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SALMUS – Saving Our Northern Freshwater Pearl Mussel Populations

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Cover: Buried mussel individuals at Urakkajärvenoja, Finland.
Photo: Aune Veersalu.

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Heikki Erkinaro (ed.)

SALMUS
– Saving Our Northern Freshwater Pearl Mussel Populations

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Title SALMUS – Saving Our Northern Freshwater Pearl Mussel Populations

Abstract

Freshwater pearl mussel (Margaritifera margaritifera) (FPM) is a critically endangered taxon (CR) in Europe. The species is dependent on juvenile salmonid fish as larval hosts and has also high-quality criteria for stream habitat conditions. Main factors preventing successful recruitment of FPM are lack of suitable host fish and siltation of river bottoms due to adverse land-use practices in the river catchments.

The SALMUS project was implemented in 2019–2022 by eight organizations from four countries with the aim to increase biological knowledge base and to develop conservation methods in the Green Belt of Fennoscandia (GBF). Also, the harmonization of status assessment of rivers, by using FPM and salmonid fish as indicators of ecosystem health, was a common goal in joint river systems. Awareness-raising of northern river ecosystems and their socio-economic importance was also a central theme in the project.

Searching for new FPM occurrences, performed by aquascoping and diving in 360 separate water-bodies, resulted in 14 new populations. Viability status of local FPM populations was assessed in 45 streams with 16 populations reaching the two highest viability classes. However, most studied FPM populations do not reproduce in a sustainable manner. Conservation actions would be needed to reach a favourable status: restoration in the river channels and abandonment of adverse land-use practices in the catchment areas.

In the SALMUS project, captive breeding was used as a first-aid recovery method for FPM populations in the large Tuloma River system where Atlantic salmon has not been available as a host fish for the main river FPM populations since the 1960s due to river harnessing. Transplantation of mussel juveniles back to their home river after living for one year attached in the gills of their host fish resulted in successful recruitment.

Development and cross-border harmonization of ecological monitoring methods were also key goals of the project. Novel methods assessing physical condition of FPM individuals and measuring oxygen conditions in the stream bottoms were tested in the project. Both methods, accompanied with an in-stream restoration approach, were also adopted in permanent use of participating organizations.

Values and other perceptions on northern river ecosystems were explored with an ecosystem service survey. The results showed that non-monetary services and values were strongly recognized as beneficial across all stakeholder groups and people largely supported more resourcing and effective management practices to safeguard the wellbeing of river ecosystems.

Keywords freshwater pearl mussel, salmonid fish, river ecosystems, ecological monitoring, cross-border cooperation

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Tekijä(t) Heikki Erkinaro (toim.)

Julkaisun nimi SALMUS – Pohjoisten virtavesiemme jokihelmisimpukan suojelu

Tiivistelmä

Jokihelmisimpukka eli raakku (*Margaritifera margaritifera*) on äärimmäisen uhanalaiseksi (CR) luokiteltu laji Euroopassa. Raakku tarvitsee elinkierrossaan lohikalojen poikasia loisena elävän toukkavaiheen väli-isännäksi. Laji vaatii menestyäkseen myös laadukkaan jokielinympäristön. Nykyään tärkeimpiä raakun lisääntymisen estäviä tekijöitä ovatkin väli-isäntälajien (lohi, taimen) puuttuminen sekä jokipohjien liettyminen valuma-alueiden haitallisten maankäyttötapojen takia.

SALMUS-projekti toteutettiin vuosina 2019–2022 neljän maan ja kahdeksan kumppanin kesken päätavoitteenaan biologisen tietämyksen lisääminen hankkeen kohdelajeista ja suojelumenetelmien kehittäminen Fennoskandian vihreällä vyöhykkeellä. Tavoitteena oli myös ekologisten seurantamenetelmien yhtenäistäminen jokihelmisimpukkaa ja lohikaloja ympäristön tilan ilmentäjinä hyödyntäen. Projektissa lisättiin myös pohjoisten jokiekosysteemien ja niiden sosioekonomisen merkityksen tunnettuutta.

Kaikkiaan 360 vesikiikareilla ja pintasukeltamalla tutkitulta vesistöalueelta löytyi 14 uutta raakkuesiintymää. Populaation tila-arvio tehtiin 45 raakkujoella, tutkituista populaatioista 16 arvioitiin kuuluvan nykytilaltaan korkeimpiin elinkykyinen/mahdollisesti elinkykyinen -luokkiin. Suurin osa tutkituista raakkupopulaatioista ei kuitenkaan lisäänny nykyisin kestävästi. Suotuisan suojelutason saavuttaminen vaatisi suojelutoimia etenkin jokiuomia kunnostamalla sekä luopumista valuma-alueiden haitallisista maankäyttötavoista.

SALMUS-projektissa elvytettiin Tuulomajoen latvaosien raakkukantoja myös simpukanpoikasten laitoskasvatuksen ja istutusten avulla. Luttojoen raakku ei ole pystynyt lisääntymään voimalaitosrakentamisen seurauksena 60 vuoteen Atlantin lohen puututtua alueelta. Ikääntyneet raakkukannat saivat nyt kaivattua täydennystä lohenpoikasten kiduksissa kalanviljelyaltaissa kasvatetuista piensimpukoista.

Ekologisten seurantamenetelmien kehittäminen oli myös eräs projektin keskeisistä tavoitteista. Hankkeessa kehitettiin maasto-oloissa käytettävä simpukkayksilöiden fyysisen kunnon arviointimenetelmä sekä pohjasedimentin happiolosuhteita mittaava, naulojen ruostumisnopeuteen perustuva seurantamenetelmä. Lisäksi projektissa testattiin pohjasedimentin rakennetta ja laatua parantavaa kunnostusmenetelmää.

Ekosysteemikyselyllä selvitettiin ihmisten arvoja ja arvostuksia pohjoisiin jokiekosysteemeihin liittyen. Tulokset osoittivat, että luonnon tuottamia ei-rahallisia palveluja ja arvoja pidettiin kauttaaltaan eri vastaajaryhmissä hyödyllisinä. Vastaajat kannattivat myös resurssien ja tehokkaiden säätelytoimien lisäämistä jokiekosysteemien hyvinvoinnin turvaamiseksi.

Avainsanat	jokihelmisimpukka, raakku, lohikalat, jokiekosysteemi, ympäristöseuranta, ekosysteemipalvelut, rajayhteistyö		
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Författare Heikki Erkinaro (red.)

Publikation SALMUS – Bevara våra nordliga flodpärlmusselpopulationer

Sammandrag

Flodpärlmussla (*Margaritifera margaritifera*) (FPM) är en akut hotad art i Europa. Arten är beroende av lax och öring som fungerar som värdfisk för musslans larver. Musslan är även en indikatorart som visar på det ekologiska tillståndet i strömmande vattendrag. Brist på värdfisk och igenslamning av bottnar på grund av intensiv markanvändning inom avrinningsområdet kan vara huvudorsaken till ogynnsam rekrytering till flodpärlmusslebestånden.

SALMUS-projektet genomfördes under 2019–2022 av åtta organisationer från fyra länder med målet att öka den biologiska kunskapsbasen och utveckla metoder för bevarande av biologiska värden inom Fennoskandias Gröna Bälte. Ett annat gemensamt mål var att använda flodpärlmussla och laxfisk som indikatorer på hur väl ekosystemen mår. Detta gjordes genom att använda samma metoder för bedömning i alla länder. En annan central del i projektet var att belysa vikten av friska ekosystem och dess socioekonomiska betydelse.

360 olika vattendrag undersöktes med vattenkikare och med hjälp av snorkling i syfte att upptäcka hittills okända förekomster av flodpärlmussla, totalt hittades 14 nya populationer. I 45 vattendrag undersöktes hur livskraftiga populationerna var, 16 vattendrag bedömdes ha de två högsta klasserna av livskraftighet. Men i merparten av de undersökta vattendragen konstaterades att de inte rekryterar tillräckligt väl för att bibehålla livskraftiga populationer. Olika åtgärder som till exempel biotopvård i vattendrag och förändrad markanvändning i avrinningsområdet krävs för att uppnå livskraftiga populationer.

För att ge FPM-populationer inom Tulomaälvens avrinningsområde en chans att återhämta sig genomfördes odling av musslor inom SALMUS-projektet. Sedan 1960-talet har lax inte varit tillgänglig som värdfisk i Tulomas huvudfåra på grund av vattenkraftverk. Efter att ha suttit fast ett år på värdfiskens gälar i odling planterades unga musslor tillbaka till sin hemälv med lyckat resultat.

Utveckling av olika ekologiska övervakningsmetoder och harmonisering av dessa över landsgränserna var också viktiga mål inom projektet. Inom projektet testades nya metoder för att bedöma fysisk kondition hos enskilda individer av FPM samt att mäta syretillgången i bottensubstratet. Båda metoderna, tillsammans med biotopvård i vattendrag, tillämpas i dag permanent av de deltagande organisationerna.

Genom en enkätstudie undersöktes hur människor uppfattar och värderar nordliga ekosystem i rinnande vatten (ekosystemtjänster). Resultatet visade att icke-monetära tjänster och värderingar förknippades som positiva av alla intressegrupper. I stort sett alla i undersökningen tyckte att mer resurser och en effektiv förvaltning krävs för att säkerställa välmående ekosystem.

Nyckelord flodpärlmussla, lax, öring, ekosystem, vattendrag, ekologisk övervakning, ekosystemtjänster, samarbete över landsgränser

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Dahkki(t)	Heikki Erkinaro (doaimm.)
Almmustuhttima namma	SALMUS – Davvi skálžonáliid gáhtten

Čoahkkáigeassu

Skálžu (*Margaritifera margaritifera*) lea hui áittavuložiin (CR) klassifiserejuvvon šládja Eurohpás. Skálžu dárbbaša eallingierddustis luossaguliid veajehiid parasihttan eallán suoksaáigodaga gaskaisidin. Šládja gáibida ceavzimii maiddái alladási johkaeallinbirrasa. Otná beaivve skálžžu lassáneami váldohehttehussan lea gaskaisitšlájaid (luossa, dápmot) váilun ja johkabotniid mohteluvvan golganguovlluid vahátlaš eanageavahanvugiid geažil.

SALMUS-prošeakta ollašuhttui jagiid 2019-2022 njealji riikka ja gávzzi guoimmi gaskka ja váldomihttomearrin lei biologalaš dieđu lasiheapmi fidnu čuozáhatšlájain ja suodjalanvugiid ovddideapmi Fennoskandia ruoná avádagas. Mihttomearrin lei maiddái ekologalaš čuovvunvugiid ovttaiduhttin skálžžu luossaguliid ávkkástallamin birrasa dili čájeheaddjin. Prošeavttas lasihedje maiddái davvi johkaekovuogádagaid ja daid sosioekonomalaš mearkkašumi dovddusvuođa.

Buohkanassii 360 čáhcekiikkáriin ja čázeoaibuokčamiiguin dutkojuvvon čázádatguovllus gávdne 14 ođđa skálžodihttoma. Populašuvnna dilleárvvoštallan dahkkui 45 skálžojogas, dutkojuvvon populašuvnnas 16 árvvoštalle gullat dálá dili dáfus alimus eallinnávccalaš/vejolaččat eallinnávccalaš –luohkáide. Stuorámus oassi dutkojuvvon skálžopopulašuvnnain eai goittotge lassán dál suvdilit. Heivvolaš suodjalandási fáhten gáibidivččii suodjalandoaimmaid eandalii johkarokkiid divvumiin ja luohpan golganguovlluid vahátlaš eanageavahanvugiin.

SALMUS-prošeavttas ealáskahtte Doallána gierragiid skálžonáliid maiddái skálžočivggaid lágádusšaddadeami ja gilvimiid vehkiin. Lohtu skálžu ii leat ceavzán lassánit fápmolágádushuksema čuovvumuššan 60 jahkái go Atlántta luossa váilu guovllus. Boares skálžžut ožžo dál váillahuvvon dievasmahttima luossaveajehiid suvddiin guollegilvináldáin šaddaduvvon smávvaskálžžuin.

Ekologalaš čuovvunvugiid ovddideapmi lei maiddái prošeavtta okta guovddáš mihttomeriin. Fidnus ovddidedje luonddudiliin ávkkástallon skálžoooktagasaid fysalaš veaju árvvoštallanvugiid ja bodnesedimeantta oksygenadiliid mihtidan, spihkáriid ruostunlektui vuođđuduvvan čuovvunvuogi. Lassin prošeavttas geahččaledje bodnesedimeantta ráhkadusa ja šlája buorideaddji divvunvuogi.

Ekovuogádatjearahallamiin čielggadedje olbmuid árvvuid ja árvvus atnimiid johkavuogádagaid ektui. Bohtosat čájehedje, ahte luonddu buvttadan ii-ruđalaš bálvalusaid ja árvvuid atne ollislaččat sierra vástideaddjijoavkkuin ávkkálažžan. Vástideaddjit guottihedje maiddái resurssaid ja beaktilis čuovvundoaimmaid lasiheami johkaekovuogádagaid buresveadjima dorvvasteapmin.

Čoavddasáni	skálžu, luossaguolit, johkaekovuogádat, birasčuovvun, ekovuogádatbálvalusat, rádjeovttasbargu		
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Tittel	SALMUS – Bevaring av våre nordlige elvemuslinger

Sammendrag

Elvemusling (*Margaritifera margaritifera*) er en kritisk truet art (CR) i Europa. Arten er avhengig av unge laks eller ørret som er vert for elvemuslingelarvene (glochidiene), men de er også avhengig av at elvene og habitatet, samt vannet, holder høyt kvalitets nivå. I hovedsak er det mangel av vertsfisk og nedslamming av elvebunnen fra ulike former av arealbruk i nedbørsområdet til elva som er de generelt mest negative faktorene for elvemuslingbestandene.

SALMUSprosjektet ble gjennomført fra 2019 til 2022 med åtte organisasjoner fra fire land med formål om å øke kunnskapen om elvemuslinger og dens verter og utvikle bevaringsmetoder i Det Grønne Beltet i Fennoscandia (GBF). Også harmonisering av statusvurdering av elver, ved å bruke FPM og laksefisk som indikatorer på økosystemhelse, var et felles mål i felles elvesystemer. Bevisstgjøring av nordlige elveøkosystemer og deres sosioøkonomiske betydning var også et sentralt tema i prosjektet.

Leting etter nye forekomster av elvemusling, som ble utført ved vannkikkert og snorkling i 360 ulike vannforekomster, resulterte i 14 nye populasjoner. Levedyktighetsstatusen til elvemuslingbestander fra 45 bekker/elver blevurdert, og 16 av dem nådde de to høyeste levedyktighetsklassene. Imidlertid reproduserer de fleste undersøkte bestandene av elvemusling ikke til et bærekraftig nivå. Bevaringstiltak vil være nødvendig for å oppnå en gunstig reproduksjoene, slik som restaurering i elvekanalene og stoppe uønsket arealbrukspraksis i nedslagsfeltene.

I SALMUS prosjektet ble oppavl brukt som en førstehjelpsmetode for elvemuslingbestander i det store Tuloma-elvesystemet, hvor atlantisk laks ikke har vært tilgjengelig som vertsfisk for hovedelvens elvemuslibestandene siden 1960-tallet på grunn av elveregulering. Tilbakeplassering av oppalte elvemuslingunger tilbake til forelsdrenes hjemelv ble etter å ha levd i ett år gav vellykkede resultater som bedrer rekrutteringen.

Utvikling og grenseoverskridende harmonisering av økologiske overvåkingsmetoder var også sentrale mål for prosjektet. Nye metoder for å vurdere fysisk tilstand til elvemuslinger og måle oksygenforhold i bunnsedimentene ble testet i prosjektet. Begge metodene ble brukt i restaureringstiltak, og tatt i bruk av deltakende organisasjoner.

Verdier og andre vurderinger fra befolkningen om våre nordlige elveøkosystemer ble undersøkt med en spørreundersøkelse om økosystemtjenester. Resultatene viste at ikke-økonomiske tjenester og verdier ble sterkt anerkjent som fordelaktige på tvers av alle interessentgrupper, og folk støttet i stor grad mer ressurser og effektiv forvaltningspraksis for å ivareta livskraften til elveøkosystemene.

Nøkkelord	elvemusling, laks og ørret, elveøkosystemer, økologisk overvåkning, økosystemtjenester, grensekryssende samarbeid

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Contents

1 Targets and Results of the Project

Heikki Erkinaro

1.1 Background

The endangered freshwater pearl mussel (*Margaritifera margaritifera*) has the longest life span recorded in the freshwater or terrestrial fauna of Fennoscandian countries. Besides its longevity, freshwater pearl mussel (FPM) is famous for the pearl fishing history. The main reasons for the present endangered status of this iconic species are harnessing of rivers preventing free migration of salmonids and adverse land-use practices in the catchment areas resulting in siltation of the riverbeds.

FPM has a complex life cycle which makes the species highly susceptible to recruitment failures (Fig. 1). The life cycle includes dependence on juvenile salmonid fish (Atlan-

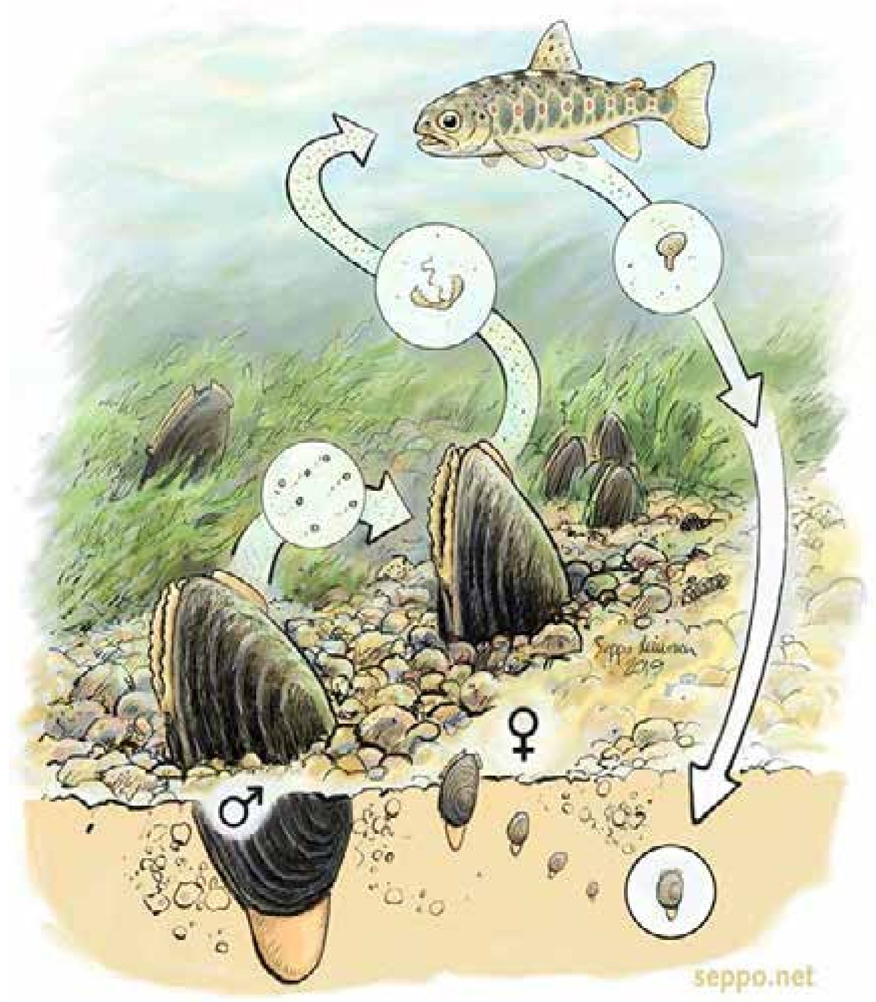

Figure 1. The life cycle of a freshwater pearl mussel. Fertilized mussel eggs develop into tiny glochidia larvae. These larvae need to attach themselves to the gills of young host fishes (Atlantic salmon or brown trout), where they live as parasites over the winter. In the following summer, after dropping off from the host fish, juvenile mussels dig themselves into the bottom substrate. They live submerged for a couple of years before starting the century-long life as filtrating individuals on the river bottom. Picture: Seppo Leinonen.

tic salmon or brown trout) as larval hosts. The absence of suitable juvenile host fish and unfavourable river bottom conditions for the FPM juveniles – living their first years burrowed in the riverbed – are two main factors preventing successful recruitment.

Freshwater pearl mussel is listed on the IUCN Red List of Threatened Species as a critically endangered taxon (CR) in Europe. FPM populations have decreased also in areas thought to be the strongholds of the species occurrence (i.e., Fennoscandia and North-Western Russia). Therefore, national conservation strategies and action plans for the conservation of FPM have been introduced in Sweden and Norway already in the 1990s and 2000s, respectively. Also, Finland got its first national strategy and action plan for the protection of freshwater pearl mussel quite recently in 2021.

In northern Fennoscandia, FPM has been the object of many international projects aiming at improvement of knowledge base and development of conservation methods. Most project partners of SALMUS have been involved in these EU projects during the last two decades. Cooperation of the partners has been motivated especially by many joint cross-border FPM river systems and shared, similar conservation challenges with the target species. In this respect, the so-called Green Belt of Fennoscandia, a network of protected areas along the borders between three countries (Finland, Russia, and Norway), has shown to be a relevant and fruitful framework for joint FPM conservation work.

Freshwater pearl mussel inventories at Niemioja in the Urho Kekkonen National Park. Photo: Heikki Erkinaro.

Based on these previous experiences, obvious needs for further conservation cooperation have been identified: (I) Searching for new uncovered FPM populations was considered as one of the central goals in helping to safeguard the existence of mostly endangered occurrences. In addition, methodological development and introduction of novel mapping tools was assessed to increase effectiveness of this work. (II) Harmonisation of monitoring methods was also seen to be necessary for improving utilisation of common knowledge base in the conservation management of joint cross-border river systems. (III) Also, inclusion of the host fish aspect in the FPM conservation development was considered to be essential while these species share similar environmental quality criteria and are extremely tightly intertwined by the compulsory parasite stage of FPM in salmonid juveniles. (IV) Finally, ecosystem service approach was regarded to benefit FPM conservation work due to many related, well-known ecosystem aspects linked with FPM and salmonid fish. In line with this, also awareness-raising of the importance of healthy freshwater ecosystems was one of the needs identified with the goal of strengthening pro-environmental attitudes and behaviour of people.

The Kolarctic CBC Programme awarded in 2017 financing to a project consortium consisting of eight partners from four neighbouring countries to promote above-named goals in the conservation work of FPM and its salmonid host fish species. The SALMUS project (Salmonid Fish and Freshwater Pearl Mussel – Riverine Ecosystem Services and Biodiversity in the Green Belt of Fennoscandia) was ready to start its work after a delay in March 2019. The implementation period of the project ended in August 2022.

Participating organizations in the project were Metsähallitus Parks and Wildlife (Lead Partner), Natural Resources Institute Finland (Luke), Alleco Ltd. and University of Jyväskylä from Finland, County Administrative Board of Norrbotten from Sweden, Norwegian Institute for Bioeconomy Research (NIBIO) from Norway and Institute of North Industrial Ecology Problems (INEP KSC RAS) and Karelian Research Centre of the Russian Academy of Sciences (KarRC RAS), both from Russia.

After the start of the war in Ukraine, the European Commission suspended participation of the Russian Federation in the implementation of cross-border cooperation programmes between the European Union and Russia. In accordance with this, all contributions by the Russian project partners of SALMUS have been omitted from this report.

1.2 Objectives

The overall objective of the SALMUS project was to enhance cooperation and to streamline common practices for assessing the status of streams and rivers, by using especially freshwater pearl mussel (FPM) and salmonid fish as indicators of ecosystem function and health. The project also strove for improving the knowledge base on riverine ecosystems in the Green Belt of Fennoscandia (GBF) with a simultaneous provision of a toolkit of best practices and methodologies for assessment of riverine ecosystem health. Furthermore, our project wanted to raise people’s awareness of riverine ecosystems and their socio-economic importance in the GBF, and thus by these means to improve the status and attractivity of the cross-border watersheds.

1.3 Project area & activities

The original idea of the project was to improve and develop conservation work of cross-border river ecosystems in the so-called Green Belt of Fennoscandia, a network combining protected areas along the border regions of Finland, Russia, and Norway. In addition to project actions in the GBF area, some Swedish river systems were included in the project as reference sites to increase the joint knowledge base on northern river ecosystems and for strengthening the basis in harmonizing of monitoring methodologies (Fig. 2). Difficulties in border-crossing, caused by the persistent covid lockdown situation, impeded most joint field work activities since the beginning of 2020. After the commencement of the war in Ukraine and exclusion of the Russian Federation from all international cooperation, project results by Russian partners were not included in this report.

Totally 29 separate project activities of SALMUS were grouped in four work packages:

- I Development of the cross-border cooperation and methodology
- II Improvement of knowledge base
- III Development of novel techniques and practices
- IV Information and Communication plan.

Activities in the work packages I and IV were mostly related to project management and communication (internal & external) practices. Therefore, only substance studies belonging to work packages II and III are covered by this final report. There were some necessary deviations from the original work plan and project structure due to changes in external conditions, most notably after the total omission of Russian contribution from the project. Next, summarizing results of all realized project activities are presented under six thematic sections. In addition, original work reports by each partner are included as annexes of this final report.

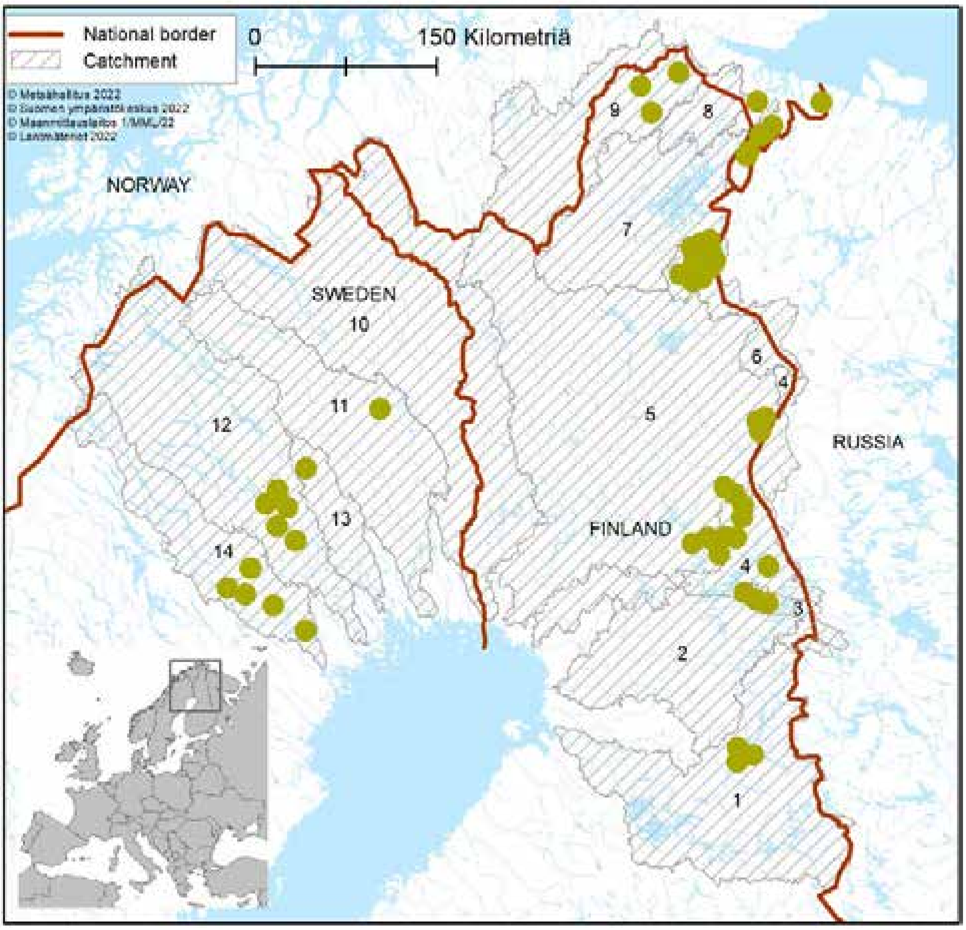

Figure 2. Project area and location of the rivers (dots) with status assessed FPM populations in Finland, Sweden, and Norway. Main catchment areas: 1. Oulujoki 2. Iijoki 3. Karelian Kem/Vienan Kemijoki 4. Koutajoki 5. Kemijoki 6. Lutto (Tuloma) 7. Pasvik/Paatsjoki 8. Neiden/Näätämö 9. Teno/Tana 10. Torneälven/Tornionjoki 11. Kalixälven 12. Luleälven 13. Råneälven 14. Piteälven.

