of the Barents region.

Acknowledgements

The help of all the organizations and people who provided restoration plans, inventory data, and other sources of information, as well as insights into the prioritization of restoration plans, is greatly appreciated.

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Appendix

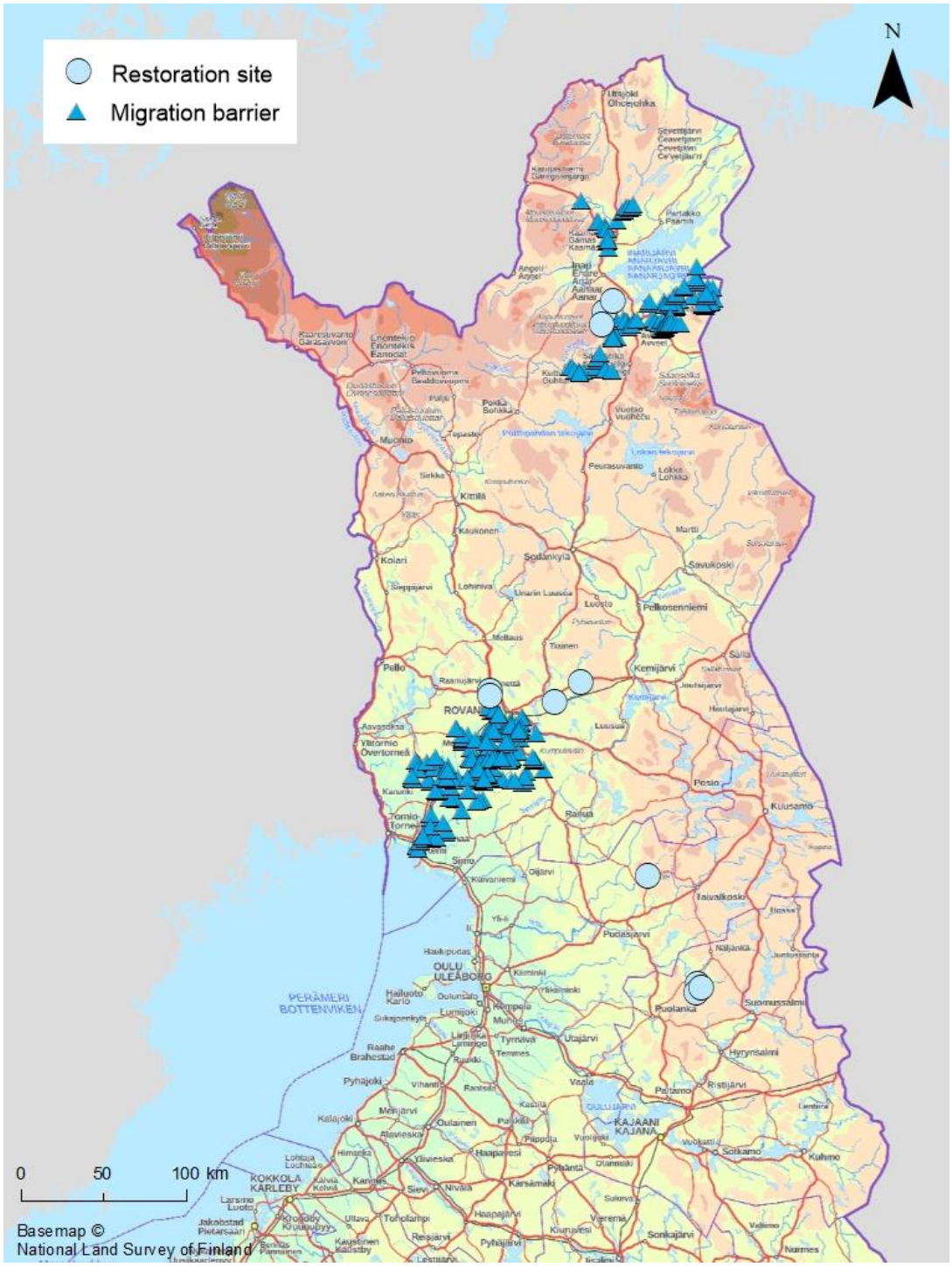

Figure A1. A map showing the location of the sites in the unimplemented restoration plans and the inventoried migratory barriers in Finland.