1.4 Results

1.4.1 Freshwater pearl mussel population studies

1.4.1.1 Inventory of new freshwater pearl mussel populations

Background

The first prerequisite in the conservation of any threatened species is to know where populations of the target species are located. Regarding freshwater pearl mussel (FPM), existence of still uncovered FPM populations in the Green Belt of Fennoscandia (GBF) was the starting point for our inventory surveys. This presumption was based both on historic FPM records as also on the large unmapped areas still waiting for first inventories to take place. At the same time, our idea was to introduce and test new searching methods of FPM populations with options for wider method replication in the upcoming inventories. Quite recently, Finland got its first national strategy and action plan for the protection of freshwater pearl mussel 2020–2030 (Ministry of Environment 2021). Searching for new uncovered population is also defined in the action plan as an essential element of future conservation work for FPM.

Methods

A total of 505 sites in 360 different Finnish streams was studied either by using an aquascope or by electrofishing. In this context, electrofishing method was used for inspection of gills of young host fish (brown trout or Atlantic salmon) to possibly find glochidia larvae of FPM attached in the gills. This novel investigation method was tested at 65 sites in 39 different streams 2019–2020. The second novel searching method, eDNA, was also piloted in the project. Results of this approach are discussed in the annexed chapter "eDNA method". Aquascoping (accompanied with snorkeling at few localities) was used at 440 sites in 321 different rivers. Most areas studied were situated in the Finnish-Russian border zone and its nearby areas in the GBF (latitudinally between municipalities of Ilomantsi in the south and Inari in the north, see Fig. 3).

Results and discussion

In total, 13 new FPM populations were found by aquascoping/snorkeling method (Table 1). Two populations were classified as extinct, while only old FPM shells could be found at these sites. In addition, one new population occurrence was found by the eDNA method (see the annexed chapter "eDNA method"). In contrast, no new FPM populations were found by electrofishing method.

It was a positive result that many new FPM populations could still be found in Finnish rivers of the GBF. Many of these rivers belong to cross-border river systems as our primary aim was the development of joint monitoring methods and improvement of the database for border-crossing rivers. Aquascoping proved to be a good and cost-effective method for FPM population searching. It is possible to investigate quite many sites per

Table 1. Newly found freshwater pearl mussel populations in the SALMUS project

River catchment	Name of the stream
Kemijoki	Sätsijoki
Kemijoki	Ahvenoja
Kemijoki	Tammakkolamminoja
Kemijoki	Hangasjoki
Kemijoki	Lauttajoki
Kemijoki	Vääräjoki
Kemijoki	Salmijoki
Kemijoki	Köykenejoki
Kemijoki	Purkaoja
Koutajoki	Myllyoja
Oulujoki	Lahnajoki
Oulujoki	Korpijoki
Oulujoki	Leväjoki
Karelian Kem	Välijoki

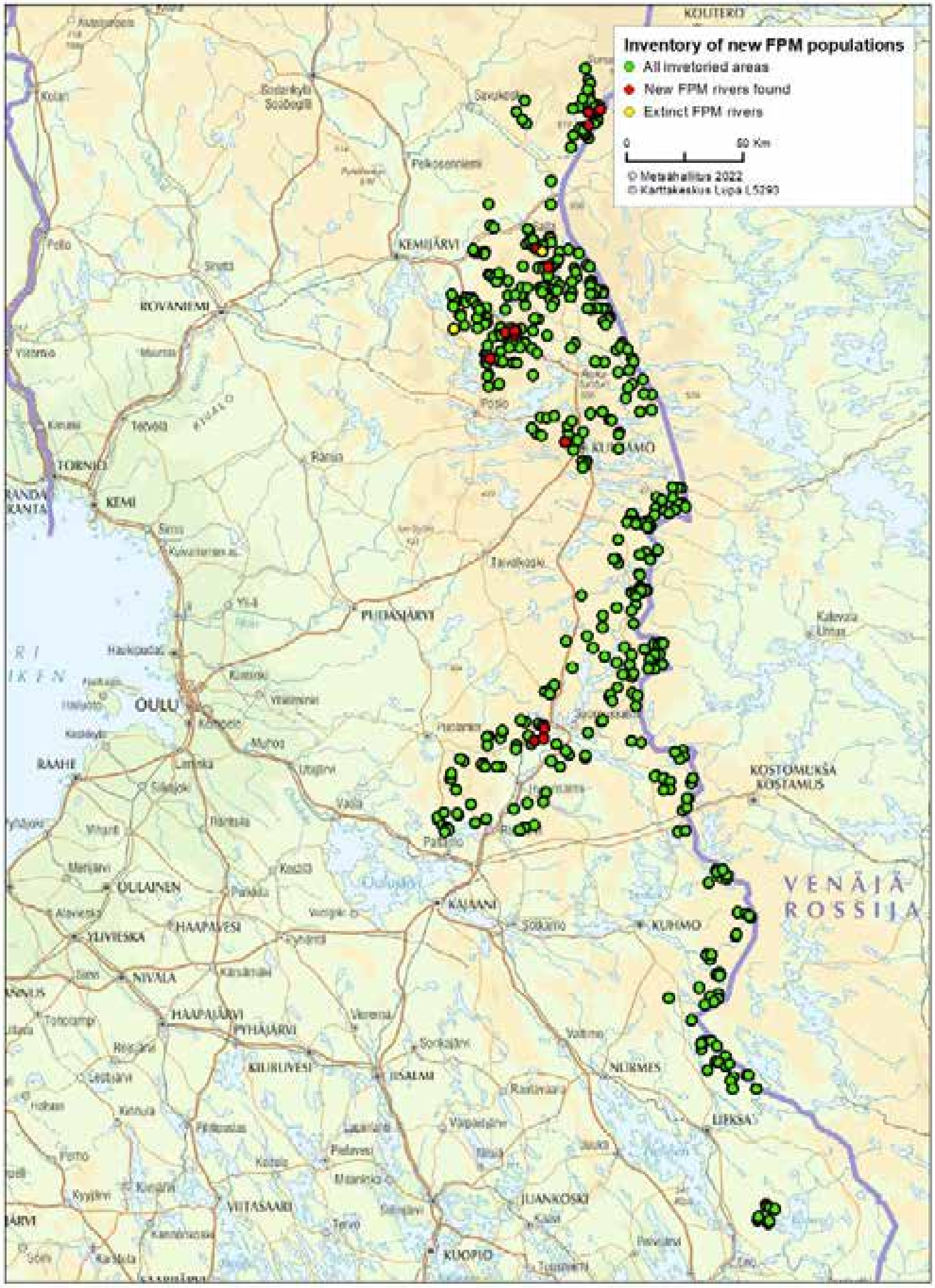

Figure 3. Study areas in searching for new freshwater pearl mussel populations in 2019–2021. All mapped sites are marked in green, new populations found in red and extinct populations in yellow.

one day by using this method with a team of 2–3 persons. However, because time is always a limited resource it is important to prioritize investigations at most potential sites based on biological expertise and preliminary site-specific knowledge. In contrast, there were big challenges in using electrofishing as a searching method. It was quite difficult to get enough fish individuals for a representative sample size in early summer. Fish seem to enter rapid areas (being then more easily catchable by electrofishing) not until waters have got warmer, and it is highly probable that FPM glochidia larvae have already detached from fish gills at that point of the season.

Most new FPM populations found were quite aggregated by location (see Fig. 3). It is obvious that this patchy occurrence pattern may partly reflect immigration history of the species but also differences in the prevailing environmental conditions of the river systems. Immigration history was highlighted for example in the case of River Vuoksi catchment (Ilomantsi municipality) where no FPM populations were found, which is in line with the absence of any historic records existing from that catchment. Another interesting observation was that all border-near parts of the River Oulujoki catchment seemed to be totally without any FPM populations. Reasons for this phenomenon were obviously related to environmental conditions because streams in these areas proved to have mainly dark humic waters, river channels were strongly modified and only few brown trout were altogether met in electrofishing surveys or in other stream inventories. As the result, Emäjoki area is probably the only remaining subcatchment of Oulujoki river basin still inhabited by FPM populations. Some other, still unknown reasons must be behind the present poor status of northern River Näätämönjoki FPM populations. In our inventories, no new populations could be found despite of good availability of suitable host fish individuals and the otherwise high ecological status of local rivers. However, this result was not a surprise because the remaining FPM population of Näätämönjoki mainstem has been assessed to be on the brink of extinction already in the previous studies (e.g., Oulasvirta 2015). Some earlier negative impact may have crushed the population under the threshold of viable population size and local reproduction potential has practically ceased due to extremely low numbers of FPM individuals.

Population status assessments were made for almost all newly found FPM populations of the project (see the annexed report "Status of the freshwater pearl mussel populations") so that the conservation status and urgency for further actions needed could be assessed for these populations. In addition, electrofishing surveys were performed at all newly found FPM sites to examine the status of mussels' host-fish populations. This knowledge is critical when evaluating preconditions of a population for successful reproduction. Results from these studies are presented in the report section "Host fish studies".

1.4.1.2 Status assessments of freshwater pearl mussel populations

Background

Knowledge about the population status of endangered species is a vital part in all conservation management enabling planning and prioritizing of actions needed. Regarding freshwater pearl mussel (FPM), the proportion of FPM populations with assessed viability status differs a lot among the participating SALMUS countries. Before the onset of the project, about one third of the Finnish FPM populations had been assessed by the population viability while in Russia status assessments were in practice totally lacking. On the contrary, in Sweden and Norway, the status of almost all known populations has been assessed at least once. Also, the assessment methods used so far are slightly different. Accordingly, one of the key goals in this project was to harmonize monitoring and assessment methods in neighboring countries so that conservation of joint border-crossing river systems in the Kolarctic Programme area could be managed on a more reliable, uniform knowledge basis. In practice, viability status assessment work of SALMUS project was focused on those FPM rivers of the Green Belt of Fennoscandia (GBF) area considered to be in urgent need of updated population status knowledge. Also, practically all FPM populations newly found in the SALMUS project's inventories were included in the assessment program. In addition, certain rivers from Sweden were included in this activity as for comparison.

Methods

In the beginning of the project, a method harmonization workshop was organized in Sweden for demonstrating use of different assessment methods and for harmonizing methods to be used in this project. However, this goal was not reached with all partners because the Russian main actor Karelian Research Centre could not at all participate in the workshop in the summer 2019. Later, all attempts to demonstrate and introduce the use of FPM assessment methods in Russia failed because of the covid pandemic lockdown situation.

FPM population assessments of the project were performed by using standardized methods. Concrete field work methods and the criteria for viability assessment differ slightly between Sweden, Norway, and Finland. Nevertheless, all these methods are used in national FPM monitoring programs, and they comply with the related CEN standards. The viability criteria used in FPM population assessments are distribution range of the mussels within the river, population size, and proportion of juvenile FPM individuals showing success in recruitment. More details about the field methods and evaluation criteria are presented in the annexed report "Status of the freshwater pearl mussel populations".

Results and discussion

Altogether 45 FPM populations were examined in this project, out of which 25 were situated in Finland, 12 in Sweden and 8 in Norway. A viability status could be determined for 38 different populations. 16 populations were classified as *Viable* or *Maybe-viable*, 16 reached the class *Non-viable* and 5 populations were categorized to the classes *Dying* or *Dying soon*. In addition, one population was detected to be *extinct*. However, there were 7 populations which could not be classified for different reasons, mostly due to insufficient data on individual length measurements or total population size.

A positive result was the fact that so many populations were functional having successful recruitment in such an extent that they could be classified as *Viable/Maybe-viable* (16 out of 37, 43% of the assessed populations). Perhaps the most imminent negative finding was met in the River Lutto where viability status could be assessed after extensive mapping efforts. The age structure of the Lutto main river population is strongly skewed and no signs for recruitment in the last decades could be detected. Reproduction problems of this population were already known from earlier studies, but the estimated low total population size for this large river was after all a negative surprise. Atlantic salmon has been the host fish for the Lutto main river FPM populations, but salmon has not been able to ascend to the headwaters of the Tuloma system after construction of the Upper Tuloma hydropower plant in the 1960s.

Trends in population statuses are difficult to identify while most FPM populations assessed here have not been part of any previous monitoring program. However, positive signs in recent recruitment success suggest that improvement in some target rivers' condition would have happened. Possible reasons behind these observations are still highly ambiguous, but some possible changes may have occurred in local recovery from earlier acidification episodes. Also, temperature conditions may have been more favorable for the northern FPM populations during the last decades. Stream restoration actions have not taken place in the target areas assessed here and hence cannot account for the positive changes perceived.

Nevertheless, viability status of more than half of the assessed FPM populations did not reach classes *Viable* or *Maybe-viable*. Generally, low status of FPM populations is linked with recruitment problems due to poor habitat quality of stream beds or insufficient availability of host fish for successful reproduction. These both reasons were also in our assessment surveys estimated to have the highest impact on the present status of populations.

In Finland, the first national strategy and action plan for protecting the FPM was published in the beginning of 2021 (Ministry of the Environment 2021). In the action plan, viability assessments of FPM populations have been addressed as one of the most urgent actions needed for successful conservation implementation. The SALMUS project contributed to this need by increasing the percentage share of Finnish FPM populations now having a viability assessment from 30% to 44%.

1.4.2 Host fish studies

1.4.2.1 Population status of Atlantic salmon and brown trout

Background

Freshwater pearl mussel (FPM) and its salmonid host fish species Atlantic salmon and brown trout are intertwined by close connections. Young host fish are indispensable for the completion of FPM life cycle while the mussel's parasite stage takes place in the gills of young fish. In addition, both FPM and salmonid fish share same high-quality criteria for the environment they live in. SALMUS project was the first attempt among the participating partners to assess the population statuses of FPM and salmonids in the same project. The primary aim with this was to determine the reproduction possibilities of FPM populations in relation to status of local salmonid populations. In addition, combined biological data would corroborate knowledge base for all environmental considerations in joint cross-border river systems.

Natural Resources Institute Finland (Luke) has monitored juvenile densities of salmonid populations in the Kolarctic Programme area for many decades, mostly by electrofishing. Long time-series provide a sound basis for detection of general trends in fish densities as more specific occurrence data on circumstances at FPM target rivers of the project.

Methods

Densities and distribution of Atlantic salmon and brown trout were investigated in late summer or early autumn by electrofishing using standard methods and following the approved CEN guidelines (CEN 2003). Besides salmon and brown trout, also the occurrence of other species was recorded. Only one electrofishing pass was made at each site. So, all density results in our studies reflected uncorrected individual numbers per 100 m^2 without any estimation.

Most electrofishing sites visited during the SALMUS project are permanent study sites belonging to long-term monitoring programs. However, some additional areas were also studied to check the status of salmonid populations in areas known for the present occurrence of FPM populations.

Results and discussion

Long-term monitoring of juvenile salmonids does not indicate clear increasing or decreasing trends in north-eastern salmonid populations of Finland. This suggests that the populations have probably not faced any major changes in prevailing environmental pressures. It also implies that reproduction conditions for local FPM populations have stayed unchanged in this respect.

However, the juvenile densities of many studied headwater areas are constantly at a rather low level. This pattern is highlighted especially in the headwater mainstems of the Tuloma catchment. The absence of original Atlantic salmon populations is the most probable explanation for permanently low salmonid densities while mainstem habitats have never been the preferred habitat for brown trout in this area. The construction of Upper Tuloma hydropower plant has since the 1960s totally prohibited migration of Atlantic salmon to the upper reaches of the

A young-of-the-year brown trout juvenile at River Suomujoki in the Urho Kekkonen national park. Photo: Jaakko Erkinaro.

river system and brown trout has not been able to colonize empty habitats.

There are two interesting mismatch situations between present condition of fish stocks and occurrence of FPM. First, ecologically pristine River Näätämöjoki catchment supports relatively stable Atlantic salmon populations, but the local FPM populations are now at the brink of extinction. Näätämöjoki provides an example where the recruitment problems of FPM are not easily explicated by either host fish problems or poor environmental conditions. Second, mainstem of the River Lutto shows permanently very low juvenile brown trout densities. At the same time, extensive FPM surveys have revealed that local FPM populations consist solely of old individuals without any recorded recruitment during the last several decades (see the annexed report "Status of the freshwater pearl mussel populations"). The most probable explanation for this pattern is the absence of original FPM host fish species Atlantic salmon in the Finnish headwater areas for the reasons mentioned above. Another reason for reproduction failure could originate from the documented low juvenile brown trout densities. A minimum density of five young-of-the-year (0+) juvenile brown trout per 100 m^2 has been proposed as a threshold value for functional FPM reproduction performance (Söderberg et al. 2008). By comparison, small headwater tributaries do normally show higher juvenile salmonid densities. In addition, those small-size habitats have never been primarily inhabited by Atlantic salmon, apart from some tributaries used as nursery habitats by juvenile salmon. Therefore, local FPM populations may have adapted for using brown trout as a suitable host already over long periods of time.

Some serious threats can be identified for northern salmonid populations. There is a recent, explosive growth in population sizes of an invasive species pink salmon (*Oncorhynchus gorbuscha*), ascending for spawning to rivers throughout northern Atlantic area. Although competitive relationships between pink salmon and original species, especially Atlantic salmon and anadromous brown trout, are not yet known well, the speed of the change is alarming. This invasion may have drastic effects on northern salmonid populations and affect negatively also local FPM populations.

Another continuous threat is posed by climate change which is shaping ecosystems radically especially at high latitudes. In addition to possible interspecific competition changes, the highest water temperatures experienced may become a critical aspect for many salmonid species. However, viable temperature range conditions may differ between juvenile salmonids and freshwater pearl mussels. Accordingly, it is quite possible that negative consequences to FPM will not be primarily due to direct physiological temperature effects but rather due to habitat changes or decreased survival in its host fish populations.

1.4.2.2 Invasive species brook trout in the River Tuloma system

Background

Invasive species are nowadays a global threat to local biota and healthy biodiversity in all ecosystems. Brook trout (*Salvelinus fontinalis*) was introduced in the late 1970s to the Finnish headwaters of River Tuloma, in the Kuutusoja catchment draining to the River Suomujoki, for improving local recreational values. Because this species is not a suitable host for FPM in Finland (Salonen et al. 2016), its occurrence may – through the possible displacement of the original host species brown trout – crucially threaten successful reproduction of FPM populations. Moreover, the local situation is even more critical while the adjacent River Suomujoki is estimated to have the largest FPM population existing in Finland.

The aim of this study was to update knowledge about the occurrence range of brook trout in the Kuutusoja catchment. In addition, future management options were outlined for this invasive species.

Methods

The knowledge base on the brook trout populations of Kuutusoja catchment dates to the 1990s when Metsähallitus carried out first test fishing and removal actions by electrofishing and gillnetting. In SALMUS, we used both electrofishing and gillnetting to investigate the occurrence range and density of brook trout both in Kuutusoja river and in the lake Kuutusjärvi with tributaries draining to it. In addition, the occurrence of other fish species was observed as well to get a more comprehensive picture of the local fish communities. The survey was completed in August 2019.

Results and discussion

Long-term monitoring results clearly show that brook trout has not expanded its occurrence range during the last two decades. Nor has the number of fish individuals caught by electrofishing and gillnetting increased in the same period. This was a positive result suggesting that presence of invasive brook trout does not pose a notable threat for the reproduction conditions of local FPM populations at the moment. Results gained by eDNA method in 2019 were identical with the test fishing results in showing quite a similar range of occurrence for the species.

Proposed management principles for the Kuutusoja area are in line with earlier practices, including the maintenance of the existing fence barrier at the lake outlet combined with intensive removals of brook trout by gillnetting and electrofishing from the lake and its small tributaries (Vuontela et al. 2021). Regular monitoring is also recommended in the catchment area, not least because of the critical location of the mighty FPM river Suomujoki nearby.

Management practices proposed for the Kuutusoja catchment comprise an integrative set of different actions which can be replicated also elsewhere as a management protocol for this invasive fish species.

1.4.2.3 Genetic mixed-stock analysis of Lake Pääjärvi brown trout populations

Background

A genetic mixed-stock analysis was applied to measure proportions of different river-specific salmonid fish populations in the Russian Lake Pääjärvi basin. This catchment area is inhabited by one of the few vital adfluvial brown trout populations remaining in the Green Belt of Fennoscandia. These valuable fish stocks are harvested both in lake and in the rivers draining to the Lake Pääjärvi. Genetic mixed-stock analysis helps to determine the share of different subpopulations in the entire fish population. This knowledge is valuable for optimal fisheries management and targeted conservation actions. More detailed stream-specific data may also increase possibilities for conservation planning of FPM populations at a finer scale.

Methods

A baseline sample set of 515 young brown trout individuals was captured from 13 rivers draining to the Lake Pääjärvi by electrofishing in the late summer of 2016. Catch samples of brown trout have been collected twice from the Lake Pääjärvi, in 1995 (n = 194) and 2016 (n = 246), for detecting temporal variation in the genetic stock characteristics of the populations.

For genetic analysis, DNA of each fish specimen was extracted from the scale samples and analysed in the laboratory for variation at 16 microsatellite loci.

Results and discussion

The results showed that in the Lake Pääjärvi basin there were three distinctive population groups, Western, Eastern, and Southern group, differing clearly by genetic distance. The home rivers of these population groups also formed a reasonable pattern so that neighboring rivers were geographically close to each other in the genetic dendrogram (see the annexed report section “Host fish studies”). In general, the brown trout stock composition had stayed genetically quite similar between the study periods of 1995 and 2016. This result suggests that no major environmental pressure has been able to significantly shape the stock composition during these two decades. Specific management needs for different sub populations are not apparent based on these results. On the other hand, the results also indicate that many brown trout home rivers may not have a large breeding population, especially some rivers of the Southern population group did not contribute remarkably to the brown trout mixed stock in Lake Pääjärvi. No river-specific conclusions on FPM population conservation can either be drawn based on these results. More detailed studies on many unmapped parts of the catchment area should be performed to obtain a reliable picture of local FPM recruitment potential.

1.4.3 Developing conservation methods

1.4.3.1 Captive breeding, case Lutto River

Background

Most freshwater pearl mussel (FPM) populations worldwide are in a non-functional status. It means that, despite of occasional recruitment taking place, populations are expected to go extinct in a long run. The main reasons for this negative situation are lack of suitable host fish and degradation of pearl mussel habitats, mostly due to siltation of interstitial spaces on stream bottoms. Therefore, artificial breeding programs have become a widely used first-aid means for saving some of the most vulnerable non-functioning populations. The idea here is to cultivate glochidia-infested host fish and newborn juvenile mussels in the breeding stations over the most sensitive juvenile period before introducing the mussels back to their home rivers. This method has been adopted also in the management practices of Nordic countries. Research and development work on optimal breeding methodologies is ongoing in many organizations.

One of the aims in the SALMUS project was to assess and develop efficient practices for restoration of Atlantic salmon populations back to the upper reaches of the River Tuloma catchment. Most river areas of this large catchment, including all its headwaters in Finland, have not been accessible for Atlantic salmon because of a hydropower plant construction more downstream in the Russian part of the Tuloma catchment in the 1960s. This migration obstacle has left FPM of the Finnish Lutto River without a suitable host fish for decades. However, original project plans to introduce Atlantic salmon individuals to Finnish Lutto river areas had to be abandoned after the occurrence of a devastating *Gyrodactylus salaris* parasite in the lower reaches of Tuloma river system. Thus, captive breeding of Lutto river FPM individuals was decided to be started in SALMUS project as a compensatory action to help survival of this valuable over-aged population. This undertaking was aimed to simultaneously develop and increase knowledge about breeding practices of FPM.

Methods

In late August 2020, sixty FPM individuals were collected at the Lutto River and transported to Konnevesi Research Station. After the mussels had released glochidia larvae, Atlantic salmon parr were infected with these glochidia. Next summer, some 6,000 FPM

Electrofishing at River Kitkajoki, Kuusamo Finland. Photo: Pekka Korhonen.

juveniles, newly dropped from the gills of host-fishes, were collected at the Konnevesi station. In August 2021, two thousand tiny juvenile individuals were transplanted back to the Lutto River. Ten netted plastic boxes were filled with sieved gravel containing 200 FPM juveniles each. Boxes were fixed to the river bottom with metal poles at two suitable river areas.

Results and discussion

Five of altogether 10 gravel boxes were inspected for survival and growth of mussels in August 2022. The average percentage for juveniles found alive from the original number (200 individuals per box) was 64 %. Some loosened or dislocated nets indicated that quite a big number of individuals may have escaped from the cages. In line with this, the actual survival percentage based solely on individuals found alive (individuals found alive vs. all individuals found) was about 97%. High survival success documented here indicates that conditions have been favorable for juveniles during their first year in the river. As for the growth of individuals, the mussels were 2.5 times longer (average size 1.9 mm) in early August 2022 compared to the original length one year earlier.

Maintenance of the gravel boxes will still be needed with cleaning of nets from algae and checking of general box condition. These measures will be continued by the ongoing LIFE Revives project which also has FPM conservation activities taking place in the rivers Lutto and Suomu. Also, monitoring of the survival success will be undertaken by the same field team. In 2023, this first test batch of transplanted individuals will be released so that the juveniles can freely move and be located themselves on preferred microhabitats. Expectations for the survival success

A dense freshwater pearl mussel bed at Urakkajärvenoja, Finland. Photo: Aune Veersalu.

after that are high because the environmental conditions of the target area are quite optimal for the species. These project actions clearly showed the potential of captive breeding in conservation of Lutto River FPM. In the prevailing circumstances, this method is also the only way to save river's unique FPM population from eventual extinction.

1.4.3.2 Improvement of juvenile FPM habitats

Background

Problems in habitat quality, especially in oxygen conditions of the bottom substrate are main reasons for recruitment failures of many FPM populations. Siltation of the bottom is mostly caused by adverse land-use practices of the catchment area, and it is normally carried to the stream environment as fine sediment by ditches. Siltation poses a critical threat especially for young FPM individuals still living burrowed in the bottom. Proper water exchange in the interstitial spaces of the bottom enables sufficient oxidation which is crucial for the early stages of the FPM as also for the eggs of many stream-spawning salmonid fish. Colmation is another negative sedimentation-inferred effect on bottom habitats. Hard bottom surface makes burrowing of young mussels often difficult or impossible.

The aim of our studies was first to investigate the effect of available dissolved oxygen to juvenile FPM viability and survival. Second, the effect of substrate particle size on burrowing behavior of FPM juveniles, recently detached from the host fish, was investigated. The aim was to determine how fast FPM juveniles burrow into substrate of varying sizes and if they remain burrowed or resurface once again.

These laboratory ex-situ studies were accompanied by comparison of two different stream restoration methods tested in two northern streams (in-situ).

Methods

In laboratory experiments, young (<1 year-old) FPM individuals were exposed to three different oxygen concentration levels. Thereafter, viability of juveniles was determined by reference to foot movement or valve adduction.

In the burrowing behavior test, newly detached FPM juveniles were monitored in 12 h dark:12 h light conditions on plastic dishes containing water and a layer of sand with five different particle size classes. After placing juveniles on the substrate, all visible individuals (not burrowed) were counted at six different time points.

The aim of in-stream restorations was to clean riverbeds by removing excess fine sediment, originating from the catchment area, and to create suitable oxygen-rich habitats for juvenile FPM and spawning of brown trout. Two different restoration methods were compared to verify realized physical-chemical effects of both treatments. Validation of the restoration results was done by measurement of oxygen conditions in the interstitial space of the bottom. A traditional redox potential measurement was accompanied by a novel nail test method. In this approach, the rustiness level of the nails indicates the depth of oxygen-rich bottom substratum.

Totally nine small study sites (each 1 m^2) were selected in two adjacent rivers. In both rivers, three sites represented control sites and three sites were restored with the so-called Hartijoki method, where sand is cleaned out of the stream bed with special tools. The last three sites represented a combined restoration set with both Hartijoki method and wooden deflectors. Deflectors were used to accelerate targeted water current resulting in reduced sedimentation. The redox potential of the interstitial water was measured before and after the restoration work at each study site, and six nails for rust testing were inserted into the gravel bottom for a period of six months after the restoration had been completed.

Results and discussion

Experiments with different oxygen exposition showed that juvenile FPM cannot tolerate longer than 10-day events with very low dissolved oxygen levels at summer temperatures (≥ +17 °C). This finding highlights the importance of all possible restorative actions preventing low oxygen episodes in the substrate of FPM streams. Results of this study also support inclusion of dissolved oxygen to be included in FPM monitoring programs, in accordance with the CEN standard protocol for monitoring of FPM (Boon et al. 2019).

Burrowing behavior tests clearly showed that the proportion of burrowed FPM juveniles was dependent on the size of available substrate. As burrowing is considered an essential feature of FPM behavior and survival, particle size is a highly important indicator of FPM habitat quality. In the range of tested particle sizes, the coarsest material (500–650 µm) appeared to provide the most suitable habitat for newly detached juveniles. These results also support the view that restoration of stream bottom substrate is likely to be the most important conservation action for restoring FPM populations with poor or non-existent recruitment. To optimize the success of captive breeding actions, these results also help in identifying sites with favorable substrate conditions for the introduction of captive-bred individuals.

Comparison of stream habitat restoration methods clearly showed differences in the effects of two methods tested. Positive effects were also sustainable so that the desired effects were perceivable in both consecutive monitoring years after the restoration operation. The combined method including both Hartijoki treatment and wooden deflectors proved to attain the best results, i.e., oxygen-richest interstitial space in the bottom. This result was also verified by both monitoring methods – redox potential level was highest, and the nails were most rusted in the areas treated with this method. In summary, we were able to introduce a successful conservation method with demonstrated positive effects on the stream habitats. In addition, a novel method for restoration monitoring was adopted with a reliable validation.

All these project activities provided methods and suggestions for restoration work practices with high replication potential. In fact, stream restoration methods tested here are already adopted for concrete restoration actions, e.g., in the ongoing LIFE Revives project.

1.4.3.3 eDNA method

Background

eDNA method is nowadays widely used for various purposes of biological research. The aim in SALMUS was to use the method as a novel method for searching of new FPM populations. Developing and testing efficiency and reliability of this approach were also planned to be assessed in the project.

Methods

Three replicate water samples were collected to plastic bottles from 52 locations covering four Finnish river systems in autumn 2019, so that special attention was paid to avoid contamination of samples with ‘foreign’ DNA of FPM. Samples were filtrated in the field, and filter samples then stored in a freezer for further analysis. Five primer pairs were tested for their specificity to mitochondrial DNA of *M. margaritifera*. Based on various tests the primer pair MmarForfF1/MmarForfR1 was chosen for eDNA analysis of water samples.

Results and discussion

Based on the visual field inventories using aquascope and snorkeling, FPM populations were found from eight locations. Of these, our eDNA method (PCR/AGE) could detect five populations. Of the remaining three undetected populations, one was located 5 km upstream of the sampling point and two were categorized as *non-viable* in population status assessments. So, it seems that distance and viability status of the populations studied (including individuals' physiological activity) may both play a big role in detecting ability of the method. This dependence has been observed also in earlier related studies.

In addition, of the 44 sites that were found to be free from FPM populations based on visual inventories, our eDNA method detected one *M. margaritifera* eDNA positive site. That particular site (River Purkaoja) proved to really host FPM as a later thorough on-site inspection revealed alive mussels from the site. Thus, eDNA method found mussels from this site despite the earlier visual inspection with no results.

Based on our results, the eDNA method used (PCR/AGE) is suitable for robust and preliminary analysis of FPM eDNA. However, more sensitive methods – based on qPCR or ddPCR techniques – could have given more accurate results. In the future, PCR/AGE method presented here can be used as a basis in development of more advanced detecting methods, and already now it can be used as a preliminary or confirmatory element with traditional visual inventory methods.

1.4.3.4 Shell-opening resistance – a measure of condition of individual mussels

Background

Recruitment problems of freshwater pearl mussel (FPM) populations are mostly linked with absence of suitable host fish and degradation of stream bottom habitats. In addition to concrete environmental in-stream restoration measures, some FPM populations in poor condition have been given first aid by rehabilitation breeding programs, also in Finland. However, more detailed knowledge about the condition of different FPM populations and individuals would greatly benefit planning of all conservation actions.

The status or viability of freshwater pearl mussel (FPM) populations is often assessed by studying the size of a population and its age structure. However, there was no simple, non-destructive way to assess the condition of FPM individuals until Moorkens and Killeen (2018) described a method based on the shell opening resistance of mussels. The Shell Opening Resistance Method (SOR) utilizes the loss of adductor muscle tone as an indicator of stress.

In SALMUS project, we used the SOR measurements to indirectly evaluate the condition and stress level of individual mussels in 14 different FPM rivers. The aim was to investigate if this method could find condition differences between FPM individuals and populations, and if any spatial patterns would be detected in the project's target area, Green Belt of Fennoscandia (GBF).

Methods

Assessment of the individual mussel's condition is based on the resistance of forced shell opening, and to some degree, on the time it requires to close the valves when opened, as well as to the retraction of foot.

A five-category scale was used to describe the response of the mussel, from 5 (good condition, unstressed) to 1 (moribund). See more about classification details in the annexed report "Shell-opening resistance – a measure of condition of individual mussels". Measurement of SOR was applied in SALMUS project in connection of FPM sampling for genetic and isotope studies. In this study, SOR of thirty individuals was measured per each population. After sampling, mussels were returned alive to the spot from where they had been collected.

Results and discussion

There was a considerable variation in the shell opening resistance scores of FPM individuals between rivers. However, in most populations the median value reached was 5 (good condition, low stress). SOR median scores less than five were observed in five rivers. Also, a trend for lower SOR values (lower condition, higher stress) towards south was observed.

Trends in latitudinal median values may hint that SOR can indicate a true condition/stress status of FPM and give us useful information on FPM populations and individuals. In addition, interesting results were obtained when shell opening resistance was studied against the genetic diversity results of different FPM populations (see the annexed report "Genetic structure and diversity of freshwater pearl mussel populations"). Here, populations with very low genetic diversity exhibited low SOR scores. Therefore, SOR measurement could offer a reliable way to assess the condition of individual mussels. SOR measurements were also applied in the FPM food source studies of SALMUS project (see the annexed report "Aquatic and terrestrial food sources, and their influence on the wellbeing of *Margaritifera margaritifera*"). Based on this promising experience gathered in our project, SOR measurement was already included as a monitoring tool in the ongoing LIFE Revives project (2021–2027).

1.4.3.5 Age determination method and growth curves of FPM

Background

Detailed knowledge about populations' viability status is essential background information in all conservation action planning. Freshwater pearl mussel is a long-lived species (even > 200 years), and FPM individuals can be age determined based on the growth rings of the shells. It has been shown that growth speed of different FPM populations differs a lot, and this variability is not solely dependent on latitudinal differences between the population locations. Hence, the original aim in SALMUS was to create population-specific growth curves that could corroborate viability assessment of FPM populations and help in prioritizing conservation measures needed for each river.

Methods

In the SALMUS project 89 FPM specimens were aged from 29 rivers in northern Finland. In addition, a smaller number of mussels were also aged from Sweden and Norway, from 5 and 7 rivers, respectively. All the mussels were collected alive during summers 2019–2021. The age of mussels was determined based on shell thin sections (see more about the method in annexed report "Age determination method and growth curves of FPM"). Annual growth increments were measured as the shortest distance vertically to the winter lines in the prismatic layer. Finally, the growth curves for each population were established based on shell length and age of the mussels.

Results and discussion

The shell length of all 89 mussels examined in this study ranged between 26 and 140 mm and age (annual growth increments) between 10 and 254 years. The method clearly revealed differences in the growth rates of different target populations. However, the relationship between age and shell length of mussels showed that most individuals were placed between the curves indicating normal and low growth rate.

The most long-lived individuals ever recorded in Finland were observed in this study, especially the northernmost populations contained many individuals with more than 200 years lifespan. Interesting enough, the method was also quite accurate and in line with tracking of Lapland's climate history earlier described by dendrochronological methods. Historically known cold weather

A freshwater pearl mussel youngster with only 13 mm in length. Photo: Aune Veersalu.

periods from the 1800s were clearly visible in our growth rate data (cf. Mikkonen et al. 2015).

Some growth anomalies were detected in individual shells which may reflect adverse episodes in the environmental conditions and life-history of FPM individuals. However, the small sample size, three individuals per each site for maximizing number of populations covered in the study, did not allow any deeper population-specific considerations on these findings.

The age determination method is a promising approach because it operates with relevant life history variables of individual mussels. However, the original purpose to construct a method providing exact population-specific equivalence between individual lengths and individual ages was not able to achieve due to age-length model's inherent technical restrictions.

In addition to providing growth data, annual growth increments with elements derived from ambient water and diets of mussels enable studying of paleoenvironmental changes in environmental variables such as pH, temperature, salinity, and nutrient level. This functionality as an archive of past climate, environmental conditions, and physiological changes is a promising tool for attempts to reveal environmental changes experienced by this long-lived indicator species.

1.4.4 Genetics

1.4.4.1 Genetic structure and diversity of freshwater pearl mussel populations

Background

Maintenance of genetic diversity is one of the key factors in the success of conservation programs. High genetic diversity provides more evolutionary potential for adapting to changing pressures of the environment. This holds for both populations and separate species. Freshwater pearl mussel (FPM) has become endangered throughout its occurrence range (e.g., Machordom et al. 2003). Nowadays, the main reasons behind the bad condition of FPM populations are habitat degradation and problems in reproduction, often due to migration barriers prohibiting free movement of host-fish.

In general, populations with high genetic diversity are targeted for conservation efforts, as these populations might contain unique alleles that are not present in other populations. On the other hand, populations having unique alleles, even though their diversity might be low, may be regionally or globally important as they may represent the only population having that specific allele.

For conservation programs of FPM, the knowledge of genetic structure and differentiation of populations is important for example in all juvenile mussel restocking work. Also, genetic diversity parameters can be combined with other ecological and environmental knowledge (fish communities, habitat quality, toxic substances) for promoting sustainable conservation planning.

Methods

Genetic samples were collected from 27 rivers in 2020–2021. From each river, 30 mussels were picked up, and a 5 mm tissue piece was cut from the mantle. In addition, physical condition of the mussels was estimated using the shell opening resistance (SOR) measure (see the annexed report "Shell-opening resistance – a measure of condition of individual mussels"). After sampling, mussels were returned alive to the spot from where they had been collected. More details on the procedure of genetic analysis are available in the annexed report "Genetic structure and diversity of freshwater pearl mussel populations".

Results and discussion

Altogether 10 haplotypes from 15 rivers were discovered. A haplotype represents DNA variations which are inherited together, since there is no recombination between them. The highest haplotype diversity was discovered in Lutto mainstem (6 different haplotypes), Kolmosjoki (5) and Nohkimaoja (5) – all headwaters of the large River Tuloma basin. Lowest haplotype diversity (only one haplotype per population) were discovered in the rivers Juomajoki, Porontimajoki and Salmipuro. So, genetic diversity seems to be higher in populations of northern Lapland compared to more southern SALMUS project areas in Kuusamo and Kainuu. Also, the highest SOR values were met in northern Finland. Because of this positive correlation between haplotype richness and SOR measurements, there is a possible connection between the condition of the mussels and genetic diversity.

Based on our results, special attention in the project area should be given to conservation efforts of genetically most diverse FPM populations of the River Tuloma basin. On the other hand, certain rare haplotypes were found only in some Oulujoki river basin populations, otherwise very poor in genetic diversity. These findings imply that more studies about population structure and migration routes/barriers are still needed to obtain a more comprehensive picture of the state and conservation needs of FPM populations in northern Finland.

1.4.5 Environmental conditions

1.4.5.1 Water quality parameters

Background

Water quality plays a key role in determining biological composition and status of lotic ecosystems. Freshwater pearl mussels (FPM) are known to be sensitive for degraded physicochemical status of habitats they live in. In our study, we collected data on eight parameters generally depicting water quality to investigate if these water quality properties would correlate with the results of FPM population status assessments carried out in SALMUS.

Methods

Water samples were collected from each river in connection of other FPM sampling (genetics, shell-opening resistance tests). In total, eight variables were analyzed from each study site: chlorophyll-a, total suspended solids (TSS), concentration of dissolved organic carbon (DOC), total nitrogen (TN), dissolved oxygen concentration, pH, conductivity, and total phosphorous (TP). More about sampling procedure in the annexed report "Water quality parameters".

Results and discussion

In general, water quality parameters reflected quite well generally observed trends along the ca. 600 km long latitudinal gradient studied. Productivity is higher in the south and most variables studied here correlate with productivity level, featured clearly by e.g., chlorophyll content (Chl-a) or the amount of total nitrogen (TN). The waters studied were also less turbid in the north, indicated by lower amount of particulate matter in water suspension (TSS). The same holds for dissolved organic carbon (DOC) in our study set with less humic waters occurring in the north.

Overall, these results are in line with anticipated latitudinal trends of stream water characteristics. Interestingly, the results also comply with other findings of the FPM studies (see e.g., annexed reports on "Shell-opening resistance – a measure of condition of individual mussels" and "Genetic structure and diversity of freshwater pearl mussel populations"), although no causal relation can easily be found solely based on water quality properties.

1.4.5.2 Elemental compositions in FPM's foot tissue and river water

Background

Metals and many other elements are natural components of every aquatic ecosystem. However, especially some heavy metals are toxic in physiological effects while other metals can also cause toxic effects if consumed in excessive amounts. In addition, heavy metals and some other elements effectively accumulate in organisms causing risks especially for long-lived species. Mussels are filter-feeders and certain long-lived species, such like freshwater pearl mussel (FPM), can hence be used as reliable bioindicators of heavy metal pollution (Cevik et al. 2008). In our study, we wanted to investigate concentration of different elements in SALMUS river environments and in the soft tissue of FPM

Ceramium algae at Rytioja, Finland. Photo: Aune Veersalu.

individuals. In addition, we were interested in detecting possible spatial patterns in our study material.

Methods

Water and mussel samples were collected in 2020 and 2021 from 23 rivers located in 4 geographical regions (Kainuu, Kuusamo, Salla and Inari) in the Finnish area of Green Belt of Fennoscandia (GBF). Altogether, concentration of 28 elements in water and mussel's tissue (foot) were analyzed using two different spectrometry methods (more about methodology in the annexed report "Elemental compositions in FPM's foot tissue and river water").

Results and discussion

Concentration of elements in the river water varied substantially between rivers. Among regions concentrations seemed to be higher in southernmost sites, particularly in Kainuu. Some spatial patterns were observed. When comparing concentrations of common metals among regions there was a rather clear latitudinal increase from north to south in Fe, Al, Pb and Cd. Interestingly, Cr showed opposite pattern with highest values found from Inari region.

Concentration of elements in the mussel's tissue also varied substantially between rivers. Among regions concentrations of some elements (e.g., Ni, Cd, and Pb) seemed to be higher in northernmost sites of Salla and Inari regions. Studies on the correlation between some elements in foot and water indicated that this kind of correlation was strongest in Cr and radioactive elements such as Cs and U.

Some of the variability in metal concentrations can derive from surrounding landscape and its soil. In rivers and streams, many trace metals are carried in dissolved, colloidal, or particulate form primarily in association with organic matter (Jokinen et al. 2020). Indeed, we found notable association between amount of dissolved organic matter in the water and its Fe, Al, Mn, and Co concentrations. An evident negative effect of this association is that FPM living in brown waters are more susceptible to some metals than those in clear water rivers. Atmospheric deposition from Kola Peninsula metal industries could be one explanation for observed deviations from main trends in the north. Higher concentrations of Cr in water and FPM soft tissues as also high concentration values for Ni, Cd and Pb in FPM soft tissue are the most obvious candidates for this origin. However, small sample size of analyses (three FPM individuals per one river) and long accumulation periods for old FPM individuals sampled from the north may both cause some bias in interpretation of the results and hence any definite conclusions are difficult to be drawn.

1.4.5.3 Aquatic and terrestrial food sources, and their influence on the wellbeing of *Margaritifera margaritifera*

Background

The contribution of autochthonous (=aquatic) and allochthonous (=terrestrial) food source in the diet of freshwater pearl mussel (FPM) can affect the wellbeing of mussels but this topic has been only rarely studied. Proportional share of autochthonous and allochthonous food source is highly dependent on local stream properties, e.g., width of the channel can largely determine the share between terrestrial and aquatic components. Also, the presence of an upstream lake may play an essential role in diet proportions below the outlet area. In the previous studies the terrestrial sources have been addressed a major importance in the FPM diet, but the relationship between food sources and condition of the populations needs clarification (Geist et al. 2005, Brauns et al. 2021).

In this study we aimed to determine relative proportions of aquatic and terrestrial sources in the diet of FPM, and to find out if differing proportions of diet sources affect the condition of FPM populations.

Methods

Our study was based on stable isotope analysis, and we used fitting of Bayesian mixing models for our data. The shell opening resistance (SOR) scores and local FPM density were used as indicators of the condition in FPM populations. See more info about the SOR method in the annexed report "Shell-opening resistance – a measure of condition of individual mussels".

The data was collected in 2019 and 2020 from 14 rivers in connection of other FPM sampling of the SALMUS project (genetics, shell-opening resistance tests, water chemistry). Samples were collected from three sampling sites in each river – next to the mussel bed in the river, from the lake outlet, and from some tributary nearby.

Results and discussion

Aquatic food source was mostly preferred by FPMs in the rivers studied, but the terrestrial food source was also used in different proportions by all studied mussel populations. However, there was large variation between the rivers, and sometimes the Bayesian mixed model showed also remarkable within-river variation. This primary result supports those studies addressing the importance of aquatic food sources for aquatic organisms, but it is not in accordance with the previous studies concerning the diet of FPM (Geist et al. 2005, Brauns et al. 2021). This could be partly related to many differences in the study designs – e.g., definition of food sources, inclusion of different-aged individuals with differing foraging behavior and use of partly different isotopes in analyses may all contribute to deviations between the studies.

The Bayesian mixing model also showed that terrestrial food source seemed to increase the condition of mussels when using the mean of SOR scores as a proxy. Higher proportion of terrestrial detritus in the diet may thus result in better individual condition. Nevertheless, this finding should be taken only as suggestive due to model's large confidence intervals.

Approaches used in this study can in the future be linked with other environmental characteristics, e.g., differences in local land-use practices. In addition, more robust knowledge about the dietary properties of FPM may contribute to development of conservation practices, especially in captive breeding and restorative planting programs.

1.4.5.4 Brook inventories

Background

Physical stream channel condition is the primary factor determining success in the life cycle of freshwater pearl mussels (FPM). It has largely been shown that stream bed conditions are critical especially for the young mussels living burrowed in the bottom sediment for the first few years of life cycle (e.g., Geist & Auerswald, 2007). In small streams and brooks, many environmental pressures are also accentuated due to smaller discharge and higher possibility for extreme conditions.

In our project, stream inventories were made in total 21 FPM rivers located in Oulujoki and Iijoki catchments in 2019–2021. The aim of the studies was to assess human impact in stream channels and riparian zones with an inventory method that has been in local use already for two decades. Streams were selected outside project's study area so that the data gathered could benefit upcoming, concrete restoration work, e.g., in the LIFE Revives project (2021–2027). One objective was also to examine the relationship between stream habitat characteristics and the status of local FPM populations. FPM population status assessments had been done earlier in eight of the studied streams.

Methods

The total length covered by stream inventories was approximately 99 km, and altogether 285 separate stream segments were identified. Mean width of streams was 3,7 m and the mean depth 0.5 m. Different habitat properties were estimated with a classification scale (0–5) which was based on both visual inspection and some in-stream measurements.

Results and discussion

Estimated value for the natural state of the environment varied between 3.1 and 5.0 with the mean value of 3.9. Classes 4 and 5 represent in this scheme pristine or near pristine conditions.

Overall, 85% of inventoried stream segments (241/285) were classified as altered by human impact of different magnitude and only 44 segments (15%) reflected pristine conditions, respectively. Despite the quite high average value for the estimated natural state of all study sites (3.9), more precise habitat properties did not reflect appropriate conditions with perhaps only one exception – number of shelter places for young fish – gaining a value 2.7/5. The value for potential spawning beds was poor (1.1/5) as was also the case with amount of wood material in the stream channel (1.6/5).

The factor that had altered natural status of streams most was sand (impact value 2.2/5, incidence 55% of all stream segments), followed by timber cutting in the riparian zone (1.7/5, 40%), forest drainage (1.9/5, 35%) and cleaning of the channel (2.5/5, 25%), respectively. Total or partial migration barriers for fish were observed in 10/285 segments.

Timber cutting of riparian zones was often done already long ago or it had been quite moderate in effect (protection zone was found in most cases). Sediment load originating from old, already overgrown ditches was still perceivable in many stream areas. The result has most often been a concrete-like bottom, where interstitial spaces are filled with fine sediment. This was also shown by low spawning site values (average 1.1/5, only 15% of all sites reaching values more than 3/5).

All inventoried streams have been used earlier for timber floating, which can still be seen as stream bottom cleanings and channel straightening. However, the average impact of cleaning on the channel was quite low (impact value 2.5/5).

In total 557 suggestions of different restoration actions were recorded for the 285 inventoried stream segments. Actions most often suggested were addition of wood material into the channel, graveling (restoration of spawning sites with Hartijoki method), blockage of forest ditches, and addition of stones into the channel.

Our results give a good overview of local habitat conditions in 21 different FPM streams. Identifying consistent correlations between stream habitat characteristics and the status of local FPM populations would greatly benefit conservation work and adoption of optimal restoration methods needed. However, analysis of our study material is still underway because FPM status assessments for all study streams will be finalized only during the ongoing LIFE Revives project.

1.4.5.5 Temperature, acidification, and conductivity measurements in SALMUS rivers

Background

Temperature is a decisive factor shaping all freshwater ecosystems. For example, a certain threshold level of cumulative day-degrees may be needed for realization of some key life-cycle functions such as reproduction. Also, even shorter episodes of extreme temperatures (high or low) can be critical for survival of individuals or the whole population. In SALMUS, we monitored temperature conditions experienced by freshwater pearl mussel (FPM) in some of the project's target rivers along the latitudinal gradient of northeastern Finland, from southern Kuusamo region to northernmost Utsjoki region. Our aim was to monitor temperature conditions experienced, including e.g., yearly minimum/maximum temperatures and mean/median values for each river site. Also, yearly cumulative degree days were summed up for each study river for comparison with critical levels required for FPM.

In addition, some separate measurements were done on pH level and conductivity of some minor streams, located mainly in the northernmost Lapland.

Methods

Totally 34 temperature data loggers were placed in 31 different FPM streams. All loggers were installed during the field season of 2020 and data offload of the first logger batch was performed in 2021. There were several logistical and technical problems at different phases of the monitoring. So, for this report data of only 22 loggers could be utilized.

Results and discussion

Average yearly temperatures varied between +4 °C and +6 °C and were generally higher in Kuusamo region more south, but average temperatures varied a lot between rivers of the same region as well. Median yearly temperatures were also very low due to long and cold winter prevailing in the project's target areas, lowest median value was met in Utsjoki region (+0.6 °C), but the level was not remarkably higher in other study areas (Kuusamo +1.3 °C, Inari +1.3 °C, and Salla +1.2 °C).

The highest single temperatures of the monitoring period occurred in all regions in July 2021. The highest water temperature (+26.1 °C) was recorded in the river Meskusjoki.

Sampling of juvenile brown trout at River Suomujoki in the Urho Kekkonen national park. Photo: Jaakko Erkinaro.

Cumulative degree days (CDD) were calculated for a one-year period where possible. According to Schmidt & Vandre (2010), some FPM growth can be observed already when the temperature is > +5 °C, but actual growth starts at temperature > +8 °C (Scheder et al., 2014). So, in our study we calculated also CDD using threshold temperatures of +5 °C and +8 °C in addition to CDD with no treshold (0 °C). According to Larsen (2005), 1,350 degree-days is needed to complete parasitic stage of FPM in Norway. In 2021, CDD of all our study rivers reached that level, although logging period of the needed one whole year could not be completed in every river due to logistical problems.

FPM prefers cool oligotrophic rivers, and an optimal temperature limit <+25 °C is suggested by Degerman et al. (2009). In our material, some maximum temperature peaks exceeded this limit in July 2021 (Meskusjoki +26.1 °C, Välijoki +25.7 °C, Ristinmorostonjärvenoja +25.6 °C), but average and medium month temperatures remained well below +20 °C (the highest recorded was +19 °C in Kuusamo region) in spite of the extremely hot summer 2021.

Average temperature of the year 2020/2021 was in the logger data (all rivers included) +5.2 °C and the median only +1.1 °C. These low figures are explained by very long-lasting low temperature winter period. In spring, maximum temperatures generally rose over +5 °C in May and in the end of the growth period in October temperatures could still exceed +5 °C, but the median temperatures were already lower (highest median was recorded in Kuusamo region +4.6 °C) which means the start of hibernation period for FPM. Accordingly, in our data set the main feeding and growing season took place from June to August, with a slowing down already in September.

Temperature monitoring period with the data loggers was far too short for any thorough conclusions because years are so different in tempterature conditions. Also, as pointed out earlier, some logistical and technical challenges prevented uniform data storaging schedules and relevant comparisons between different areas. In the light of global climate change, temperature monitoring of endangered FPM habitats should be a continuous pursuit at some representative sites. In fact, most of our temperature loggers are still in function and recording data which will be offloaded for further use in other actions, e.g., in the ongoing LIFE Revives project.

pH and conductivity in rivers

Many river systems of the project area are low in conductivity and buffer capacity, and hence susceptible to acidification due to local geology (Aspholm et al. 2015). Acidification peaks usually take place during floods of snow-melting season in spring. For FPM, pH values 6.2–7.5 are supposed to be optimal (Degerman et al 2009). While preferring oligotrophic streams, an appropriate environment for FPM has also usually low electrical conductivity. The maximum conductivity level of 200 μS/cm has been suggested, but many researchers do not allow higher level than 50–90 μS/cm for a reproducing population (Absolon & Hruška 1999).

In SALMUS, monitoring of pH was performed in a simple way while appropriate meters for measurement were broken or otherwise unavailable in the critical spring period. Instead, a substitutive colorimetric measurement method was used for pH monitoring.

In our monitoring, low pH values were observed during the snow-melt season of 2021 in all sites. In the Utsjoki mainstem pH remained above 6.2, but pH values < 6.0 were observed in both monitored tributaries of Utsjoki river. Conductivity values during the same spring period varied between 30 and 62 μS/cm. Conductivity has a dual nature in FPM environments because low levels, normally optimal for FPM, are prone to dropping of pH level more easily compared to rivers with high conductivity level in the conditions of low buffer capacity, as is the case in our target rivers.

Regarding pH and conductivity levels measured, our results were not alarming for the environment of FPM. However, as pointed out earlier, our measurement equipment was not adequate for a reliable result. Some observations from the Teno River tributaries suggested that there could have been much lower pH values occurring during the snow-melting flood peak. Those critical short-term peaks are nevertheless difficult to record without intensive monitoring.

1.4.6 Ecosystem services

1.4.6.1 Survey on ecosystem services produced in northern rivers

Background

Freshwater mussels have proved to be extremely effective engineers of their ecosystems. Mussels filter phytoplankton, bacteria, detritus, and even certain types of dissolved organic matter from the water column and deposit a large part of these materials as pseudofaeces into the river bottom, producing nutrient rich and easily assimilated food source for benthic invertebrates in rivers. This process also supports salmonid fish populations, resulting finally in transport of nutrients from the water to the riverbed. In addition, the physical presence of bivalve shells creates habitat for epiphytic and epizoic organisms and provides refugia for benthic fauna.

Besides providing these regulating ecosystem functions, the historical pearl fishing and all traditions linked to this subject give an example of cultural significances connected to this species.

Salmonid fish in turn are an important food source worldwide. Moreover, salmonid fish provide opportunities for wellbeing with recreational fishing. Fishing tourism may also make considerable profit for local economies. All abovementioned positive effects can be viewed as ecosystem services produced by these freshwater ecosystem members.

The ecosystem service concept was originally introduced to demonstrate the benefits provided directly or indirectly by natural habitats to humans and to increase awareness of the importance of biodiversity and its conservation (Daily et al. 1997, Birkhofer et al. 2015). Through the years, the concept has undergone a transition from valuing ecosystem services primarily in monetary terms of economically important species towards more function-related assessments that distinguished between three main types of ecosystem services (Millennium Ecosystem Assessment 2005): 1. Provisioning services such as food, wood and water; 2. Regulating services such as flood regulation and climate regulation; and 3. Cultural services: spiritual and recreational ecosystem services.

Nonmonetary ecosystem services and services with no material benefit to humans (e.g., existence value of biodiversity, sentimental value of a place or memories, and educational value) have been studied quite little in freshwater ecosystems. A better integration and emphasis on non-monetary values in ecosystem assessments would enable more holistic freshwater assessments (Vári et al. 2022). Inclusion of different stakeholder groups and socio-cultural preferences (e.g., indigenous communities) would fit in well with this approach (Martín-López et al. 2014).

We decided to use a questionnaire to ask different stakeholders in the community of the Fennoscandian Greenbelt, where 90% of viable freshwater pearl mussels (FPM) are found, about their perceptions, attitudes, and values towards FPM and its salmonid host species, Atlantic salmon, and brown trout. We were especially interested in characterizing non-monetary and non-use ecosystem service values as these have been traditionally understudied.

Methods

An online survey was developed to assess the perceptions and attitudes of people of different societal backgrounds towards freshwater ecosystems and some species that live in them. We included questions and statements that covered a wide range of ecosystem services encompassing the three abovementioned types of ecosystem services but put an emphasis on generally neglected and understudied socio-cultural ecosystem services.

The questionnaire consisted of several 10-point Likert scale statements regarding freshwater species like Atlantic salmon and brown trout, the two host species of FPM. For the latter, some questions were included as well. Statements concerning management were developed to capture potentially competing interests and preferences among respondents from different backgrounds.

Several questions/statements in the questionnaire asked about potential educational and learning benefits of different freshwater species and biodiversity in general as well as educational aspects of angling. Also, other aspects like willingness of people to attend guided outdoor excursions were asked to assess the educational potential and value of freshwater systems and some species that live in them.

Although a stronger emphasis was placed on exploration of socio-cultural ecosystem services and their values to stakeholders, we also included a contingent valuation method (CVM, Whitehead & Haab 2013) in form of willingness-to-pay (WTP) to evaluate economic values of freshwater ecosystem services.

The survey was translated into eight languages: English, Norwegian, Finnish, Swedish, Russian, northern Sami, Skolte Sami, and Lule Sami. The language selection was based on the main languages spoken in the study area (i.e., Greenbelt of Fennoscandia), including some of the larger indigenous languages in the area.

The survey was distributed through various channels to reach different target groups (an online survey link on NIBIO's website, distribution on social media like LinkedIn and Twitter etc.).

We anticipated that local communities with an on average older population will have less access to these channels and prepared > 2,500 print copies of the survey which were distributed to local schools, mailboxes in Sami villages, library busses etc. in north-eastern Finnmark (Norway) and northern Finland. The questionnaires were distributed in envelopes with stamps on them so that participants could easily send the questionnaires to NIBIO Svanhovd.

Results and discussion

The results presented here (see the annexed report "Ecosystem services and values of freshwater ecosystems and species living in them") are preliminary and an update of this report will be published as a scientific article later. This is because filled-in questionnaires have been received continuously from the distribution of printed copies to local communities, and that material could not be analysed in this connection. So, data here are based solely on the online answers received as of May 2022.

In total, 283 responses were obtained through the online website (www.nibio.no/ecosystem-services-survey). Of those, 167 person (59%) completed the survey, 66 persons (23%) partially completed the survey, and 50 persons (18%) received the survey, but did not answer any questions.

Our preliminary results already revealed some interesting patterns. First, respondents strongly recognized non-monetary ecosystem services and values as beneficial across stakeholder groups. This suggests that non-monetary and non-use ecosystem services and values are highly useful components for

An ideal freshwater pearl mussel population consisting of different age groups Photo: Heikki Erkinaro.

holistic ecosystem service assessments in freshwater ecosystems, like cross-border river systems of GBF. This is encouraging given the severe underutilization of these types of ecosystem services and values in most present freshwater ecosystem management practices. However, much work is needed to integrate different non-monetary ecosystem services and values into standardized ecosystem service assessments for freshwater ecosystems. In practice, that means development of quantifiable indicators which translate values and non-monetary services to more distinguishable and numerically comparable concepts. More specific stakeholder perceptions and attitudes as well as assessment of demographic and spatial differences in preferences for ecosystem services and values will be disentangled in analyses of the final dataset.

Second, the results clearly showed that more is expected from industrial stakeholders to protect aquatic ecosystems and species inhabiting them. Importantly, participants clearly believed both inland and marine commercial fisheries should contribute to biodiversity conservation. Hence, future research should assess how these industries are currently contributing and where improvements need to be made (this applies also to other industries that use freshwater ecosystem services, like tourism and hydroelectric power companies, etc.). However, in practice, payment for ecosystem services (PES) schemes have remained underused for various reasons. Companies' internal policies for biodiversity conservation engagement has been argued to be confounding (e.g., Stephenson & Walls 2022), but also the voluntary nature of all related initiatives has retarded development of effective practices (Thompson 2021). Therefore, it is recommended that future research focuses on how to improve business engagement and payment schemes in the Green Belt of Fennoscandia (GBF) for long-term preservation of freshwater ecosystem services in this region. In addition, the role of governmental involvement in PES schemes should be reviewed for the GBF.

Third, different management interventions for relieving pressure from salmonid fish species and river ecosystems were largely accepted by respondents whereas others were only weakly supported. These results show that communication to the public on why other fish species than salmonid fishes should be targeted for fishing/angling and introduction of increased fishing license fees may be possible additional future measures to improve management of freshwater ecosystems in the GBF.

A Freshwater pearl mussel bed on white coarse sand bottom at Ahvenoja in the Urho Kekkonen National Park. Photo: Aune Veersalu.

Fourth, the questionnaire also highlighted several aspects (e.g., illegal fishing, river damming) that were not part of the actual structured questionnaire but that were brought up in the comment section and should accordingly be part of future discussions on natural resource management strategies in this region.

1.5 Discussion

A total of 14 new FPM populations were discovered in the searching activities of SALMUS. This result clearly shows the high potential for still finding uncovered populations in the project's target area. In practice, searching for new populations was in SALMUS performed only in Finnish watersheds. The result also highlights the importance to continue searching for new FPM populations in the nearest future while most of those populations are evidently small and may thus be under immediate risk of extinction due to local adverse environmental conditions. In fact, most newly found populations of our study did show skewed age distribution with poor documented recruitment success. The importance of searching for new FPM populations is also acknowledged as an essential part of conservation strategies in national conservation action plans.

One central goal of the SALMUS project was to assess applicability of two novel methods in searching for FPM. An eDNA-based method was developed and tested in the project with quite promising verification results for its sensitivity to identify FPM rivers based on mussels' genetic markers in collected water samples. However, there were some restrictions in the detection ability of the method, at least related to actual distance of the population location from the sampling point but also regarding viability and physiological activity of the population in question. Nevertheless, the method proved to be a reliable tool for preliminary mappings and for confirmation of visual field inventory results. In contrast, the use of another searching method - inspection of host fish gills for detecting possible parasiting mussel larvae attached - proved to be quite unpractical method in most study sites. The reason was that host fish individuals, potentially carrying the mussel larvae, were not easily catchable with electrofishing in the early summer when FPM glochidia larvae have not yet dropped off from the fish gills. Later, when juvenile fish already inhabit suitable flow sections of the rivers with higher catchability, the water temperatures have already risen so that host fish do not anymore carry FPM larvae in their gills. In addition, separate inventories done by electrofishing and visual survey methods (mostly by aquascope and snorkeling) to attain the desired precision of the actual population location would double the needed work input.

The status assessment of FPM populations revealed that almost half of the studied populations could be classified to highest *Viable/Maybe-viable* categories. This positive result showed that sufficient recruitment is still occurring quite regularly in many northern rivers. Nevertheless, poor viability status of most studied populations was clearly associated with some fundamental factors presently impeding completion of FPM life cycles. The absence of original, suitable host fish species due to river harnessing has largely prevented free migration of salmonids. Especially, low viability status of some Atlantic salmon dependent FPM populations can easily be attributed to this reason. At the same time, northern salmon-dependent FPM populations have been detected to support highest genetic diversity of all studied populations, suggesting that these populations should be prioritized in future conservation work.

In practice, many earlier extant populations of the large River Tuloma catchment have not recruited after the construction of Upper Tuloma hydropower plant (in Russia) in the 1960s preventing the access of Atlantic salmon to upper reaches of the river system. Unfortunately, no apparently realistic solution to overcome this catchment-wide problem can be foreseen soon. However, first steps to restore the over-aged FPM population in the River Lutto, the main Finnish headwater river of the River Tuloma system, were taken when 6,000 mussel juveniles were successfully planted back to their home river after one year's captive breeding at the research station of Jyväskylä university in Konnevesi, Finland. This promising restoration effort actualizes FPM recruitment in the river areas of Lutto for the first time since the 1960s. In addition, the continuity of local FPM restorative breeding program is fortunately safeguarded in the nearest future as part of the ongoing Life Revives project (2021–2027) activities.

Poor environmental condition of FPM habitats, especially due to siltation of interstitial spaces in the river bottoms, was another crucial factor clearly responsible for the low recruitment success and viability status of many populations studied. At most sites, both in-stream and catchment-wide restoration measures would be critically needed to alleviate poor habitat conditions and to ensure the commencement of recruitment as soon as possible. Cost-effective restoration programs should be started in prioritized FPM occurrence areas with the aid of all available financing sources. One promising resource option might be offered by national commitments and programs that EU member states are now preparing to reach the targets of EU Biodiversity Strategy during the 2020s. After all, the reasons accounting for perhaps better than anticipated recruitment success documented in many studied FPM populations are not so obvious. Some positive changes may have occurred in local recovery from earlier acidification episodes and due to decreased siltation load after the decades of more adverse land-use practices. In addition, temperature conditions for FPM may have been more favorable in our northern target area during the last decades.

Salmonid fish are an obligatory element in the life cycle of FPM; hence inclusion of monitoring and status assessment of host fish populations was an essential part in our project. Partial or total absence of host fish due to migration barriers and other adverse environmental conditions are some of the most crucial problems causing the endangered status of FPM everywhere. In our study areas, however, no clear trends in the status of salmonid populations could be observed. This result suggests that reproduction conditions have stayed stable for most FPM populations of the project area in this respect. Nevertheless, the totally prevented access of Atlantic salmon to the headwater areas of the large River Tuloma catchment is still clearly the biggest threat to the very existence of many local declining FPM populations, as already discussed above. Considering some more global threats posed by climate change and invasive non-native species, the dependence of FPM on salmonid fish may make the situation of mussel populations more vulnerable in the future. The wellbeing of FPM can be threatened by many indirect effects, e.g., through radical changes in environmental conditions and behavior of its host species. In general, this intrinsic relationship between the FPM and its salmonid host fish should be emphasized in all status assessment work as also in joint restoration planning while the same strict, high-quality requirements for functional river environment concern both species.

One of the key goals in the project was to develop and harmonize monitoring methods among the project partners enabling the increase of comparable knowledge base for the joint river catchments. Development of different monitoring and river restoration methods was a rewarding project task resulting in adoption of novel, effective methods into everyday work practices of partner organizations. An age determination method, based on the measurement of growth increments from thin sections of the FPM shells, was used to analyze growth rates and to construct population-specific growth curves based on ages and shell lengths of the target population individuals. Totally 41 populations from three partner countries were studied by this method. The existence of some FPM populations supporting very old (> 200 hundred years) individuals was revealed in northern Finland and Norway. In the whole study set, the relationship between age and the shell length of mussels showed normal or low growth rate when compared to a large baseline material derived from earlier age determination of many Fennoscandian and North-Western Russian FPM populations. This pattern was most probably explained by the generally cold weather conditions in our target areas. Nevertheless, perhaps the most promising perspectives for this method might be achieved in the future when applied in backdating of local paleoenvironmental conditions associated with variables such as pH, temperature, and nutrient level of the rivers.

The use of two different environmental monitoring methods was developed during the project. The first one was a method measuring circumstances in the interstitial space of the river bottom simply by using the rustiness level of nails, inserted into the bottom substratum, as an indicator for prevailing oxygen conditions. This crucial habitat property has normally been defined by an electronic redox measurement device. Assessment of physical condition of FPM individuals was another introduced methodological novelty. This method is based on the shell opening resistance (SOR) of mussels, using the loss of adductor muscle tone as an indicator of individual stress. Both methods gave promising results – the applicability of the nail test method was validated by simultaneous redox potential measurements and the SOR method gave reasonable results in concordance with other collected site-specific data (e.g., genetic diversity of FPM populations and the water quality).

Restoration of stream beds with the so-called Hartijoki method was the third methodological approach developed and tested in the project. This method aims at cleaning stream beds from sand with special tools, and during our project the method was adopted into permanent use with some additional modifications (wooden deflectors) to make the desired restoration effects more sustainable. Effectiveness and functionality of this in-stream method was verified by both redox potential measurements and by using the nail test method developed here.

In summary, all these methods do have high replicability potential and they have already been adopted to concrete restoration actions, e.g., in the ongoing LIFE Revives project (2021–2027). Despite the recent drawbacks in international cooperation, also in the very cross-border river catchments of our project area, methodological harmonization and sharing of best practices should be in the focus of all future conservation work taking place, not least because of common challenges in joint river systems and generally limited resources for adequate conservation measures.

Studies on the prevailing environmental conditions of the FPM rivers showed that many water quality properties correlated with the latitude in an expected manner indicating higher productivity and generally higher content of most metals and other elements in the south. On the contrary, some heavy metals reached highest values in northern study rivers, most probably referring to the metal industry depositions of the Kola Peninsula. Based on our monitoring work at selected study sites, neither acidification status or the amount of yearly cumulative degree days

Searching for mussels by using an aquascope. Photo: Heikki Erkinaro.

needed for successful realization of FPM life cycle seemed to risk survival or recruitment of FPM populations in the project area.

The results of the shell opening resistance (SOR) method suggested possible correlations between individual condition of the mussels and the location of populations. On average, northern populations seemed to be in a better physical condition having at the same time the highest genetic diversity of all studied populations. In addition, our studies on FPM food sources of terrestrial and aquatic origin suggested that higher share of diet with terrestrial origin could increase the condition of FPM individuals. Despite all these interesting findings, definite causal connections were impossible to determine due to strong intercorrelation of many variables. In the future, integration of more detailed data on environmental circumstances and physical condition of the mussel individuals might probably benefit the status assessment process by giving a more comprehensive picture of local stressors and identified needs for successful recruitment in the target FPM populations.

Finally, raising awareness of the importance of northern river ecosystems and some of its key species was a highly rewarding aspect in the project implementation. The conservation problematics of our target species gained large attention through various information channels. Exhibitions at eight visitor centers in Norway, Russia, and Finland were some of the most popular outreach activities performed. Also, the live webcam installed at a clear tiny FPM brook reached 135,000 total views providing at the same time unique, valuable data on temporal movement behavior of the FPM in its natural habitat.

A real interest in our project subject was demonstrated also in many personal contacts and general positive feedback. In line with this, the survey results on ecosystem services of northern rivers showed that people largely recognize non-monetary ecosystem services and values as beneficial across all stakeholder groups. In all, these experiences clearly show the potential of freshwater pearl mussel and its salmonid host fish species as largely recognized members or flagship species of healthy river ecosystems. The species are not only objects of conservation efforts but may also act as effective pro-environmental drivers in conservation campaigns of northern river ecosystems. These results also suggest that more holistic ecosystem aspects should be incorporated in freshwater ecosystem management. This would probably be advantageous for the commitment of people to local conservation pursuits as for the general sustainability of management decisions.

1.6 Summary

The freshwater pearl mussel (*Margaritifera margaritifera*) is classified as a critically endangered taxon (CR) in Europe. Most European freshwater pearl mussel (FPM) populations with a functional life cycle exist in northern Fennoscandia and Northwest Russia but mussel populations have decreased also in these areas. FPM is dependent on juvenile salmonid fish (Atlantic salmon or brown trout) as larval hosts. The species has also high-quality criteria for the stream habitat conditions, shown especially by the juvenile mussels living for a couple of years burrowed in the bottom substratum. Main factors preventing successful recruitment of FPM are lack of suitable host fish and siltation of river bottoms due to adverse land-use practices in the river catchments.

The SALMUS project was implemented in 2019–2022 with eight organizations from four neighbour countries sharing the aim to increase biological knowledge base and develop conservation methods in joint river systems of the Green Belt of Fennoscandia (GBF). Also, the harmonization of practices in assessing the status of river areas, by using especially FPM and salmonid fish as indicators of ecosystem function and health, was targeted for strengthening conservation cooperation among the partner countries. Awareness-raising of northern river ecosystems and their socio-economic importance was also a cross-cutting theme in the project.

Searching for new FPM occurrences, performed with an aquascope or by diving, was undertaken in totally 360 separate waterbodies resulting in 14 newly found populations. In addition, viability status of local FPM populations was assessed in 45 streams with 16 populations reaching the highest *Viable* or *Maybe-Viable* classes. The newly found FPM populations and existence of many recruiting mussel populations were both positive results. Nevertheless, most studied FPM populations do not reproduce anymore in a sustainable manner. In most cases, large-scale conservation actions would be needed to reach a favourable population status: restoration in the river channels and abandonment of adverse land-use practices in the adjacent catchment areas.

Many local Atlantic salmon dependent FPM populations are already on the brink of extinction due to river harnessing preventing migration of host fish individuals. Upper parts of the large Tuloma River system, for example, have been without access of host fishes since the 1960s due to a hydropower plant more downstream in Russia. Captive breeding was used as a first-aid recovery method for the over-aged Lutto River FPM population, located in the Finnish headwaters of the Tuloma River system, with no present documented reproduction. Tiny FPM juveniles were planted back to their home river after living for one year attached in the gills of their host salmon in fish farming tanks. First inspections for juvenile survival in the river have showed success in recruitment after a pause of 60 years without reproduction.

Development of ecological monitoring methods was also one key action of the project with a final goal of methodological cross-border harmonization. Due to the pandemic lockdown, harmonization process could not be fully implemented. However, novel methods assessing physical condition of FPM individuals and measuring oxygen conditions in the stream bottoms were tested and validated in the project. Both methods, accompanied with an effective in-stream restoration approach (the so-called Hartijoki method), were also adopted in permanent use of many organizations and in the ongoing Life Revives project (2021–2027).

Values and other perceptions on northern river ecosystems were explored with an ecosystem service survey. The results showed that non-monetary services and values were strongly recognized as beneficial across all stakeholder groups and people largely supported more resourcing and effective management practices to safeguard the wellbeing of river ecosystems.

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2 Freshwater Pearl Mussel Inventories and Development of Brook Restoration Methods in SALMUS

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2.1 Freshwater pearl mussel river inventories

2.1.1 Study area

All inventories were performed at the Finnish-Russian border zone and its nearby areas in the Green Belt of Fennoscandia (target areas lying between Ilomantsi and Inari, Fig. 4). Study sites were located mainly in joint river basins nearby Finnish-Russian border zone. In addition to these near the border cartchments, streams running to Emäjoki in Oulujoki cathment and to Jumiskojoki in Kemijoki cathment were examined more thoroughly. Rivers belonging to the Koutajoki and Vienan Kemijoki catchment areas were examined quite completely covering all main river areas situating in the Finnish territory. Also some sites in the Kiiminkijoki basin were visited when bypassed on the field trips elsewhere (Kiiminkijoki was not included in the project target areas). The aim of the study was to check the present-day relevance of historical freshwater pearl mussel (further FPM) population occurrences and map the distribution of remaining FPM populations in the programme area.

Studied rivers/streams were selected by preliminary office work and examination based on maps; potential FPM rivers were listed based on e.g. river morphology, soil type and lake percentage of the catchment areas. Historical data on pearl fishing or earlier shell findings were available in some sites. Dependent on the lenght of the stream, approximately 1–5 study sites were mapped in each river/stream visited. Streams were inventoried by electrofishing (early summer season) or aquascoping/snorkeling (later at the normal summer water level). Approximately 1.5 study sites per each river were visited. 440 sites were inventoried by aquascoping, 106 km in total, thus averiging 250m/site (variation 10–2,800 m). 63 sites were inventoried by electrofishing, totalling in 72 ares, i.e. in average 1.1 ares/site (variation 0.1–5 ares). When a new FPM population was found, the goal was to determine upper and lower limits for its distribution in the river. If possible, the approximated viability of the population was also estimated based on the total number of FPMs and the size distribution of individuals found.

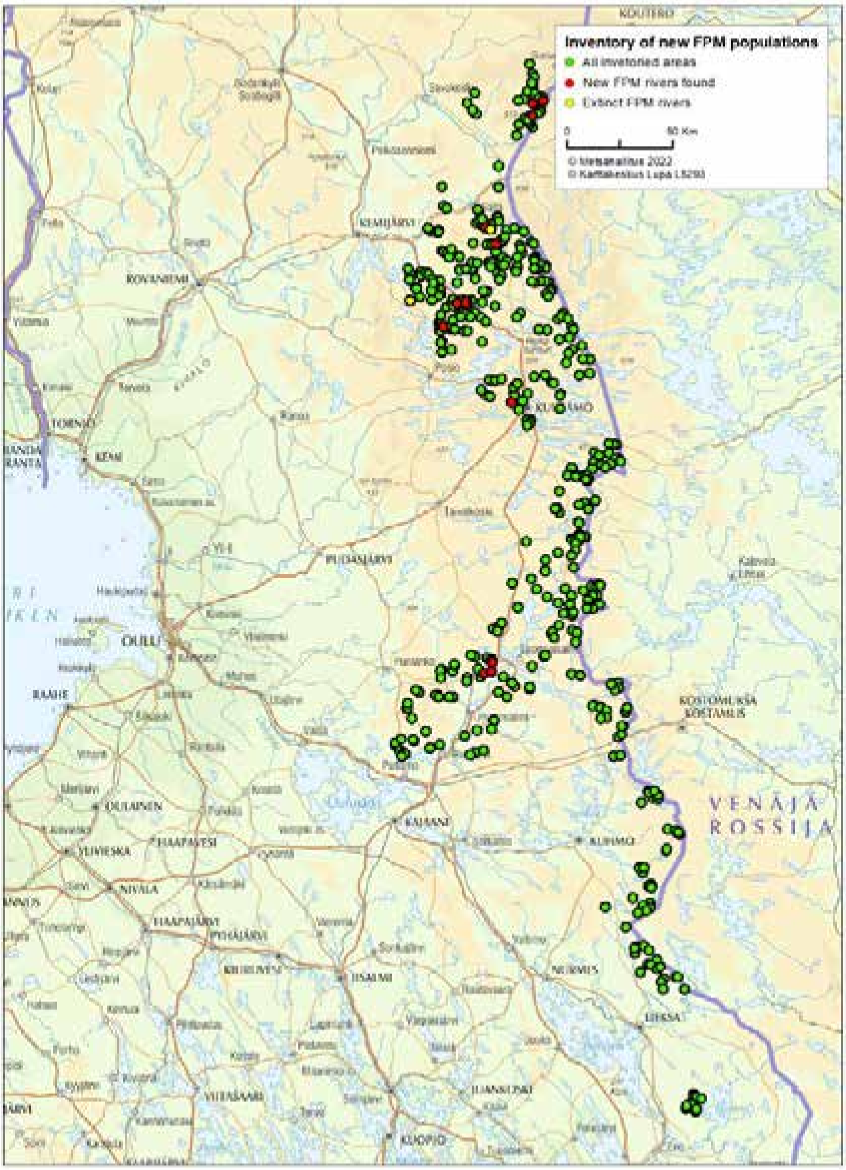

Figure 4. Study area in 2019–2021. All mapped study sites are marked as green, new populations found in red and extinct populations in yellow.

2.1.2 Results

All field work was done between June and September months in 2019–2021.

Total number of field days used for the inventories was 79. On average, 6.5 sites/areas were examined in one day using electrofishing or aquascoping/snorkeling.

The following seven main catchment areas were studied during the project implementation, totalling in 360 separate rivers/streams and 505 sites in these rivers.

- Näätämöjoki river basin: 4 sub-catchments; 3 rivers/streams; 12 sites.
- Koutajoki river basin: 29 sub-catchments; 82 rivers/streams; 113 sites.
- Oulujoki river basin: 66 sub-catchments; 136 rivers/streams; 170 sites.
- Kemijoki river basin: 25 sub-catchments; 77 rivers/streams; 131 sites.
- Vienan Kemijoki river basin: 12 sub-catchments; 40 rivers/streams; 47 sites.
- Vuoksi river basin: 11 sub-catchments; 21 rivers/streams; 32 sites
- Kiiminkijoki river basin: 1 sub-catchment; 1 river/stream; 2 sites.

Potential occurrence on FPM glochidia larvae in fish gills was examined by **electrofishing** method in early summer. Glochidia investigations were performed in Näätämöjoki, Kemijoki, Koutajoki and Oulujoki catchment areas, totalling in 63 sites (of 39 rivers) in 2019 and 2020. Primary objective with this was to catch at least 5–10 individuals of young salmonids (brown trout or Atlantic salmon) for inspecting possible presence of glochidia in the fish gills.

Water temperatures varied between +10.0 and +22.9 °C during the electrofishing surveys. The total area studied with this method was ca. 75 ares (1.2 ares/site studied).

Fish were caught from 57 study sites. Trout and/or salmonids were met at 24 study sites, respectively. Other fish caught were grayling, pike, bullhead, alpine bullhead, minnow, roach, bleak, nine-spined stickleback, burbot and perch.

New populations of FPM were not found by electrofishing method. It was quite difficult to get enough fish individuals for a reliable sample size in early summer. This held true especially with young fish individuals, as noticed already in our previous studies (e.g., Raakku! project). Fish seem to move to rapid areas (being more available for electrofishing) just after the waters have got warmer, and it is highly probable that glochidia larvae have already detached from fish gills at that point of the season. In this study, sufficient fish samples were caught only in Näätämöjoki and Silisjoki areas, both inhabited by Atlantic salmon. Electrofishing is also quite a laborious and slow method to perform compared to aquascoping/snorkeling.

In total 321 rivers and 440 sites (total length 105.5 km, on average 250 meters/site) were studied by **aquascoping/snorkeling** in Kemijoki, Koutajoki, Oulujoki and Vuoksi river basins (Table 5). Approximately 20 sites were not examined in detail, because of poor potential for being a suitabble FPM habitat detected on the closer inspection.

In total 13 new FPM populations were found by aquascoping/snorkeling method. In addition, one new population occurrence was verified by eDNA method (Purkaoja). Two populations were classified as extinct (Tuohenlusikkalammenoja, Vierusjoki), only old FPM shells were found on these sites. Duck mussels (*Anodonta anatine*) were found in 5 rivers. Population status assessments of these newly-found FPM rivers are reviewed in its own report ("Status of the freshwater pearl mussel populations").

2.1.3 Summary

Overall, aquascoping is a good and cost-effective method for searching new FPM populations. With a team of 2–3 persons, it is possible to investigate quite many sites per day. Because time is limited, it is important to prioritize investigations at most potential sites based on experience and preliminary knowledge.

Searching of new FPM populations is a challenging affair, because the precise occurrence site of FPM individuals along the river channel is often quite arbitrary. The population can inhabit lower, upper or middle reach and individuals can live aggregated or scattered along a longer stretch. If the river/stream is remarkably modified, population can be already extinct or the last survived individuals can remain living in deep pools (from where it is difficult to observe them). Therefore, also a lot of luck is needed in the successful search of new populations. In our project, this was manifested in some very typical cases. In Salmisenjoki, e.g., no FPM individuals were met at the most potential sites, whereas the remaining population was found in the lower reach from a boggy slow-flowing area, which was checked only because the only suitable place for car parking was nearby. FPM population of Purkaoja was not found in physical mappings until the eDNA method was used, this was because the remaining population occurred only in a short reach

Figure 5. Study methods: aquascoping, electrofishing, snorkeling and place names. Photos: Pirkko-Liisa Luhta and Eero Moilanen.

that was too narrow and partly overgrown by vegetation to investigate even with the otherwise practical aquascope method.

Therefore, it is very possible that among the studied 360 rivers some populations remained unfound. Areas, where it is most likely that populations still remained to be found, are Jumisko-Maanankavaara area in Kemijoki river basin, streams running to Emäjoki in Oulujoki river basin, and upper streams of the Koutajoki catchment. In addition, some areas in Kuusamo could have been investigated more carefully (Kitkajoki-Kuusinkijoki-Oulankajoki).

The areas near the Russian border belonging to the Oulujoki river basin seem to be totally empty of any FPM populations. In line with this, streams in this area turned out to be mainly dark humic waters, river channels were strongly modified and only few brown trout were altogether met in electrofishing surveys or in stream mappings with aquascope and snorkeling. So, Emäjoki area is probably the only remaining subcatchment of Oulujoki basin still inhabited by FPM populations.

Vuoksi river basin was visited for inventories primarily because no systematic FPM inventories have been earlier performed in that basin. In addition, no historical data was available for confirming any previous existence of FPM populations or pearl fishing in the area. Anyway, continuous occurrence history of migrating salmonid fish (brown trout and land-locked salmon) in Lieksa-Nurmes areas would have enabled suitable conditions also for FPM in this area.

Careful planning of field work and selection of study sites are very important tasks in finding new FPM populations. When selecting representative study sites, one has to take into account all possible factors that may affect stream hydromorphology (tributaries, groundwater springs, lakes etc.) Especially, water temprerature appears to play a key role in defining suitable habitat requirements for FPM. Inventory study sites should be situated both in upper and lower reaches with relation to main tributaries and ground water formations of the channel, because temperatures may vary significantly between sites even inside quite a short stretch. Besides aquascope and waders, thermometer is indeed an important tool in the field. Suitable temperature regime for FPM can be estimated approximately based on known FPM locations nearby (control sites). More thorough field investigations are needed, if temperature of the target site is quite similar to control sites (±2 °C) and also other habitat characteristics favour potential occurrence of FPM. In this study, we noticed that temperature variation between FPM rivers was much smaller compared to the total variation including also rivers without FPM populations.

2.2 Stream habitat inventories in FPM rivers

Stream inventories were made in total 21 FPM rivers located in Oulujoki and Iijoki catchments in 2019–2021. The aim of the studies was to assess human impact in streams and riparian zones with an established inventory method already for two decades in use. Streams were selected outside project's study area, because these target streams have been planned to be restored in LIFE Revives -project between 2021–2027. FPM population status assessments have been done earlier in eight of the studied streams – Haukioja, Juurikkaoja, Lohijoki, Norssipuro, Nuottioja, Korpijoki, Mutajoki and Varisjoki.

Total length of stream inventories was approximately 99 km, and altogether 285 separate stream segments were identified. Mean width of inventoried streams was approximately 3.7 m and mean depth 0.5 m. Streams consisted of rapid-like segments (33%), strong current segments (25%) and slow-flowing segments (43%) – percentage shares estimated here from the total length of the study. Dominant benthic vegetation type was aquatic moss (55%) and the average coverage of benthic plants was 2.1/5 (scale from 1 to 5). Shading of the riparian zone reached on average a value of 2.4/5. Estimated value for the natural state of the environment varied between 3.1 and 5.0 – with the mean value of 3.9. Values depicting the natural state for separate segments varied between 1 and 5. Classes 4 and 5 represent in this scheme pristine or near pristine conditions.

Figure 6. FPM in Korpijoki. Photo: Pirkko-Liisa Luhta.

Overall, 85% of inventoried stream segments (241/285) were classified as altered by human impact of different magnitude. Only 44 segments (15%) reflected pristine conditions. Despite the quite high average value for the estimated natural state of all study sites (3,9), habitat variables perceived did not reflect apprpropriate conditions with perhaps

Table 2. Newly found FPM populations in the SALMUS project.

Year	Main river basin	Sub-catchment area	Ca no.	Municip.	River / stream	FPM population co-ordinates Upper ETRS-TM35FIN	FPM population co-ordinates Upper ETRS-TM35FIN	FPM population co-ordinates Lower ETRS-TM35FIN	FPM population co-ordinates Lower ETRS-TM35FIN	FPM population co-ordinates Upper ETRS-TM35FIN	FPM population co-ordinates Upper ETRS-TM35FIN	FPM population co-ordinates Lower ETRS-TM35FIN	FPM population co-ordinates Lower ETRS-TM35FIN
2019	Kemijoki	Sätsijoen va	65.477	Salla	Sätsijoki	7459616	605160	7458993	605040	7456596	601510	7456414	600022
2019	Kemijoki	Saukko-ojan va	65.476	Salla	Ahvenoja	7463224	606031	7463265	605732	-	-	-	-
2019	Kemijoki	Ruuhijoen va	65.376	Salla	Tammakkolamminoja	7403604	579570	7403669	578691	-	-	-	-
2019	Kemijoki	Ruuhijoen va	65.376	Salla	Hangasjoki	7403669	578691	7404077	578698	-	-	-	-
2020	Kemijoki	Lauttajoen va	65.395	Posio	Lauttajoki	7367420	566146	7367199	563485	-	-	-	-
2020	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Vääräjoki	7356129	559482	7356437	558600	-	-	-	-
2020	Kemijoki	Lauttajoen va	65.395	Posio	Salmijoki	7366363	569284	7366580	568996	-	-	-	-
2020	Kemijoki	Lauttajoen va	65.396	Posio	Köykenejoki	7368104	568923	7367408	568029	-	-	-	
2020	Koutajoki	Hevosojan–Myllyojan va	73.084	Salla	Myllyoja	7395636	583437	7395499	583956	7395314	584225	7395225	584537
2020	Oulujoki	Lahnajoen alaosan a	59.473	Suomussalmi	Lahnajoki	7190421	577593	7189456	577435	-	-	-	-
2020	Oulujoki	Korpijoen va	59.435	Suomussalmi	Korpijoki	7192861	581482	7192333	581279	-	-	-	-
2020	Oulujoki	Varisjoen va	59.436	Suomussalmi	Leväjoki	7197541	581911	7197487	581965	-	-	-	-
2019	Vienan Kemijoki	Meskusjoen va	74.043	Kuusamo	Välijoki	7320648	590748	7319031	592292	-	-	-	-
2021	Kemijoki	Saukko-ojan va	65.476	Salla	Purkaoja	7462114	600838	7461824	600850	-	-	-	-

Figure 7. Stream inventory in Lahnajoki. Photo: Eero Moilanen.

only one exception (number of shelter places for young fish), which gained a value just above the average of the scale used (2.7/5). The value obtained for the amount of potential spawning beds was poor (1.1/5) as was also the case with amount of wood material in the stream channel (1.6/5).

The factor that had altered most the streams was sand (impact value 2.2/5, sand was present at 55% of stream segments), followed by timber cutting in the riparian zone (1.7/5, 40%), forest drainage (1.9/5, 35%) and cleaning of the channel (2.5/5, 25%), respectively. Total or partial migration barriers were observed in 10 segments. Variskongäs waterfall is a natural migration barrier situating in the river Varisjoki.

Timber cutting of riparian zones was often done years back, or had been quite moderate in effect (protection zone was found in most cases). However, some riparian zones had also fresh forest cuts undertaken in recent years. Forest ditches were often overgrown with little water flow or sediment load to the stream channel anymore. In most cases, however, there was at least one ditch that had been dug up so completely that it reached the main stream, inevitably transporting high sediment load from the ditched area to the stream channel during the first years after ditching. Historical sediment load can still be seen as hard, concrete-like bottoms, where interstitial spaces are filled with fine sediment. This was also shown by generally low spawning site values (1.1/5, only 15% of all sites reaching values more than 3/5).

All inventoried streams have been used earlier for timber floating, which can still be seen as stream bottom cleanings and channel straightenings. However, the average impact of cleaning of the channel was quite light (impact value 2.5/5). Usually some bigger stones had been removed from the stream channel manually. Nevertheless, even quite slight modifications to stream channel can alter local hydro-morphology significantly.

In recent years, quite remarkable human impact through fish farming has taken place at the streams studied. In total, 7 fish farms or fish farming pools (not in use anymore) were found. Part of the stream water flow had been guided to fish farm pools in at least three documented cases. Especially in Lahajoki the effect of this action was very detrimental, while a stretch of about 300 meters in the main stem was almost totally dried in the summer 2021.

Figure 8. Forest cutting of the riparian zone in Korpijoki, Suomussalmi. Photo: Eero Moilanen.

Figure 9. Sediment-loading farmland ditch in Korpijoki. Photos: Eero Moilanen.

Figure 10. Big overgrown stones from old stream cleanings in the riparian zone of Lahnajoki, Suomussalmi. Photo: Eero Moilanen.

Figure 11. Forest harvester track over Lahnajoki. Photo: Pirkko-Liisa Luhta.

Figure 12. Forest cut near to the stream channel in Lahnajoki. Photo: Pirkko-Liisa Luhta.

Figure 13. Deep ploughing in a forestry area of the Saukko-oja cathment area. Photo: Pirkko-Liisa Luhta.

Figure 14. Dry main stem in the lower reach of Lahnajoki next to the fish farm. Photo: Pirkko-Liisa Luhta.

Figure 15. Excavation of stream bed for a swimming place in Varisjoki. Dead FPM individuals were found on dry land. Photo: Pirkko-Liisa Luhta.

Figure 16. FPM shells found on an ATV trail and a crushed FPM individual on the stream bed of Saukko-oja. Photos: Pirkko-Liisa Luhta.

Figure 17. Migration barrier in Nuottipuro. Photo: Eero Moilanen.

There were quite few human settlements along the shores of the inventoried streams. It seemed to be a common practice that people have created swimming places near to the summer cottages by excavating bottom material out of the streambed. In Varisjoki, e.g., excavations had been done in the very FPM population area. Consequently, crushed and dead FPM individuals were found mid in the sediment deposits on the dry land.

Occurrence of fish in the studied streams was assessed by visual observation and electrofishing. No other fishing equipments were used.

In total, 557 suggestions of different restoration actions were recorded for the 285 inventoried stream segments. Most popular suggested restoration actions were addition of wood material into the channel (213 segments, 75% of all inventoried), graveling (restoration of spawning sites with Hartijoki method, 172 segments, 64%), blockage of forest ditches (80 segments, 28%) and addition of stones into the channel (66 segments, 23%).

Table 3. Summary of stream inventories in FPM rivers.

Main catchment area	Oulujoki, Iijoki
No of rivers	21 pcs
Total lenght	99058 m
Inventors	Eero Moilanen, Mikko Oranen, Pirkko-Liisa Luhta
Inventory years	2019, 2020, 2021

Section summary

Sections	285 pcs	Range	6–33 pcs
Average width	3.7 m	Range, x min/max	2.3–5.83 m
Average depth	0.49 m	Range, x min/max	0.2–1.1 m
Deep pools, average	0.87 m	Range, x min/max	0.5–1.61 m

Type of flow

Rapids	31.6%	Range, min/max	12.9–54.0%
Quick flow	23.4%	Range, min/max	8.5–56.7%
Slow flow	42.6%	Range, min/max	9.2–74.6%
Still water	1.4%	Range, min/max	0.0–19.5%

Forest type of the shore

Paine	3.0%
Spruce	21.3%
Deciduous	33.8%
Mixed forest	37.2%
Shrubbery	3.1%

Growth type of the shore

Peatland	28.5%
Meadow	15.7%
Moor	35.3%
Herb-rich	9.0%
Paludified	11.1%

Bottom grain size % summary in all sections (tot. 288 pcs).

Bottom grain size	Most common	Second common	Largest
Mud	11	7	0
Clay	4	7	0
Sand	27	11	7
Fine gravel	2	8	1
Gravel	2	3	1
Small stones	3	3	1
Stones	4	6	1
Large stones	5	16	1
Small boulders	31	15	13
Boulders	9	20	34
Large boulders	1	5	31
Solid rock	0	0	10

Most common bottom vegetation in all sections (%)

Moss	55
Hay	27
Other	16
No vegetation	2

Average bottom vegetation cover	21	Range	0.8–3.5
Average shading of shore	2.4	Range	1.0–3.7

Habitat variables for different sections (5–0) %.

Habitat variables	% 5	% 4	% 3	% 2	% 1	% 0	Aver. 0–5
Spawning beds	2	4	9	13	22	50	1.1
Deep pools	0	1	8	16	37	37	1.0
Shelters	8	16	26	37	12	1	2.7
Meandering	0	4	33	48	11	4	2.2
Width variation	0	8	25	47	19	1	2.2
Wooden material (bottom)	0	2	11	41	39	7	1.6
Pristinity	28	43	20	6	3	0	3.9

Factors that affected the state of pristinity (5–0): total of 515 factors / 285 sections.

Factors	% 5	% 4	% 3	% 2	% 1	% 0	Aver. 0–5	sect. pcs	% of tot. pcs
Forest ditches	3	2	2	8	20	0	1.9	101	35
Felling of the shore forests	0	1	4	14	21	0	1.7	115	40
Tillage of the logged forest areas	0	0	0	0	0	0	2.3	3	1
Cleaning of the river channel	3	3	6	8	6	0	2.5	73	26
Solid material in the bottom	0	6	13	20	16	0	2.2	157	55
Weakened quality of water	0	0	0	0	4	0	1.1	11	4
Eutrophication	0	0	0	1	1	0	1.8	6	2
Migration barriers	1	2	0	1	0	0	3.5	10	4
Other factor changed pristinity	0	0	1	2	11	0	1.3	39	14

The need for restorations, pcs & % total of 577 actions in 285 sections.

Need for restorations	Tot. pcs	% of tot. pcs
Stoning / restoring rapids	66	23
Add wood material	213	75
Re-watering orig. river bed	18	6
Restoring spawning beds	172	60
Const. sediment settling pools	6	2
Removing migration barriers	11	4
Raise the water level	2	1
Blocking ditches	80	28
Other catchment or river rest.	9	3

2.3 In-stream restoration and nail tests

The aim of the study was to clean the river bed from fine sediment and to create suitable habitats (oxygen-rich gravel bed with good interstitial water flow) for juveline FPM and spawning places for brown trout. The effects of river bed modifications were examined with nail tests, all this being a part of SALMUS Work Package 3: Development of novel techniques and practices. Studies were executed in Säkkisenoja and Pirinoja in 2020 and 2021, both streams not inhabited by FPM.

Totally 9 study sites (each 1 m^2) were selected in both rivers, with a minimal difference in hydro-morphological conditions between the sites. In both rivers, three sites represented control sites, with no restoration operations done. Three sites represented restoration with the so-called Hartijoki method, where stream bed is purified from sand with special tools down to the depth of 20–25 cm (Figs 21–24). Also, three sites represented a restoration combination performed with Hartijoki method and wooden deflectors (Fig. 18) where the function of wooden deflectors is to increase water flow to the site restored, so that the river bed would more easily stay clean and oxygen-rich. Restoration was performed in 2020. Grain sizes on the stream bed of study sites was assessed using a Wenworth scale before and after the restoration. In addition, water temperature was measured.

At each study site 6 nails (8 inches in length) were inserted in the gravel/sand bottom for six months. The redox potential of the interstitial water was measured before and after the restoration work at each Pirinoja site in 2020. Since the redox meter got broken, no redox measures could be done in Säkkisenoja in 2020. Nail tests were repeated once again in 2021 – one year after the actual restorations to monitor the persistence of restoration effects.

Figure 18. Restoration with Hartijoki method in Pirinoja, wooden deflector above the restoration area. Photo: Pirkko-Liisa Luhta.

Figure 19. Tools used in Hartijoki method. A "claw" for softening of hardened stream bed below, sieving tools for different-sized gravel in the middle, and a "hoe" for movig stones on the top. Photo: Pirkko-Liisa Luhta.

Figures 20. Restoration with Hartijoki method, same place before and after the treatment. Photos: Pirkko-Liisa Luhta.

Nails were photographed immediately after they were lifted from the stream bottom – after having been about one month in the stream (see Figs 21 and 22). Nails were stabilized by drying to prevent continuation of rust formation. Afterwards, they were preserved in airy conditions for potential further examination. As shown in figures 23–25, both tested restoration methods showed clearly positive effects on the stream bed conditions. The effects were also sustainable so that the desired effects were perceivable in both consecutive monitoring years after the restoration operation. The combined method including both Hartijoki treatment and wooden deflectors proved to attain the best results, i.e., oxygen-richest interstitial space in the bottom.

Figure 21. Photographing, drying and data collection of nails lifted from the stream bottom. Photo: Eero Moilanen.

Figure 22. An example of nail test results of Pirinoja and Säkkisenoja based on photographs. Photos: Pirkko-Liisa Luhta.

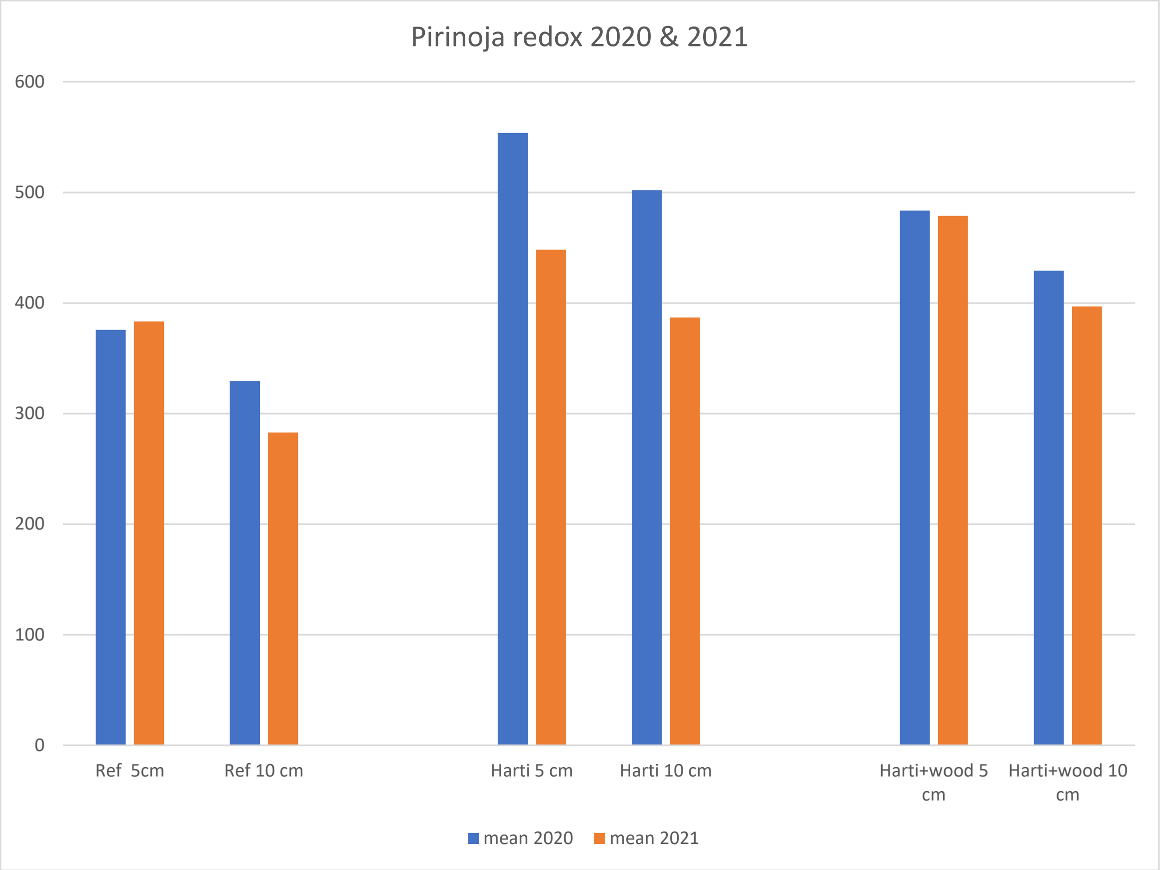

Figure 23. Results from Redox measurements in Pirinoja 2020–2021.

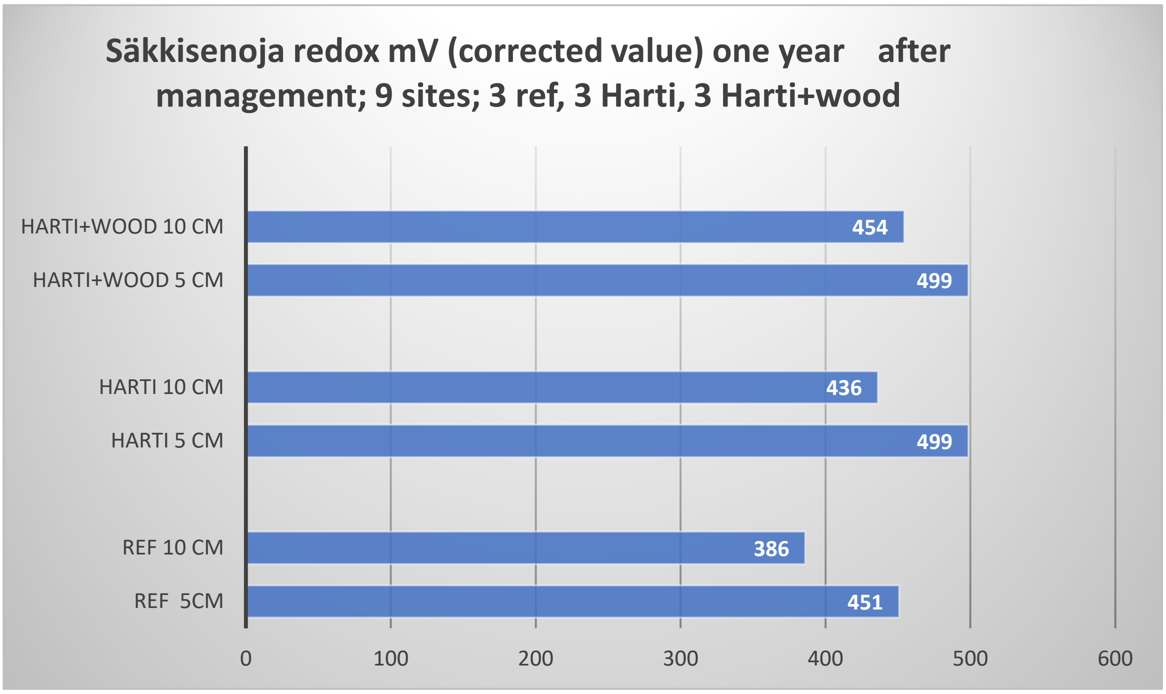

Figure 24. Results of Säkkisenoja Redox measurements in 2021.

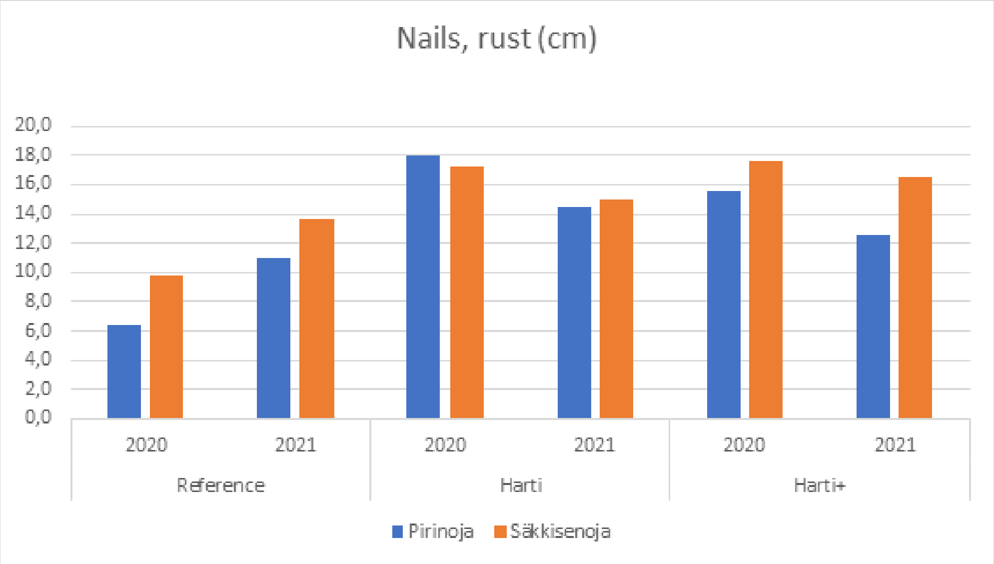

Figure 25. Mean rustiness of nails (cm) in different sample groups in Pirinoja and Säkkisenoja in 2020-2021.

Table 4. Field data of nail tests.

Year	Start date	End date	River	Set (1,2,3)	Coord. KKJ	Method Ref/Harti/Harti+	Bottom grain size, Wenworth scale Before	Bottom grain size, Wenworth scale After	Research area mean depht cm	Current speed m/s	Nails Pcs	Water °C	Redox before restoration corrected value mV 5 cm	Redox before restoration corrected value mV 10 cm	Redox after restoration corrected value mV 5 cm	Redox after restoration corrected value mV 10 cm
2020	9/9/2020	10/8/2020	Pirinoja	1	3544408-7273559	Ref	PG/PF	PF	30	0.7	6	11.1	139 and 169	69 and 91	-	-
2020	9/9/2020	10/8/2020	Pirinoja	1	3544409-7273558	Harti	PG/PF	PF	30	0.7	6	11.1	96 and 159	28 and 43	347 and 349	268 and 265
2020	9/9/2020	10/8/2020	Pirinoja	1	3544414-7273550	Harti+	PG/PF	PF	30	0.7	6	11.1	115 and 105	39 and 40	259 and 246	252 and 126
2020	9/9/2020	10/8/2020	Pirinoja	2	3544408-7273549	Ref	PG/PF	-	30	0.7	6	11.3	86 and 88	46 and 11	-	-
2020	9/9/2020	10/8/2020	Pirinoja	2	3544415-7273545	Harti	PG/PF	GG/PF	40	0.7	6	11.3	144 and 129	98 and 70	335 and 360	291 and 278
2020	9/9/2020	10/8/2020	Pirinoja	2	3544426-7273545	Harti+	PG/PF	GG/PF	32	0.7	6	11.3	80 and 102	39 and 65	316 and 336	220 and 346
2020	9/9/2020	10/8/2020	Pirinoja	3	3544442-7273540	Ref	GF	-	30	1	6	11	177 and 299	193 and 271	-	-
2020	9/9/2020	10/8/2020	Pirinoja	3	3544446-7273538	Harti	PG/CF	PG/CG	30	1	6	11	269 and 299	206 and 126	306 and 330	340 and 274
2020	9/9/2020	10/8/2020	Pirinoja	3	3544450-7273535	Harti+	PG/CG	PG	30	1	6	11	169 and 193	72 and 89	197 and 251	194 and 141
2020	9/10/2020	10/8/2020	Säkkisenoja	1	3533425-7278188	Ref	CF	-	35	0.6	6	8	-	-	-	-
2020	9/10/2020	10/8/2020	Säkkisenoja	1	3533418-7278175	Harti	SG/GF	CF/PF	45	0.6	6	8	-	-	-	-
2020	9/10/2020	10/8/2020	Säkkisenoja	1	3533417-7278174	Harti+	SG/GF	CF/CG	35	0.6	6	8	-	-	-	-
2020	9/10/2020	10/8/2020	Säkkisenoja	2	3533397-7278151	Ref	SG/CF	-	30	0.8	6	8	-	-	-	-
2020	9/10/2020	10/8/2020	Säkkisenoja	2	3533392-7278155	Harti	SG/GG	PG/CG	30	0.8	6	8	-	-	-	-
2020	9/10/2020	10/8/2020	Säkkisenoja	2	3533387-7278153	Harti+	SG/PF	PG/CG	28	0.8	6	8	-	-	-	-
2020	9/10/2020	10/8/2020	Säkkisenoja	3	3533344-7278133	Ref	SG/CF	-	25	0.7	6	8	-	-	-	-
2020	9/10/2020	10/8/2020	Säkkisenoja	3	3533338-7278127	Harti	CF	PG/CF	21	0.7	6	8	-	-	-	-
2020	9/10/2020	10/8/2020	Säkkisenoja	3	3533339-7278126	Harti+	SG	CG/PG	25	0.7	6	8	-	-	-	-
2021	8/17/2021	9/15/2021	Pirinoja	1	3544408-7273559	Ref	PG/PF	PF	20	0.8	6	14	-	-	77 and 144	108 and 235
2021	8/17/2021	9/15/2021	Pirinoja	1	3544409-7273558	Harti	PG/PF	PF	15	0.8	6	14	-	-	179 and 211	440 and 449
2021	8/17/2021	9/15/2021	Pirinoja	1	3544414-7273550	Harti+	PG/PF	PF	20	0.8	6	14	-	-	215 and 254	411 and 380
2021	8/17/2021	9/15/2021	Pirinoja	2	3544408-7273549	Ref	PG/PF	-	20	0.74	6	14	-	-	90 and 205	242 and 228
2021	8/17/2021	9/15/2021	Pirinoja	2	3544415-7273545	Harti	PG/PF	GG/PF	15	0.74	6	14	-	-	285 and 269	257 and 291
2021	8/17/2021	9/15/2021	Pirinoja	2	3544426-7273545	Harti+	PG/PF	GG/PF	10	0.74	6	14	-	-	299 and 307	441 and 441
2021	8/17/2021	9/15/2021	Pirinoja	3	3544442-7273540	Ref	GF	-	20	0.68	6	14	-	-	263 and 237	387 and -
2021	8/17/2021	9/15/2021	Pirinoja	3	3544446-7273538	Harti	PG/CF	PG/CG	15	0.68	6	14	-	-	225 and 236	445 and 439
2021	8/17/2021	9/15/2021	Pirinoja	3	3544450-7273535	Harti+	PG/CG	PG	25	0.68	6	14	-	-	257 and 257	310 and 398
2021	8/18/2021	9/15/2021	Säkkisenoja	1	3533425-7278188	Ref	CF	-	40	0.63	6	12.1	-	-	436 and 457	386 and 426
2021	8/18/2021	9/15/2021	Säkkisenoja	1	3533418-7278175	Harti	SG/GF	CF/PF	43	0.63	6	12.1	-	-	520 and 496	526 and 402
2021	8/18/2021	9/15/2021	Säkkisenoja	1	3533417-7278174	Harti+	SG/GF	CF/CG	35	0.63	6	12.1	-	-	482 and 469	465 and 469
2021	8/18/2021	9/15/2021	Säkkisenoja	2	3533397-7278151	Ref	SG/CF	-	30	0.8	6	12.1	-	-	440 and 459	359 and 373
2021	8/18/2021	9/15/2021	Säkkisenoja	2	3533392-7278155	Harti	SG/GG	PG/CG	27	0.8	6	12.1	-	-	526 and 531	473 and 475
2021	8/18/2021	9/15/2021	Säkkisenoja	2	3533387-7278153	Harti+	SG/PF	PG/CG	33	0.8	6	12.1	-	-	508 and 531	461 and 465
2021	8/18/2021	9/15/2021	Säkkisenoja	3	3533344-7278133	Ref	SG/CF	-	25	0.67	6	12.1	-	-	454 and 459	-
2021	8/18/2021	9/15/2021	Säkkisenoja	3	3533338-7278127	Harti	CF	PG/CF	20	0.67	6	12.1	-	-	467 and 452	391 and 350
2021	8/18/2021	9/15/2021	Säkkisenoja	3	3533339-7278126	Harti+	SG	CG/PG	30	0.67	6	12.1	-	-	507 and 494	430 and 435

Table 5. Streams mapped in the SALMUS project in search for new FPM populations. Inventory method mostly aquascope, in some cases snorkeling.

Year	Date	Main river basin	Sub-catchment area	Code	Municipality	River	Coordinates (KKJ27)	Coordinates (KKJ27)	Water temp. C°	Fish species detected	Vk=Aquascoping area, meters, yp=upstream, ap=downstream, Lt=Natural river section
2019	18.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Ölkynoja	3620128	7291952	13,4	-	Vk n. 200 m tiestä ap. Perattua koskea/nivaa.
2019	18.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Tervajoki	3620032	7290944	12,4	-	Vk n. 600 m ap. Lt koskea/nivaa.
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Vieremänjoki	3619492	7258866	No record	-	Vk n. 350 m yp. Lt nivaa/koskea
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Vieremänjoki	3621174	7259141	No record	-	Vk. n. 150 m ap. Lt suvantoa/virta suvantoa, paikoin oiottu kanavaksi.
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Venäjän Naavajoki	3623923	7258501	No record	*Esox lucius*	Vk n. 300 m yp. Lt koskea/nivaa/virtasuvantoa.
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Venäjän Naavajoki	3624954	7259413	No record	*Salmo trutta*	Vk n. 50 m ap. Lt suvantoa/nivaa.
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Rytioja	3626026	7259823	No record	-	Vk n. 200 m yp. Lt koskea/nivaa/virtasuvantoa.
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Venäjän Naavajoki	3625511	7259910	No record	*Esox lucius*	Vk n. 100 m yp. Lt nivaa.
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Sulanlamminpuro	3625438	7259889	No record	*Salmo trutta,* *Esox lucius*	Vk n. 350 m ap. Lt nivaa/koskea/virtaa
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Itäpuro	3623273	7261270	No record	*Salmo trutta*	Vk n. 350 m ap. Lt nivaa/koskea/virtaa.
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Itäpuro	3622848	7260393	No record	-	Vk n. 250 m ap. Lt nivaa/virtasuvantoa.
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Kortepuro	3623689	7259944	No record	-	Vk n. 250 m ap. Lt nivaa/virtaa.
2019	23.7.	Oulujoki	Venäjän Naavajoen va	59.527	Suomussalmi	Naavajoki	3621642	7256903	No record	-	Vk n. 150 m yp. Lt suvantoa/virtasuvantoa.
2019	11.7.	Kemijoki	Naruskajoen keskiosan a	65.472	Salla	Rovakaltionoja	3601432	7473726	10,3	-	Vk tiestä yp n. 250 m.
2019	11.7.	Kemijoki	Naruskajoen keskiosan a	65.472	Salla	Majavaoja	3596883	7467505	14,6	-	Vk tien yp/ap yht. n. 300 m.
2019	12.7.	Kemijoki	Sätsijoen va	65.477	Salla	Sätsijoki	3597302	7458382	10,7	-	Lt syvää nivaa, ei voitu sähköttää eikä kiikaroida.
2019	12.7.	Kemijoki	Kuolajoen alaosan a	65.481	Salla	Tuohioja	3584843	7435800	16,4	*Perca fluviatilis*?	Vk n. 350 m järvestä ap. Mt:n tuhoama puro (hakkuut, perkaukset ja hiekkaa)
2019	10.7.	Kemijoki	Sätsijoen va	65.477	Salla	Käärmeoja	3601088	7454046	9,9	-	Vk n. 400 m rajasta ap. Lt suvantoa.
2019	10.7.	Kemijoki	Sätsijoen va	65.477	Salla	Käärmeoja	3599943	7455634	9,9	-	Vk n. 400 m yht. yp/ap. Lt koskea/nivaa.
2019	10.7.	Kemijoki	Sätsijoen va	65.477	Salla	Käärmeoja	3599458	7456146	10,3	-	Vk n. 200 m ap. Lt koskea/nivaa.
2019	10.7.	Kemijoki	Sätsijoen va	65.477	Salla	Sätsijoki	3601159	7459612	12,5	*Salmo trutta*	Vk n. 600 m rajavyöh. Ap. Lt nivaa/koskea/suvantoa.
2019	10.7.	Kemijoki	Saukko-ojan va	65.476	Salla	Kapujängänoja	3603534	7468868	11,6	-	Vk n. 100 m yp. Lt nivaa/suvantoa.
2019	10.7.	Kemijoki	Saukko-ojan va	65.476	Salla	Vasa-aavanoja	3605738	7468353	11,6	-	Vk n. 300 m yht. yp/ap. Lt nivaa/suvantoa.
2019	10.7.	Kemijoki	Saukko-ojan va	65.476	Salla	Ahvenoja	3605941	7466471	14,7	FPMs 500 pcs.	Vk n. 700 m yp. Lt suvantoa/nivaa/koskea. Raakkuja n. 500 kpl.
2019	10.7.	Kemijoki	Naruskajoen keskiosan a	65.472	Salla	Muotkaoja	3601949	7470375	6,6	-	Ei katsottu lainkaan. Hitaasti virtaavaa suvantoa.
2019	11.7.	Kemijoki	Naruskajoen keskiosan a	65.472	Salla	Muotkaoja	3598708	7471191	8,8	-	Vk n. 200 m yp. Lt nivaa/suvantoa.
2019	3.7.	Vienan Kemijoki	Meskusjoen va	74.043	Kuusamo	Välijoki	3590985	7323684	15,7	FPMs	Vk n. 400 m. Lt koskea/nivaa. Raakkuja yht. n. 2000 kpl koko joessa ehkä.
2019	3.7.	Vienan Kemijoki	Meskusjoen va	74.043	Kuusamo	Meskusjoki	3594682	7321862	No record	-	Vk n. 100 m yp. Lt suvantoa.
2019	3.7.	Vienan Kemijoki	Oivanginjärven va	74.041	Kuusamo	Matkajoki	3596260	7324409	15,5	-	Vk n. 200 m yp. Lt nivaa. Pikkujärvisimpukkaa joitakin kpl.
2019	3.7.	Vienan Kemijoki	Mutkajoen va	74.042	Kuusamo	Ylijoki	3592316	7327879	11,7	-	Vk n. 300 m. Lt nivaa/koskea.
2019	3.7.	Vienan Kemijoki	Mutkajoen va	74.042	Kuusamo	Rajapuro	3592612	7327061	13,7	*Salmo trutta*?	Vk n. 200 m. Lt nivaa/koskea.
2019	3.7.	Vienan Kemijoki	Oivanginjärven va	74.041	Kuusamo	Kotijoki	3592283	7330889	15,7	*Salmo trutta*?	Vk n. 200 m. Kanavaa/nivaa.
2019	3.7.	Vienan Kemijoki	Oivanginjärven va	74.041	Kuusamo	Pulkkaoja	3593681	7332587	14,7	-	Vk n. 200 m. Lt nivaa.
2019	3.7.	Vienan Kemijoki	Nissinjoen va	74.082	Kuusamo	Nissinjoki	3598976	7327654	14,4	-	Vk n. 500 m. Perattua koskea/nivaa.
2019	3.7.	Vienan Kemijoki	Säynäjäjoen va	74.033	Kuusamo	Säynäjäjoki	3594630	7319991	15,3	-	Vk n. 300 m. Lt koskea/nivaa.
2019	20.6.	Kemijoki	Aatsinginjärven va	65.483	Salla	Aatsinginjoki	3584368	7411730	13,3	*Salmo trutta*	Vk n. 400 m. Lt koskea/nivaa
2019	20.6.	Kemijoki	Aatsinginjärven va	65.483	Salla	Aatsinginjoki	3584576	7411179	13,3	-	Vk n. 300 m. Lt nivaa.
2019	20.6.	Kemijoki	Aatsinginjärven va	65.483	Salla	Aatsinginjoki	3585208	7409390	No record	*Salmo trutta*	Vk n. 600 m. Lt nivaa/koskea.
2019	20.6.	Kemijoki	Ruuhijoen va	65.376	Salla	Hangasjoki	3578758	7406654	No record	*Salmo trutta*	Vk n. 150 m. Lt suvantoa/nivaa.
2019	20.6.	Kemijoki	Ruuhijoen va	65.376	Salla	Hangasjoki	3578825	7406886	No record	*Salmo trutta*	Vk n. 200 m. Lt suvantoa/koskea.
2019	20.6.	Kemijoki	Ruuhijoen va	65.376	Salla	Hangasjoki	3578307	7406689	18,7	*Salmo trutta*	Vk n. 300 m. Lt suvantoa/koskea.
2019	20.6.	Kemijoki	Ruuhijoen va	65.376	Salla	Hangasjoki	3577203	7407675	12,9	*Salmo trutta*	Vk n. 400 m. Lt nivaa/koskea.
2019	8.7.	Kemijoki	Ruuhijoen va	65.376	Salla	Tuohilusikanlammenoja	3580992	7405490	15,7	*Phoxinus phoxinus,* *Salmo trutta,* FPM shells	Vk n. 800 m ap. Lt koskea/nivaa/suvantoa.
2019	8.7.	Kemijoki	Ruuhijoen va	65.376	Salla	Ruuhijoki	3576207	7408473	12,2	-	Vk n. 100 m. Lt koskea/nivaa.

Year	Date	Main river basin	Sub-catchment area	Code	Municipality	River	Coordinates (KKJ27)	Coordinates (KKJ27)	Water temp. C°	Fish species detected	Vk=Aquascoping area, meters, yp=upstream, ap=downstream, Lt=Natural river section
2019	8.7.	Kemijoki	Ruuhijoen va	65.376	Salla	Ruuhijoki	3574463	7408591	12	-	Vk n. 50 m. Lt nivaa/suvantoa.
2019	8.7.	Kemijoki	Ruuhijoen va	65.376	Salla	Hangasjoki	3576578	7408330	11,6	-	Vk n. 50 m. Lt nivaa/suvantoa.
2019	8.7.	Kemijoki	Ruuhijoen va	65.376	Salla	Pyhäjoki	3575738	7414104	15	*Perca fluviatilis*	Vk n. 400 m. Lt nivaa/koskea.
2019	8.7.	Kemijoki	Ruuhijoen va	65.376	Salla	Pyhäjoki	3574969	7415017	14,7	-	Vk n. 300 m yp. Lt koskea/nivaa.
2019	9.7.	Kemijoki	Saukko-ojan va	65.476	Salla	Purkaoja	3601151	7465496	13,1	*Phoxinus phoxinus*	Vk n. 400 m. Lt nivaa/koskea. Hiekkaista. Kirkas vesi.
2019	9.7.	Kemijoki	Sätsijoen va	65.477	Salla	Sätsijoki	3604985	7462149	15,3	FPMs	Vk n. 400 m. Lt koskea/nivaa. Raakkuja suuren hetteen ja järven välillä. Louhikkoista.
2019	9.7.	Kemijoki	Sätsijoen va	65.477	Salla	Sätsijoki	3604987	7461513	13,6	-	Vk n. 600 m. Lt koskea/nivaa.
2019	9.7.	Kemijoki	Sätsijoen va	65.477	Salla	Sätsijoki	3603411	7460526	12,2	-	Vk n. 300 m. Lt nivaa/koskea. Hetteitä paljon jokeen.
2019	9.7.	Kemijoki	Sätsijoen va	65.477	Salla	Sätsijoki	3599991	7459349	13,2	-	Syvää louhikkoista, vuolasta, perattua koskea. Ei voinut vesikiikaroida.
2019	18.6.	Koutajoki	Kieskisjoen va	73.014	Salla	Ylikieskisenoja	3607643	7388396	15,4	*Salmo trutta*	Vk n. 300 m tiestä ap. Lt nivaa. Kirkas vesi.
2019	18.6.	Koutajoki	Sorsajoen va	73.016	Salla	Saarioja	3603896	7387296	20,1	-	Vk n. 250 m. tien ap. Lt puroa.
2019	20.6.	Koutajoki	Onkamojoen keskiosan a	73.082	Salla	Hanhioja	3581432	7406909	14,7	-	Vk n. 200 m. Lt nivaa/koskea.
2019	20.6.	Koutajoki	Onkamojoen keskiosan a	73.082	Salla	Tunturioja	3581327	7407165	11	-	Vk n. 100 m. Lt nivaa/koskea.
2019	20.6.	Koutajoki	Onkamojoen keskiosan a	73.082	Salla	Hanhioja	3581216	7407201	15,8	-	Vk n. 200 m. Lt nivaa.
2019	3.6.	Oulujoki	Kesselinjärven–Kälkäsen a	59.974	Kuhmo	Kuusijoki	3657373	7093835	13,7		Vesikiikarointi n. 100 m ap.
2019	4.6.	Oulujoki	Kesselinjärven–Kälkäsen a	59.974	Kuhmo	Kesselinjoki	3651665	7102678			Ei kalast.;vuolas ränni
2019	13.8.	Koutajoki	Paljakan a	73.041	Kuusamo	Salmilampeen laskeva	3624638	7350406	No record	*Phoxinus phoxinus, Salmo trutta?*	Vk n. 350 m yp. Lt Koskea/nivaa/suvantoa
2019	13.8.	Koutajoki	Paljakan a	73.041	Kuusamo	Junnonoja	3619909	7348477	13,2	*Phoxinus phoxinus*	Vk. n. 250 m yp. Lt koskea/nivaa/suvantoa.
2019	13.8.	Koutajoki	Paljakan a	73.041	Kuusamo	Kivioja	3618216	7347096	13,1	-	Vk n. 400 m yp. Lt koskea/suvantoa.
2019	13.8.	Koutajoki	Paljakan a	73.041	Kuusamo	Koverusjoki	3617211	7342596	15,1	*Phoxinus phoxinus, Salmo trutta?*	Vk n. 300 m ap. Lt/perattua koskea/nivaa.
2019	13.8.	Koutajoki	Paljakan a	73.041	Kuusamo	Lohioja	3628172	7343902	14,2	*Phoxinus phoxinus*	Vk n. 150 m ap. Lt/perattua koskea.
2019	13.8.	Koutajoki	Paljakan a	73.041	Kuusamo	Kiekeröoja	3624775	7344214	12,1	-	Vk n. 250 m yp. Lt koskea/suvantoa.
2019	20.8.	Vienan Kemijoki	Virmajoen yläosan a	74.07	Kuusamo	Virmajoki	3630295	7299852	14,1	-	Vk n. 600 m ap. Lt suvantoa/koskea/nivaa.
2019	20.8.	Vienan Kemijoki	Kuikkajoen yläosan va	74.06	Kuusamo	Pikku-Vihtajoki	3629857	7294916	15,5	-	Vk n. 700 m ap. Lt koskea/nivaa/suvantoa.
2019	20.8.	Vienan Kemijoki	Virmajoen yläosan a	74.07	Kuusamo	Virmajoki	3633012	7298232	10	*Salmo trutta*	Vk n. 200 m ap. Lt koskea/nivaa/suvantoa.
2019	20.8.	Vienan Kemijoki	Virmajoen yläosan a	74.07	Kuusamo	Virmajoki	3632765	7298543	10	-	Vk n. 200 m yht. ap/yp. Lt koskea/nivaa/suvantoa.
2019	20.8.	Vienan Kemijoki	Virmajoen yläosan a	74.07	Kuusamo	Värtönjoki	3637232	7299516	14,9	Some fish species.	Vk n. 200 m yht. ap/yp. Lt koskea/nivaa (ositt. Perattua).
2019	20.8.	Vienan Kemijoki	Virmajoen yläosan a	74.07	Kuusamo	Pikkupuro	3641399	7297339	17,1	-	Vk n. 100 m yp. Lt nivaa/suvantoa.
2019	20.8.	Vienan Kemijoki	Virmajoen yläosan a	74.07	Kuusamo	Virmajoki	3640208	7296643	14,9	*Perca fluviatilis / Rutilus rutilus*	Vk n. 300 m yp. Lt suvantoa/nivaa.
2019	20.8.	Vienan Kemijoki	Virmajoen yläosan a	74.07	Kuusamo	Kangasoja	3640000	7296694	No record	-	Vk n. 100 m yp. Lt/perattua koskea.
2019	20.8.	Vienan Kemijoki	Virmajoen yläosan a	74.07	Kuusamo	Palopuro	3642969	7295650	15,5	-	Vk n. 200 m yp. Lt suvantoa/nivaa/koskea.
2019	21.8.	Vienan Kemijoki	Kuikkajoen yläosan va	74.06	Kuusamo	Kuikkajoki	3629410	7292033	14	-	Vk n. 650 m yp. Lt koskea/nivaa/suvantoa.
2019	21.8.	Vienan Kemijoki	Kuikkajoen yläosan va	74.06	Kuusamo	Vihtajoki	3633795	7293965	14,4	*Salmo trutta*?	Vk n. 500 m ap. Lt nivaa/suvantoa.
2019	21.8.	Vienan Kemijoki	Kuikkajoen yläosan va	74.06	Kuusamo	Kiekkipuro	3638152	7294401	15,2	-	Vk n. 400 m yp. Lt koskea/nivaa.
2019	21.8.	Vienan Kemijoki	Kuikkajoen yläosan va	74.06	Kuusamo	Vihtajoki	3635670	7292885	14,2	-	Vk n. 200 m yp. Lt nivaa.
2019	21.8.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Juomapuro	3626269	7289715	13,1	-	Vk n. 150 m yp. Lt koskea/nivaa/suvantoa.
2019	21.8.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Mäntypuro	3627043	7289026	16,6	-	Vk n 150 m ap. Lt koskea/nivaa/suvantoa.
2019	21.8.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Lantisenpuro	3622385	7288828	No record	-	Vk n. 200 m yp. Lt nivaa.
2019	22.8.	Oulujoki	Hossanjärven a	59.522	Suomussalmi	Laurinlammenpuro	3622892	7266912	11,3	-	Vk n. 200 m yp. Lt koskea/nivaa/suvantoa.
2019	22.8.	Oulujoki	Hossanjärven a	59.522	Suomussalmi	Latvajoki	3623008	7266567	15,2	-	Vk n. 100 m yp. Lt koskea.
2019	22.8.	Oulujoki	Ryönäjoen va	59.538	Suomussalmi	Huuranjoki	3625619	7276057	14,1	-	Vk n. 200 m ap. Lt/perattua koskea/nivaa.
2019	22.8.	Oulujoki	Ryönäjoen va	59.538	Suomussalmi	Huuranjoki	3622988	7275162	13,4	-	Vk n. 300 m yp. Lt suvantoa/nivaa/koskea.
2019	22.8.	Oulujoki	Karsikkojoen va	59.537	Suomussalmi	Karsikkojoki	3613773	7271619	13,7	*Esox lucius*	Vk n. 500 m yp. Lt koskea/nivaa.
2019	22.8.	Oulujoki	Karsikkojoen va	59.537	Suomussalmi	Karsikkojoki	3612522	7273465	13	-	Vk n. 300 m yp. Lt koskea/nivaa.
2019	22.8.	Oulujoki	Karsikkojoen va	59.537	Suomussalmi	Vaaranlamminpuro	3611759	7273351	12,7	-	Vk n. 200 m yp. Lt koskea/nivaa.
2019	5.6.	Oulujoki	Hukkajärven va	59.973	Kuhmo	Louhenpuro	3670866	7118659	No record	-	Majavanpato. Alapuoli täysin pilalle perattua kanavaa. Ei katsottu.

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2019	5.6.	Oulujoki	Hukkajärven va	59.973	Kuhmo	Raatepuro	3670143	7119895	No record	-	Täysin pilalle perattua kanavaa. Vanha uoma kanavan vierellä kuivilla. Ei katsottu.
2020	16.6.	Koutajoki	Hirvasjärven a	73.073	Salla	Järvenpäänoja	3566671	7386583	No record	-	Vanha lrl-lammikon alakanava. Ei katsottu ollenkaan. Täysin luonnontilansa menettänyt.
2020	16.6.	Koutajoki	Hirvasjärven a	73.073	Salla	Saukko-oja	3566619	7386219	14,7	-	Vk 150 m ap. Koskea, jota on rankasti kaivettu.
2020	16.6.	Koutajoki	Aholanvaaran a	73.072	Salla	Kallio-oja	3573999	7382425	17,5	-	Vk yp/ap yhteensä 400 m. Lt koskea. Kirkas vesi.
2020	16.6.	Koutajoki	Lausojan va	73.077	Salla	Salmioja	3572856	7386296	16	-	Vk yp 150 m. Kaivettua/Lt koskea.
2020	16.6.	Koutajoki	Lausojan va	73.077	Salla	Salmioja	3571912	7386843	18,3	-	Vk yp 100 m. Kaivettua/Lt nivaa.
2020	16.6.	Koutajoki	Puonimaojan va	73.076	Salla	Latvaoja	3572524	7390032	16,8	*Phoxinus phoxinus*	Vk yp/ap yht. 300 m. Lt koskea/nivaa.
2020	16.6.	Koutajoki	Koutajoen va	73.015	Salla	Nurmioja	3581820	7388793	16,3	-	Vk yht. yp/ap 300 m. Lt nivaa/koskea. Hieno puro. Yläosa tarkistettava!
2020	17.6.	Koutajoki	Kieskisjoen va	73.014	Salla	Kermusoja	3595461	7396566	No record	*Phoxinus phoxinus*	Syvää hidasvitaista suvantoa. Ei katsottu.
2020	18.6.	Koutajoki	Hevosojan–Myllyojan va	73.084	Salla	Hevosoja	3584938	7398620	15,3	-	Vk yp 300 m. Lt koski/niva. Hieno!
2020	18.6.	Koutajoki	Hevosojan–Myllyojan va	73.084	Salla	Myllyoja	3584350	7398464	18,2	*Esox lucius, Phoxinus phoxinus, Salmo trutta*(?), FPMs	Vk ap 500 m. Lt koski/niva/virtasuvanto. Raakkuja n. 150 kpl.
2020	18.6.	Koutajoki	Hevosojan–Myllyojan va	73.084	Salla	Myllyoja	3583646	7398736	19	Some fish species, FPMs	Vk yp/ap 350 m, yht. 700 m. Lt koski/niva. Hieno! Raakkuja muutama tuhat.
2020	18.6.	Koutajoki	Hevosojan–Myllyojan va	73.084	Salla	Hevosoja	3584662	7399721	15	-	Vk yp 300 m. Lt koski/niva. Hieno!
2020	22.6.	Koutajoki	Hevosojan–Myllyojan va	73.084	Salla	Nimetön Sausjärveen	3580907	7398863	15,6	-	Vk yp 350 m. Lt koski.
2020	22.6.	Koutajoki	Hevosojan–Myllyojan va	73.084	Salla	Nimetön Sausjärveen	3579617	7398463	17,8	-	Vk yp/ap 200 m, yht. 400 m. Lt koski/niva.
2020	30.6.	Koutajoki	Onkamojoen keskiosan a	73.082	Salla	Halioja	3588608	7405175	17,5	-	Vk ap 250 m. Lt/perattua nivaa.
2020	22.6.	Koutajoki	Hevosojan–Myllyojan va	73.084	Salla	Sausoja	3581796	7398082	18,5	*Perca fluviatilis*	Vk yp 300 m. Lt suvanto/niva/koski.
2020	22.6.	Koutajoki	Kallunkijärven a	73.081	Salla	Myllyoja	3586888	7392527	22,1	-	Vk yp/ap 150 m, yht. 300 m. Lt koski/niva.
2020	22.6.	Koutajoki	Kallunkijärven a	73.081	Salla	Säynäjäoja	3588672	7390868	18,6	-	Vk ap 100 m, yp 400 m. Lt suvanto/niva.
2020	23.6.	Koutajoki	Kieskisjoen va	73.014	Salla	Peuro-oja	3601815	7392095	No record	-	Vk yp 200 m. Lt koski/niva.
2020	23.6.	Koutajoki	Sorsajoen va	73.016	Salla	Sammakko-oja	3601882	7387314	18,7	*Phoxinus phoxinus*	Vk ap 300 m. Perattua kanavaa ja lt koskea.
2020	23.6.	Koutajoki	Sorsajoen va	73.016	Salla	Sorsajoki	3593741	7387785	23,5	*Phoxinus phoxinus, Anodonta anatina* 5 kpl	Vk yp/ap 75 m, yhteensä 150 m. Lt niva/koski/suvanto.
2020	24.6.	Koutajoki	Niitselysjoen va	73.017	Salla	Niitselysjoki	3605722	7381294	No record	-	Vk yp 100 m. Lt niva/suvanto.
2020	24.6.	Koutajoki	Niitselysjoen va	73.017	Salla	Hangasjoki	3608805	7380567	20,5	-	Vk yp 300 m. Lt koski/niva/suvanto.
2020	24.6.	Koutajoki	Niitselysjoen va	73.017	Salla	Ahmaoja	3610097	7377414	19,5	*Phoxinus phoxinus*	Vk ap 1000 m. Lt koski/niva. Osin perattua kanavaa metsätalousalueella.
2020	24.6.	Koutajoki	Niitselysjoen va	73.017	Salla	Nimetön Ahmaojaan	3609808	7376583	16,5	-	Vk yp 200 m. Lt suvanto/niva/koski.
2020	24.6.	Koutajoki	Niitselysjoen va	73.017	Salla	Hangasjoki	3606999	7380819	21,1	-	Vk yp 250 m. Lt koski/niva/suvanto.
2020	24.6.	Koutajoki	Niitselysjoen va	73.017	Salla	Niitselysjoki	3604850	7381065	19,9	*Phoxinus phoxinus*	Vk ap 600 m. Lt koski/niva. Hieno!
2020	25.6.	Koutajoki	Savinajoen a	73.015	Salla	Palo-oja	3587507	7388617	17,1	*Phoxinus phoxinus*?	Vk 300 m ap. Lt Koski/niva/suvanto.
2020	25.6.	Koutajoki	Niitselysjoen va	73.017	Salla	Niitselysjoki	3600629	7380957	21,3	*Anodonta anatina*	Vk 50 m. Lt nivaa.
2020	25.6.	Koutajoki	Koutajoen va	73.015	Salla	Koutajoki	3586507	7383742	21,7	*Phoxinus phoxinus* + some other fish species	Vk n. 250 m yp. Lt koskea/nivaa/suvantoa.
2020	25.6.	Koutajoki	Koutajoen va	73.015	Salla	Leusoja	3585316	7381951	16	-	Vk n. 150 m yp/ap. Lt suvanto/niva/koski. Vanha kala-allas kaivettu uoman viereen (ei toiminnassa).
2020	26.6.	Koutajoki	Yli-Kitkan a	73.025	Salla	Suovajoki	3577262	7352301	No record	-	Vk n. 300 m ap. Lt koskea/nivaa.
2020	26.6.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Mourujoki	3563221	7362541	21,1	*Phoxinus phoxinus*	Vk 250 m ap, 150 m yp. Hieman käsin perattua koskea/nivaa.
2020	26.6.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Vääräjoki	3562267	7358613	21,6	-	Vk n. 400 m yp. Hieman käsin perattua koskea/nivaa/suvantoa.
2020	26.6.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Vääräjoki	3558704	7359535	20,9	FPMs	Vk n. 150 m yp. Vanhoja raakkuja melko paljon. Hieman käsin perattua koskea/nivaa.
2020	30.6.	Kemijoki	Ylä-Naruskajoen va	65.473	Salla	Moukaoja	3599621	7484168	13,9	-	Vk 250 ap. Lt nivaa/suvantoa.
2020	30.6.	Kemijoki	Ruuhijoen va	65.376	Salla	Nimetön Hangasjokeen	3579123	7407144	13,4	-	Vk n. 100 m ap. Lt koski/nivaa.
2020	1.7.	Koutajoki	Oulankajoen raja-alue	73.011	Kuusamo	Sirkkapuro	3615452	7365958	15,6	-	Vk n. 350 m ap. Lt koskea/nivaa. Tikankonttia puron lähellä.
2020	1.7.	Koutajoki	Oulankajoen raja-alue	73.011	Kuusamo	Uopajanpuro	3613028	7363080	10,5	-	Vk 150 m yp. Lt koskea. Kylmä vesi!
2020	1.7.	Koutajoki	Oulankajoen raja-alue	73.011	Kuusamo	Sirkkapuro	3614885	7364669	11,5	-	Vk 100 m yp/ap. Lt suvantoa/nivaa.
2020	1.7.	Koutajoki	305-Kuusamo	305-Kuusamo	Kuusamo	Suistopuro	3619851	7359628	14,6	-	Vk 300 m ap. Lt koskea/nivaa.

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2020	1.7.	Koutajoki	305-Kuusamo	305-Kuusamo	Kuusamo	Suoropuro	3620517	7358354	12,8	-	Vk 200 m yp. Lt koskea/nivaa.
2020	1.7.	Koutajoki	305-Kuusamo	305-Kuusamo	Kuusamo	Huotinoja	3618049	7363237	16,1	*Salmo trutta*?	Vk 100 m yp, 200 m ap.Lt koskea/nivaa/suvantoa.
2020	2.7.	Koutajoki	Niitselysjoen va	73.017	Kuusamo	Karvastentekemäoja	3607495	7375216	14,8	*Phoxinus phoxinus*	Vk 300 m ap. Lt koskea/nivaa.
2020	2.7.	Koutajoki	Niitselysjoen va	73.017	Kuusamo	Karvastentekemäoja	3608637	7373655	15,6	-	Vk 150 m yp. Lt nivaa.
2020	6.7.	Oulujoki	Akon–Juntusjärven a	59.512	Suomussalmi	Hukkajoki	3619606	7232045	13,2	-	Vk 200 m yp, 150 m ap. Lt suvantoa/nivaa.
2020	6.7.	Oulujoki	Turkkijoen va	59.516	Suomussalmi	Sarvijoki	3618742	7227891	No record	-	Vk 150 m ap. Koneella perattua nivamaista kanavaa.
2020	6.7.	Oulujoki	Pärsämönjoen va	59.517	Suomussalmi	Pärsämönjoki	3617555	7223424	13,1	-	Vk/snork. 200 m yp. Lt nivaa.
2020	6.7.	Oulujoki	Pärsämönjoen va	59.517	Suomussalmi	Pärsämönjoki	3615794	7223490	12,5	-	Vk/snork. 250 m ap, 150 m yp. Lt koskea/nivaa.
2020	6.7.	Oulujoki	Pärsämönjoen va	59.517	Suomussalmi	Kalliopuro	3620052	7222446	12,5	-	Vk 100 m yp/ap. Lt koskea/nivaa.
2020	6.7.	Oulujoki	Ehronjärven va	59.518	Suomussalmi	Raatepuro	3610582	7214996	No record	-	Vk 100 m yp/ap. Lt koskea.
2020	7.7.	Oulujoki	Löytöjoen va	59.594	Suomussalmi	Martinjoki	3629080	7236612	13,8	-	Vk 200 m ap. Lt koskea/nivaa/suvantoa.
2020	7.7.	Oulujoki	Löytöjoen va	59.594	Suomussalmi	Martinjoki	3631240	7236760	14,5	-	Vk 100 m ap. Lt koskiea/nivaa/suvantoa.
2020	7.7.	Oulujoki	Löytöjoen va	59.594	Suomussalmi	Matopuro	3632799	7237130	14,7	-	Vk 150 m yp. Lt nivaa/koskea.
2020	7.7.	Oulujoki	Löytöjoen va	59.594	Suomussalmi	Martinpuro	3633133	7236998	14,5	-	Vk 30 m yp. Lt nivaa.
2020	7.7.	Vienan Kemijoki	777-Suomussalmi	777-Suomussalmi	Suomussalmi	Hoikkajoki	3631369	7232044	13,8	-	Vk 400 m yp. Lt koski/niva/suvantoa.
2020	7.7.	Oulujoki	Taivaljoen a	59.591	Suomussalmi	Väisäsenpuro	3629614	7232060	14,6	-	Vk 400 m yp. Lt koskea/nivaa.
2020	7.7.	Oulujoki	Karttimonjoen va	59.592	Suomussalmi	Pirttipuro	3633022	7227930	16,6	-	Vk 200 m yp. Lt koskea/nivaa.
2020	7.7.	Oulujoki	Karttimonjoen va	59.592	Suomussalmi	Leväpuro	3629490	7226169	11,6	-	Vk 200 m yp. Lt koskea/nivaa.
2020	7.7.	Oulujoki	Laukkujoen a	59.595	Suomussalmi	Särkkäjoki	3627931	7229440	14	-	Vk 150 m yp. Lt koskea/nivaa.
2020	7.7.	Oulujoki	Syrjäjoen va	59.596	Suomussalmi	Syrjäjoki	3627390	7229872	No record	-	Vk 150 m ap. Lt koskea/nivaa.
2020	8.7.	Oulujoki	Taivaljoen a	59.591	Suomussalmi	Palopuro	3625151	7234428	13,9	-	Vk 250 m yp. Lt koskea/nivaa.
2020	8.7.	Oulujoki	Laukkujoen a	59.595	Suomussalmi	Särkkäjoki	3627106	7226693	13,9	-	Vk 250 m yp. Lt koskea/nivaa.
2020	8.7.	Oulujoki	Laukkujoen a	59.595	Suomussalmi	Särkkäjoki	3626821	7226033	13,9	-	Vk 150 m yp. Lt koskea/nivaa.
2020	8.7.	Oulujoki	Ehronjärven va	59.518	Suomussalmi	Hietajoki	3613528	7217876	16,5	Some fish species	Vk 450 m ap. Lt koskea/nivaa.
2020	8.7.	Oulujoki	Pärsämönjoen va	59.517	Suomussalmi	Pärsämönjoki	3620477	7223918	15,1	-	Vk 350 m yp- Lt koskea/nivaa.
2020	9.7.	Oulujoki	Lahnajoen alaosan a	59.473	Suomussalmi	Lahnajoki	3577701	7195034	16,5	Harjus, *Perca fluviatilis, Salmo trutta*(?). FPMs	Vk/snork. 2800 m ap. Useita tuhansia raakkuja. Hieman paikoin käsin perattuja koskia ja nivaa sekä virtasuvantoa. Ylimmät havaitut raakut noin pisteessä 3577939-7194037
2020	9.7.	Oulujoki	Lahnajoen alaosan a	59.473	Suomussalmi	Kivijoki	3576590	7193564	15,1	-	Vk 50 m yp, 100 m ap. Lt koskea/nivaa. Erittäin tummavetinen, heikko näkösyvyys!
2020	9.7.	Oulujoki	Korpijoen va	59.435	Suomussalmi	Korpijoki	3581624	7196022	16,5	FPMs	Vk 650 m ap. Lt nivaa/koskea. Raakkuja vähintään satoja. Ylimmät havaitut raakut pisteessä 3581698-7195858.
2020	15.7.	Oulujoki	Varisjoen va	59.436	Suomussalmi	Hiidenjoki	3573898	7203253	13,9	-	Vk 200 m ap. Lt koskea/nivaa/suvantoa. Tummavetinen, heikko näkyvyys, myös hieman tulvaa!
2020	15.7.	Oulujoki	Varisjoen va	59.436	Suomussalmi	Leväjoki	3582240	7200438	15,9	FPMs	Vk 250 m yp/ap. Paikoin hieman käsin perattua koskea ja nivaa. Raakut (n. 100 + kpl löydetty) pisteen 3582199-7200458 kosken niskalta alaspäin. Tulvaa, oli vaikea kartoittaa aluetta kunnolla.
2020	15.7.	Oulujoki	Varisjoen va	59.436	Suomussalmi	Leväjoki	3581389	7201151	17	-	Vk 50 m ap. Tulvaa ja syvää koskea (käsin perattu) ja nivaa. Vaikea kartoittaa vesikiikarilla.
2020	16.7.	Oulujoki	Mätäsjoen va	59.533	Suomussalmi	Mätäsjoki	3613882	7281408	17,1	-	Vk 250 m yp. Lt koskea/nivaa. Tummavetinen.
2020	16.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Tervajoki	3619518	7292261	15,4	-	Vk 100 m yp. Lt koski/niva/suvanto.
2020	16.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Leiviskäisenpuro	3619584	7292740	12,2	-	Vk 100 m ap. Lt nivaa. Olematonta puroa/noroa.
2020	16.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Välipuro	3624358	7288296	17,6	-	Vk 50 m yp. Lt suvanto/niva. Hidasvirtaista. Mutapohjaa/hiekkaista.
2020	16.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Luomanjoki	3627945	7287190	19,5	-	Vk 50 m yp. Käsin perattu koski, alapuoli leveätä majavan patoamaa suvantoa.
2020	16.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Itkupuro	3627149	7286319	20,5	-	Vk 100 m yp. Lt niva/suvanto.
2020	16.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Luomanjoki	3626397	7287159	18,4	-	Vk 150 m yp. Lt koski/niva, yläosa majavan patoamaa suvantoa.
2020	16.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Hyvänlamminpuro	3618810	7289705	20,5	-	Vk 100 m yp. Lt suvanto/niva/koski.
2020	16.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Salmipuro	3617662	7288989	19,5	-	Vk 200 m yp. Lt niva/suvanto.
2020	16.7.	Vienan Kemijoki	Kaartojärvien va	74.05	Kuusamo	Hoikanjoki	3621506	7288241	19	-	Vk 50 m yp. Lt koski/niva.
2020	17.7.	Koutajoki	Paljakan a	73.041	Kuusamo	Raatepuro	3613789	7353556	16,3	-	Vk 200 m ap. Lt (?) niva/koski.

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2020	17.7.	Koutajoki	Paljakan a	73.041	Kuusamo	Raatepuro	3618356	7354310	14,6	-	Vk 200 m yp. Lt koski/niva.
2020	17.7.	Koutajoki	305-Kuusamo	305-Kuusamo	Kuusamo	Sirepuro	3628039	7337308	17,7	-	Vk 300 m yp. Osin perattua, osin lt koski/niva.
2020	17.7.	Koutajoki	Vuotungin a	73.042	Kuusamo	Ropakkojoki	3623352	7336639	19	-	Vk 200 m ap. Lt koski/niva.
2020	17.7.	Koutajoki	Suiningin a	73.043	Kuusamo	Myllyjoki	3610174	7333192	17,2	-	Vk 150 m yp. Lt niva/koski.
2020	17.7.	Koutajoki	Suiningin a	73.043	Kuusamo	Myllyjoki	3611158	7332914	16,4	-	Vk 150 m yp. Lt nivaa (hienoa raakku hab!)
2020	17.7.	Koutajoki	Kurikkajoen va	73.048	Kuusamo	Leppipuro	3606918	7336514	17,4	-	Vk 200 m yp. Lt niva/koski (hienoa raakku hab!)
2020	17.7.	Koutajoki	Kurikkajoen va	73.048	Kuusamo	Matojoki	3601985	7335785	14,7	-	Vk 100 m ap. Lt koski/niva.
2020	21.7.	Oulujoki	Peranganjoen a	59.583	Suomussalmi	Hietajoki	3598009	7257555	20	-	Vk 300 m yp. Lt koski/niva.
2020	21.7.	Oulujoki	Timpinjoen va	59.526	Suomussalmi	Timpinjoki	3613003	7252247	17,3	-	Vk 100 m yp/ap. Lt koski/niva/suvanto. Tummavetinen!
2020	21.7.	Oulujoki	Matalajoen va	59.528	Suomussalmi	Matalajoki	3621537	7253438	17,9	-	Vk 300 m yp/ap.. Lt suvanto/niva/koski.
2020	21.7.	Koutajoki	305-Kuusamo	305-Kuusamo	Kuusamo	Rautapuro	3630947	7277069	17,2	-	Vk 50 m yp. Lt niva. Rautapitoista pohjaa ja vettä.
2020	21.7.	Oulujoki	Sarvijoen va	59.539	Kuusamo	Kaikopuro	3627589	7273170	22,2	-	Vk 150 m yp. Lt koski/niva.
2020	27.7.	Oulujoki	Kauhapuron va	59.655	Suomussalmi	Myllypuro	3623870	7194241	No record	-	Olematon puro ja erittäin tummavetinen. Ei katsottu enemmälti.
2020	27.7.	Oulujoki	Hallajoen va	59.637	Suomussalmi	Hallajoki	3630515	7179964	16,8	-	Vk 50 m yp/ap. Lt niva/koski. Tummavetinen.
2020	27.7.	Oulujoki	Hallajoen va	59.637	Suomussalmi	Hallajoki	3629661	7179793	16,8	-	Vk 75 m yp/ap. Lt koski/niva. Tummavetinen!
2020	27.7.	Oulujoki	Hallajoen va	59.637	Suomussalmi	Koivupuro	3633520	7179336	14,4	-	Vk 50 m yp. Lt suvanto/niva/koski. Olematon, tummavetinen puro.
2020	27.7.	Oulujoki	Hallajoen va	59.637	Suomussalmi	Koivupuro	3633141	7178975	14,5	-	Vk 50 m yp. Lt suvanto/niva/koski. Olematon, tummavetinen puro.
2020	27.7.	Oulujoki	Hallajoen va	59.637	Suomussalmi	Hallajoki	3636244	7177426	17,9	-	Vk 50 m ap.Lt (?) koski/niva. Tummavetinen.
2020	27.7.	Oulujoki	Isojoen a	59.672	Suomussalmi	Lapinlamminjoki	3636187	7174166	18,1	-	Vk 200 m ap. Lt koski/niva. Melko tummavetinen.
2020	27.7.	Oulujoki	Kivijärven a	59.633	Suomussalmi	Kuivajoki	3645135	7177007	20,2	-	Vk 50 m yp. Lt niva. Melko kirkas vesi.
2020	27.7.	Oulujoki	Kivijärven a	59.633	Suomussalmi	Kuivajoki	3645353	7176771	20,2	-	Vk 50 m yp. Lt koski/niva.
2020	24.7.	Koutajoki	Yli-Kitkan a	73.025	Kuusamo	Lohijoki	3578894	7327323	13,5	-	Vk 200 m yp/ap. Lt koski/niva.
2020	24.7.	Koutajoki	Yli-Kitkan a	73.025	Kuusamo	Lohijoki	3580937	7326243	15,9	-	Vk 500 m yp. Lt suvanto/koski/niva.
2020	24.7.	Koutajoki	Yli-Kitkan a	73.025	Kuusamo	Lohijoki	3576734	7329504	12,4	-	Vk 100 m yp. Lt niva. Hiekkaista.
2020	24.7.	Koutajoki	Naatikkajoen a	73.051	Kuusamo	Naatikkajoki	3580676	7334111	17,9	-	Vk 250 m yp. Lt niva/koski.
2020	24.7.	Koutajoki	Naatikkajoen a	73.051	Kuusamo	Naatikkajoki	3583345	7333768	17,5	-	Vk 350 m yp. Lt niva/koski/suvanto.
2020	24.7.	Koutajoki	Naatikkajoen a	73.051	Kuusamo	Naatikkajoki	3586374	7334923	17,7	-	Vk 100 m yp/ap. Lt niva.
2020	28.7.	Oulujoki	Vartiusjärven va	59.935	Kuhmo	Lahnajoki	3641646	7164974	17,7	-	Vk 250 m yp. Lt niva/koski/suvanto.
2020	28.7.	Oulujoki	Vartiusjärven va	59.935	Kuhmo	Juntinpuro	3643365	7166271	14,6	-	Vk 50 m yp. Lt koski/niva.
2020	28.7.	Vienan Kemijoki	777-Suomussalmi	777-Suomussalmi	Suomussalmi	Veihtijoki	3643782	7170099	19,4	-	Vk 50 m yp. Lt koski/niva.
2020	28.7.	Vienan Kemijoki	777-Suomussalmi	777-Suomussalmi	Suomussalmi	Veihtijoki	3643404	7170170	19,5	-	Vk 25 m yp. Lt niva/koski.
2020	28.7.	Oulujoki	Kivijärven a	59.633	Suomussalmi	Hietajoki	3645947	7178950	19,7	-	Vk 400 m yp. Lt niva/koski/suvanto.
2020	28.7.	Oulujoki	Kivijärven a	59.633	Suomussalmi	Isojoki	3633540	7173947	17,6	-	Vk 50 m yp. Lt koski/niva. Erittäin tumma vesi!
2020	28.7.	Oulujoki	Vartiusjärven va	59.935	Kuhmo	Alajoki	3639554	7155931	20,6	-	Vk 50 m yp. Lt niva.
2020	28.7.	Oulujoki	Vartiusjärven va	59.935	Kuhmo	Pohjoinen Hietajoki	3642855	7156272	15,6	-	Vk 50 m yp. Perattua kanavaa.
2020	29.7.	Oulujoki	Kaurojärven a	59.953	Kuhmo	Tahkosenjoki	3655719	7139341	19,8	-	Vk 150 m yp. Lt koski/niva. Kirkas vesi.
2020	29.7.	Oulujoki	Kaurojärven a	59.953	Kuhmo	Viiksimonjoki	3656326	7138719	18,4	-	Vk 50 m yp. Lt koski. Kirkas vesi.
2020	29.7.	Oulujoki	Kaurojärven a	59.953	Kuhmo	Hoikanjoki	3658928	7139514	No record	-	Vk 100 m yp. Käsin perattu koski.
2020	7.8.	Kemijoki	Lauttajoen va	65.395	Posio	Salmijoki	3569231	7369638	15,7	*Salmo trutta*, *Perca fluviatilis*, FPMs	Vk 1000 m yp. Lt suvanto/niva könkään ap, koski/niva/suvanto könkään yp. Raakut könkäästä alaspäin. Havaittu muutamia kymmeniä. Lämpötila könkään yläpuolella 17,6 c.
2020	7.8.	Kemijoki	Lauttajoen va	65.397	Posio	Kemioja	3569151	7371192	14,7	-	Vk 100 m yp. Lt (?) koskea/nivaa. Pientä, vähävetistä puroa.
2020	7.8.	Kemijoki	Lauttajoen va	65.398	Posio	Lehto-oja	3567818	7372108	15	-	Vk 1500 m ap sieltä täältä. Lt koski/niva. Hiekkaista ja matalaa pientä puroa.
2020	24.8.	Kemijoki	Yli-Suolijärven a	65.393	Posio	Ruokamojoki	3558344	7347508	15,5	*Salmo trutta*	Vk 250 m yp. Lt koski/niva/suvanto. Hyvännäköistä ja kirkasvetistä.
2020	24.8.	Kemijoki	Jaksamojoen va	65.397	Posio	Jaksamonjoki	3557788	7351760	15,2	-	Vk 400 m yp. Lt koski/niva. Sameaa vettä.
2020	24.8.	Kemijoki	Ala-Suolijärven a	65.392	Posio	Nuottijoki	3557019	7357724	14,2	-	Vk 150 m yp. Osittain perattua nivaa.

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2020	24.8.	Kemijoki	Ala-Suolijärven a	65.392	Posio	Nuottijoki	3557332	7357546	14,2	-	Vk 100 m yp. Lt suvanto.
2020	24.8.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Mourujoki	3556607	7361270	16,7	-	Vk 300 m yp. Osittain käsin perattua koskea/nivaa.
2020	24.8.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Vääräjoki	3557245	7360235	16,1	FPMs	Vk 100 m yp. Lt nivaa. Havaittu n. 50 m varsitien yp 1 kpl raakku.
2020	24.8.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Vääräjoki	3560431	7359292	15,7	-	Vk 50 m yp/ap. Lt niva. Ei havaittu raakkuja.
2020	24.8.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Vääräjoki	3560812	7359227	16,1	-	Vk 150 m yp. Lt niva/koski. Ei havaittu raakkuja.
2020	24.8.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Kontiojoki	3566969	7365992	15,2	-	Vk 150 m yp. Lt koski/niva/suvanto. Samea vesi.
2020	24.8.	Koutajoki	Hirvasjärven a	73.073	Salla	Oulankajoki	3573078	7399273	15,5	-	Vk 100 m yp/ap. Lt koski/niva/suvanto.
2020	25.8.	Koutajoki	Onkamojoen keskiosan a	73.082	Salla	Onkamojoki	3587438	7401248	13,4	-	Vk 100 m yp/ap. Lt koski/niva/suvanto.
2020	25.8.	Koutajoki	Onkamojoen keskiosan a	73.082	Salla	Onkamojoki	3586931	7400457	13,8	-	Vk 300 m yp. Lt koski/niva.
2020	25.8.	Koutajoki	Onkamojoen keskiosan a	73.082	Salla	Hanhioja	3586384	7400573	No record	-	Vk 250 m yp. Lt suvanto/niva/koski.
2020	25.8.	Koutajoki	Onkamojoen keskiosan a	73.082	Salla	Onkamojoki	3592513	7406375	14,3	*Phoxinus phoxinus*	Vk 250 m yp, 100 m ap. Lt koski/niva. Hieno!
2020	25.8.	Koutajoki	Onkamojoen keskiosan a	73.082	Salla	Onkamojoki	3588025	7401893	14,2	-	Vk 150 m yp/ap. Lt niva/suvanto.
2020	25.8.	Koutajoki	Koutajoen va	73.015	Salla	Koudanoja	3580351	7389992	12,6	-	Vk 50 m yp. Lt koski/suvanto. Erittäin tumma vesi!
2020	25.8.	Koutajoki	Koutajoen va	73.015	Salla	Nurmioja	3581788	7390175	11,6	*Salmo trutta*	Vk 150 m yp. Lt koski/niva/suvanto.
2020	25.8.	Koutajoki	Koutajoen va	73.015	Salla	Nurmioja	3581706	7389660	No record	-	Vk 200 m yp/ap. Lt koski/niva.
2020	25.8.	Koutajoki	Koutajoen va	73.015	Salla	Koutajoki	3581218	7388078	15,6	-	Vk 250 m yp. Lt koski/niva.
2020	25.8.	Koutajoki	Astumaojan va	73.074	Kuusamo	Astumajoki	3579470	7376203	10,1	-	Vk 250 m yp. Lt koski/niva. Hieno!
2020	26.8.	Koutajoki	Astumaojan va	73.074	Kuusamo	Astumajoki	3577872	7376470	9,1	-	Vk 100 m yp/ap. Ap koneperattua nivaa (kanavaa), yp lt nivaa.
2020	26.8.	Koutajoki	Maaninkajoen va	73.064	Kuusamo	Maaninkajoki	3583344	7369287	11,1	-	Vk 300 m yp, 150 m ap. Lt koski/niva/virtasuvanto. Hieno!
2020	26.8.	Koutajoki	Maaninkajoen va	73.064	Kuusamo	Maaninkajoki	3577258	7371279	12,4	-	Vk 350 m yp. Lt koski/niva/suvanto. Hieno!
2020	26.8.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Kuusamo	Kontiojoki	3570713	7366508	12,4	-	Vk 150 m yp. Lt koski/niva/suvanto. Erittäin pientä puroa.
2020	31.8.	Vienan Kemijoki	Tärkkämöjoen va	74.022	Kuusamo	Tärkkämöjoki	3614133	7320545	13,9	Some fish species. *Anodonta anatina*	Vk 50 m ap. Lt niva. Runsaasti pikkujärvisimpukkaa.
2020	31.8.	Koutajoki	Hiisijoen va	73.047	Kuusamo	Hiisijoki	3614319	7327760	11,9	*Salmo trutta?* *Anodonta anatina*	Vk 300 m yp. Lt koski/niva/suvanto. Jonkin verran pikkujärvisimpukkaa.
2020	31.8.	Koutajoki	Hiisijoen va	73.047	Kuusamo	Hiisijoki	3614131	7326705	11,2	*Salmo trutta?* *Phoxinus phoxinus*	Vk 150 m yp. Lt niva.
2020	31.8.	Vienan Kemijoki	Suurijärven a	74.012	Kuusamo	Penninginjoki	3640785	7303653	13,7	-	Vk 150 m yp. Lt niva/koski/virtasuvanto.
2020	31.8.	Vienan Kemijoki	Suurijärven a	74.012	Kuusamo	Haukipuro	3639534	7303709	9,6	-	Vk 50 m yp. Kaivettua, hidasvirtaista kanavaa.
2020	31.8.	Vienan Kemijoki	Suurijärven a	74.012	Kuusamo	Löytöpuro	3637397	7304085	12,3	-	Vk 50 m yp. Lt koski/suvanto.
2020	2.8.	Oulujoki	Kangasjoen va	59.437	Suomussalmi	Kangasjoki	3587268	7193506	9,1	-	Vk 150 m yp. Lt koski/niva. Hyvää habitaattia.
2020	2.8.	Oulujoki	Sakarajärven va	59.438	Suomussalmi	Suojoki	3584884	7186375	9	-	Vk 100 m yp. Lt koski/niva. Hyvää habitaattia.
2020	2.8.	Oulujoki	Sakarajärven va	59.438	Suomussalmi	Korpijoki	3588896	7183885	9	-	Vk 200 m yp. Lt koski/niva. Hyvää habitaattia.
2020	2.8.	Oulujoki	Iso-Lahnasen va	59.474	Suomussalmi	Salmijoki	3575217	7197424	13,5	-	Vk 100 m yp, 300 m ap. Lt koski/niva/suvanto.
2020	3.8.	Oulujoki	Humalajoen va	59.449	Ristijärvi	Humalajoki	3550534	7167893	13	-	Vk 200 m yp. Lt koski/niva. Hieno! Tällä alueella ei hav. raakkuja.
2020	7.9.	Oulujoki	Poikkijoen va	59.445	Paltamo	Poikkijoki	3544979	7163227	10,9	-	Vk 150 m yp. Lt niva. Erittäin liejuinen pohja!
2020	7.9.	Oulujoki	Poikkijoen va	59.445	Paltamo	Poikkijoki	3544376	7163719	11,2	-	Vk 200 m yp. Lt niva. Erittäin liejuinen pohja!
2020	4.8.	Kemijoki	Saukko-ojan va	65.476	Salla	Haltiaoja	3603996	7467631	18,4	-	Vk 100 m yp. Lt niva.
2021	14.6.	Oulujoki	Hakojoen va	59.978	Kuhmo	Kuohupuro	3656499	7084163	18,7	Some fish species	Vk 200 m yp. Osin perattu, pääosin lt koski/niva. Melko tummavetinen.
2021	14.6.	Oulujoki	Hakojoen va	59.978	Kuhmo	Karsikkopuro	3653465	7084530	15,9	Some fish species	Vk 200 m yp. Lt virtasuvantoa, kovapohjaista. Ihan ok habitaattia. Erittäin tummavetinen.
2021	14.6.	Oulujoki	Hakojoen va	59.978	Kuhmo	Kortejoki	3656800	7086334	15,4	-	Vk 300 m ap. Lt koski/niva. Ihan ok habitaattia. Tummavetinen.
2021	14.6.	Oulujoki	Hakojoen va	59.978	Kuhmo	Kuohupuro	3656499	7084163	12,3	-	Vk 200 m ap. Lt niva/koski. Ihan ok habitaattia. Tummavetinen.
2021	14.6.	Oulujoki	Hakojoen va	59.978	Kuhmo	Löytöjoki	3653296	7085014	16	-	Vk 300 m yp. Lt nivaa/koskea. Erittäin hyvää habitaattia. Erittäin tummavetinen.
2021	14.6.	Oulujoki	Hakojoen va	59.978	Kuhmo	Karsikkopuro	3654958	7082994	14,3	-	Vk 200 m yp. Paikoin hieman perattua koskea/nivaa/virtasuvantoa. Ihan ok habitaattia. Melko kirkas vesi.
2021	14.6.	Vuoksi	Jonkerin va	4,442	Kuhmo	Möntönpuro	3651038	7081768	15,5	-	Vk 270 m ap. Tien alapuolelta perattua. Sora/kivipohjaa.
2021	14.6.	Vuoksi	Suolajoen va	4,445	Kuhmo	Saari-Sepposenpuro	3635401	7084369	14,5	-	Vk 390 m yp. Tummavetinen.
2021	14.6.	Oulujoki	Hakojoen va	59.978	Kuhmo	Iso Hakojoki	3648817	7088646	18	Some fish species	Vk 300 m yp. Hieman paikoin (käsin) perattua koskea/nivaa. Ihan ok habitaattia. Melko tummavetinen.

Year	Date	Main river basin	Sub-catchment area	Code	Municipality	River	Coordinates (KKJ27)	Coordinates (KKJ27)	Water temp. C°	Fish species detected	Vk=Aquascoping area, meters, yp=upstream, ap=downstream, Lt=Natural river section
2021	15.6.	Vuoksi	Otrosjoen va	4,446	Lieksa	Otrosjoki	3645368	7074958	17,5	-	Vk + Snorkl. 200 m ap. Koneperattua koskea/nivaa. Tummavetinen!
2021	15.6.	Vuoksi	Valamanjoen va	4,447	Lieksa	Valamanjoki	3650668	7065757	16,9	-	Vk 100 m yp. Rankasti koneperattu koski/niva. Tummavetinen.
2021	15.6.	Vuoksi	Valamanjoen va	4,447	Lieksa	Valamanjoki	3653915	7065998	15,9	-	Vk 100 m yp. Rankasti koneperattu koski/niva. Tummavetinen.
2021	15.6.	Vuoksi	Valamanjoen va	4,447	Lieksa	Valamanjoki	3656343	7063926	11,2	-	Vk 300 m yp. Lt nivaa/virtasuvantoa. Hyvää habitaattia. Melko kirkas vesi.
2021	15.6.	Vuoksi	Laklajoen va	4,436	Lieksa	Kivipuro	3659780	7059320	13,2	-	Vk 300 m ap. Lt koski/niva. Erittäin hyvää habitaattia. Melko kirkas vesi.
2021	16.6.	Vuoksi	Laklajoen va	4,436	Lieksa	Laklajoki	3655876	7057202	16,1	-	Vk 200 m yp. Perattua, melko jyrkkää koskea. Melko tummavetinen.
2021	16.6.	Vuoksi	Laklajoen va	4,436	Lieksa	Liukkupuro	3657073	7056828	13,5	-	Vk 300 m yp. Lt koski/niva. Hieno! Hieman tummavetinen.
2021	16.6.	Vuoksi	Laklajoen va	4,436	Lieksa	Ohtajoki	3660096	7054899	15,9	-	Vk 200 m yp. Käsin perattua koskea/nivaa. Melko tummavetinen.
2021	16.6.	Vuoksi	Laklajoen va	4,436	Lieksa	Saarijoki	3661579	7055945	15,2	-	Vk 100 m yp/ap. Lt koski/niva. Melko tumma vesi.
2021	16.6.	Vuoksi	Häähnijoen va	4,437	Lieksa	Häähnijoki	3652254	7053356	16,5	Some fish species	Vk 100 m yp. Lt nivaa. Hieman tummavetinen.
2021	16.6.	Vuoksi	Häähnijoen va	4,437	Lieksa	Rynkänpuro	3663181	7050394	No record	-	Ihan kuiva ja mitätön liru. Ei katsottu sen enempää.
2021	16.6.	Vuoksi	Häähnijoen va	4,437	Lieksa	Häähnijoki	3662115	7048876	17,6	-	Vk 100 m ap. Osin perattu koski/niva. Erittäin tummavetinen.
2021	17.6.	Vuoksi	Kuorajoen va	4,944	Ilomantsi	Putaanjoki	3662960	7045507	15,1	-	Vk 400 m yp. Yläosa tiestä alaspäin perattua kanavaa, alaosa jyrkkää koskea/nivaa. Hyvää habitaattia paikoin. Hieman tummavetinen.
2021	17.6.	Vuoksi	Kuorajoen va	4,944	Ilomantsi	Kuorajoki	3677341	6995768	13,8	-	Vk 200 m yp. Lt (hieman perattu) nivaa. Huippu hyvää habitaattia. Melko kirkas vesi.
2021	17.6.	Vuoksi	Kuorajoen va	4,944	Ilomantsi	Putaanjoki	3677919	6993753	15	-	Vk 250 m yp. Lt nivaa/virtasuvantoa. Huippu habitaattia. Melko kirkas vesi.
2021	17.6.	Vuoksi	Kuorajoen va	4,944	Ilomantsi	Kuorajoki	3677791	6994611	13,7	*Perca fluviatilis*	Vk 100 m yp/ap. Lt koski/virtasuvanto. Melko kirkas vesi.
2021	17.6.	Vuoksi	Kuorajoen va	4,944	Ilomantsi	Kuorajoki	3678961	6994123	13,5	-	Vk 150 m yp. Lt virtasuvanto/niva. Melko kirkas vesi.
2021	17.6.	Vuoksi	Kuorajoen va	4,944	Ilomantsi	Kuorajoki	3681336	6993596	13,4	-	Vk 100 m ap. Lt virtasuvanto/niva. Melko kirkas vesi.
2021	17.6.	Vuoksi	Koitereen la	4,941	Ilomantsi	Kortepuro	3676255	6991058	11,7	-	Vk 350 m yp. Lt koski/niva/suvanto. Kirkas vesi, mutta niukasti.
2021	15.6.	Vuoksi	Jongunjoen a	4,432	Lieksa	Tetripuro	3649733	7062367	No record	-	Vk 10 m. Erittäin tummavetinen ja rankasti perattu, ei tutkittu sen enempää.
2021	15.6.	Vuoksi	Valamanjoen va	4,447	Lieksa	Valamanjoki	3649743	7065263	No record	-	Erittäin tummavetinen ja rankasti perattu, ei tutkittu sen enempää.
2021	16.6.	Vuoksi	Häähnijoen va	4,437	Lieksa	Laukkuoja	3669167	7051201	17	-	Vk 100 m yp. Kivi/sorapohjaa. Vähävetinen. Vaelluseste.
2021	15.6.	Vuoksi	Valamanjoen va	4,447	Lieksa	Valamanjoki	3649532	7064978	No record	-	Vk 50 m yp. Tummavetinen ja perattu.
2021	16.6.	Vuoksi	Häähnijoen va	4,437	Lieksa	Laukkuoja	3669765	7051091	8	-	Vk 50 m yp. Hiekkaista pohjaa. Noro.
2021	16.6.	Vuoksi	Ruunaanjärven a	4,492	Lieksa	Ruokopuro	3673217	7045257	17	-	Vk 100 m yp. Tummavetinen ja hidasvirtainen.
2021	17.6.	Vuoksi	Haukijoen va	4,943	Ilomantsi	Vihtapuro	3673784	6988892	13,5	-	Vk 250 m yp. Kirkas vesi ja hieno puro, hyvää habitaattia. Vealluseste tierummussa.
2021	17.6.	Vuoksi	Haukijoen va	4,943	Ilomantsi	Vihtapuro	3673861	6989404	13,5	-	Vk 200 m yp. Jyrkkää luonnontilaista koskea. Kirkas vesi.
2021	17.6.	Vuoksi	Haukijoen va	4,943	Ilomantsi	Raakunpuro	3674224	6990340	14,5	-	Vk 200 m yp. Pilattu ojituksilla ja täysin kanavaksi kaivettu.
2021	17.6.	Vuoksi	Haukijoen va	4,943	Ilomantsi	Haukijoki	3678397	6987347	18,5	-	Vk 200 m yp. Hienoa, luonnontilaista sorapohjaa.
2021	17.6.	Vuoksi	Koitereen la	4,941	Ilomantsi	Kortepuro	3678688	6988542	No record	-	Vk 150 m yp. Pääasiassa täysin perattua uomaa, vain pieni osuus luonnontilaista.
2021	18.6.	Oulujoki	Syväjoen va	59,463	Hyrynsalmi	Lauttajoki	3555582	7185297	16	-	Vk 300 m yp. Hienoa raakkuhabitattia, soraista, isot kivet perattu.
2021	18.6.	Oulujoki	Syväjoen va	59,463	Hyrynsalmi	Lauttajoki	3555243	7184853	16	-	Vk 50 m yp leveällä koskialueella. Hienoa raakkuhabitattia, soraista, isot kivet perattu.
2021	18.6.	Oulujoki	Syväjoen va	59,463	Hyrynsalmi	Syväjoki	3556639	7183782	No record	-	Vk 50 m yp leveällä koskialueella. Hienoa raakkuhabitattia, soraista, isot kivet perattu. Kirkas vesi.
2021	22.6.	Oulujoki	Kaiskonjoen va	59,464	Puolanka	Saarijoki	3557755	7197101	19	-	Vk 250 m yp. Luonnontilaista ja kirkas vesi.
2021	22.6.	Oulujoki	Kaiskonjoen va	59,464	Puolanka	Heinijoki	3558204	7197172	17,5	-	Vk 150 m yp. Perattua uomaa, lohkareista, tumma vesi.
2021	22.6.	Oulujoki	Kaiskonjoen va	59,464	Puolanka	Heinijoki	3557333	7196634	17,5	-	Vk 170 m yht. yp/ap. Sillan yläpuolella jyrkkää luonnontilaista koskea, alapuolella soraista pohjaa.
2021	22.6.	Oulujoki	Kaiskonjoen va	59,464	Hyrynsalmi	Latvajoki	3557665	7192961	20	-	Vk 340 m yp. Luonnontilaista, hienoa koskialuetta. Kirkas vesi.
2021	18.6.	Oulujoki	Myylyjoen va	59,463	Hyrynsalmi	Myllyjoki	3563639	7183762	12,1	Some fish species	Vk 250 m yp. Lt nivaa/koskea. Hienoa habitaattia! Kirkas vesi.
2021	18.6.	Oulujoki	Myylyjoen va	59,463	Hyrynsalmi	Myllyjoki	3561556	7183767	14,7	-	Vk 250 m yp. Lt nivaa/koskea. Hienoa habitaattia! Kirkas vesi.
2021	18.6.	Kiiminkijoki	Heinijoen–Liejeenjoen va	60,054	Puolanka	Haukioja	3547599	7186433	14,8	Some fish species	Vk 200 m yp. Lt Nivaa/koskea/viratsuvantoa. Hienoa habitaattia! Hieman tumma vesi.
2021	18.6.	Kiiminkijoki	Heinijoen–Liejeenjoen va	60,054	Puolanka	Haukioja	3545811	7187149	16,1	-	Vk 200 m yp. Lt koski/niva. Hienoa habitaattia! Hieman tumma vesi.
2021	22.6.	Oulujoki	Varisjoen va	59,436	Suomussalmi	Hiidenjoki	3571960	7203977	18,1	-	Vk 200 m ap. Lt nivaa/koskea. Hieman tummavetinen, muuten ok.
2021	22.6.	Oulujoki	Varisjoen va	59,436	Suomussalmi	Hoikanjoki	3579610	7202498	No record	-	Hidasvirtaista, mutapohjaista suvantoa. Ei katsottu sen enempää.
2021	22.6.	Oulujoki	Varisjoen va	59,436	Suomussalmi	Vähäjoki	3581638	7201905	20,8	-	Vk 200 m yp. Lt nivaa/koskea. Melko tummavetinen, muuten ok.
2021	22.6.	Oulujoki	Varisjoen va	59,436	Suomussalmi	Leväjoki	3581063	7201467	22,8	-	Vk 100 m yp. Käsin (?) perattua koskea/nivaa. Melko tummavetinen.
2021	22.6.	Oulujoki	Löytöjoen a	59,471	Hyrynsalmi	Joutenjoki	3570208	7193262	17,9	*Salmo trutta*?	Vk 500 m ap. Lt koski/niva. Osittain käsin/koneella perattua. Melko tumma vesi, muuten habitaatti ok.

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2021	22.6.	Oulujoki	Löytöjoen a	59,471	Hyrynsalmi	Joutenjoki	3569925	7191443	No record	-	Seisovavetinen suvanto, tumma vesi. Ei tutkittu sen enempää.
2021	22.6.	Oulujoki	Laajanjoen va	59,462	Suomussalmi	Laajanjoki	3563421	7196318	19	-	Vk 300 m yp. Hyvää pohjaa ja melko ,uonnontilaista. Melko kirkas vesi
2021	22.6.	Oulujoki	Laajanjoen va	59,462	Suomussalmi	Laajanjoki	3564420	7198857	No record	-	Vk 50 m yp. Hidasvirtaista suvantoa.
2021	22.6.	Oulujoki	Laajanjoen va	59,462	Suomussalmi	Valkeapuro	3564180	7199307	19	-	Vk 200 m yp. Hieno puro, mutta pahoin hiekoittunut. Kirkas vesi.
2021	29.6.	Oulujoki	Lehtojoen va	59,447	Puolanka	Lehtojoki	3541397	7178418	18	-	Vk 150 m yp. Koski/nivaa. Kivipohjaa. Erittäin tummavetinen!
2021	29.6.	Oulujoki	Lehtojoen va	59,447	Puolanka	Ruuhipuro	3541914	7178810	14	-	Vk 150 m yp. Luonnontilainen, tummavetinen ja louhikkoinen pohja.
2021	29.6.	Oulujoki	Lehtojoen va	59,447	Puolanka	Ruuhipuro	3541973	7181045	No record	-	Vk 150 m yp. Pientä puroa. Rummussa vaelluseste.
2021	29.6.	Oulujoki	Latvajoen alaosan a	59,443	Puolanka	Hulminpuro	3543899	7173806	19	-	Vk 150 m yp. Pientä, matalaa puroa, virtaa pitkin rinnettä. Kirkas vesi. Isot kasvustot ympärillä.
2021	29.6.	Oulujoki	Möykkysenjoen va	59,423	Ristijärvi	Möykkysenjoki	3557133	7161580	14,5	-	Vk 300 m yp. Hieno puhdaspohjainen koskijakso. Hyvää habitaattia.
2021	29.6.	Oulujoki	Uurajärven–Iijärven a	59,412	Ristijärvi	Kuorepuro	3552391	7159582	19	-	Vk 200 m yp. Jyrkkää, perattua koskijaksoa, mutta silti ok puroa. Kirkas vesi.
2021	29.6.	Oulujoki	Siltajoen va	59,413	Puolanka	Hoikanjoki	3536397	7160731	16,5	-	Vk 150 m yp. Lt (?) virtasuvantoa. Liejupohjaa. Ei hyvää habitaattia. Kirkas vesi.
2021	29.6.	Oulujoki	Siltajoen va	59,413	Puolanka	Hoikanjoki	3536180	7162162	18,2	-	Vk 100 m ap / 250 m yp. Lt koski/niva. Erittäin hyvää habitaattia. Kirkas vesi.
2021	29.6.	Oulujoki	Siltajoen va	59,413	Puolanka	Myllypuro	3538882	7164005	16,2	-	Vk 250 m yp. Lt niva/koski. Hyvää habitaattia. Kirkas vesi.
2021	29.6.	Oulujoki	Siltajoen va	59,413	Paltamo	Vanhajoki	3538129	7158781	19,1	Some fish species	Vk 200 m yp. Virtasuvantoa/nivaa. Hiekkaista! Ei hyvää habitaattia. Hieman tummavetinen.
2021	29.6.	Oulujoki	Siltajoen va	59,413	Paltamo	Kotijoki	3539812	7157572	18,3	-	Vk 150 m yp. Lt niva/koski/virtasuvanto. Ihan ok habitaattia. Kirkas vesi.
2021	29.6.	Oulujoki	Siltajoen va	59,413	Paltamo	Ruokosenpuro	3540569	7157010	16,1	-	Vk 100 m yp. Lt suvanto/niva. Liettynyt pahoin. Kirkas vesi.
2021	29.6.	Oulujoki	Siltajoen va	59,413	Paltamo	Kaipaalanpuro	3539221	7155861	20,8	*Salmo trutta*	Vk 200 m yp. Lt hiekkaista nivaa/koskea/virtasuvantoa. Ihan ok habitaattia. Kirkas vesi.
2021	30.6.	Oulujoki	Tervajoen alaosan a	59,751	Hyrynsalmi	Tervajoki	3582827	7172984	20,9	*Anodonta anatina*, Some fish species	Vk 150 m yp. Lt koski/Nivaa. Louhikkoista pohjaa, ei kovin hyvää habitaattia. Melko kirkas vesi.
2021	30.6.	Oulujoki	Niettuspuron va	59,726	Hyrynsalmi	Niettuspuro	3581571	7168924	20,9	-	Vk 100 m yp. Lt koski. Ihan ok habitaattia. Kirkas vesi.
2021	30.6.	Oulujoki	Tervajoen alaosan a	59,491	Ristijärvi	Tervajoki	3577689	7158681	18,8	-	Vk 100 m yp. Käsin perattua koskea ja lt nivaa. Ok habitaattia. Melko tummavetinen.’
2021	30.6.	Oulujoki	Tervajoen alaosan a	59,491	Ristijärvi	Tervajoki	3573748	7157687	18,2	-	Vk 150 m ap. Kunnostettua koskea ja lt nivaa. Ihan ok habitaattia. Melko tummavetinen.
2021	30.6.	Oulujoki	Tervajoen alaosan a	59,491	Ristijärvi	Tervajoki	3571507	7156724	17,2	*Phoxinus phoxinus*?	Vk 50 m yp. Lt nivaa. Ihan ok habitaattia. Tumma vesi.
2021	30.6.	Oulujoki	Seitenjärven–Hyrynjärven la	59,431	Hyrynsalmi	Vuorijoki	3574812	7168323	15,2	-	Vk 200 m ap. Lt koski/niva. Ok habitaattia. Melko tumma vesi.
2021	30.6.	Oulujoki	Roukajoen va	59,426	Ristijärvi	Roukajoki	3568861	7165457	17,1	-	Vk 100 m yp. Lt koski/niva. Ei kovin hyvää habitaattia. Erittäin tumma vesi!
2021	5.7.	Kemijoki	Raakunjoen va	65,315	Kemijärvi	Tonkopuro	35848728	7386376	13,4	-	Vk 200 m yp. Lt suvanto/niva. Liettynyttä pohjaa, ei hyvää habitaattia. Kirkas vesi.
2021	5.7.	Kemijoki	Raakunjoen va	65,315	Kemijärvi	Siltapuro	3548430	7385738	14,8	-	Vk 200 m yp. Lt nivaa. Erittäin hiekkaista, ei hyvää habitaattia. Kirkas vesi.
2021	5.7.	Kemijoki	Kemijärven la	65,311	Kemijärvi	Peräoja	3548240	7383570	23	-	Vk 250 m yp. Lt koski/niva/suvanto. Ok habitaattia. Hieman tummavetinen.
2021	5.7.	Kemijoki	Jumiskonjoen va	65,316	Kemijärvi	Murto-oja	3545897	7378385	22,9	-	Vk 200 m yp. Lt koski/niva/suvanto. Ei kovin hyvää habitaattia. Melko tumma vesi.
2021	5.7.	Kemijoki	Raakunjoen va	65,315	Salla	Keihäslammenoja	3551475	7385235	17,9	-	Vk 250 m yp. Lt koski/niva/suvanto. Ei kovin hyvää habitaattia (hiekkaista). Melko kirkas vesi.
2021	5.7.	Kemijoki	Raakunjoen va	65,315	Salla	Tonkopuro	3550635	7385290	19,5	-	Vk 50 m yp. Lt niva/koski. Ei hyvää habitaattia, mielettömän paksusti liejua ja hiekkaa. Melko tumma vesi.
2021	5.7.	Kemijoki	Raakunjoen va	65,315	Salla	Siltapuro	3551816	7384115	18,1	-	Vk 200 m yp. Lt nivaa. Paikoin ok habitaattia. Hieman tumma vesi.
2021	6.7.	Kemijoki	Isojärven a	65,394	Salla	Leviäisenpuro	3557525	7376797	24,7	-	Vk 250 m yp. Lt niva/koski. Hyvää habitaattia. Kirkas vesi.
2021	6.7.	Kemijoki	Lauttajoen va	65,395	Salla	Ukkosenoja	3557779	7374810	25,2	-	Vk 250 m yp. Lt koski/niva/virtasuvanto. Ok habitaattia. Kirkas vesi!
2021	6.7.	Kemijoki	Lauttajoen va	65,395	Salla	Poro-oja	3556621	7374095	23,8	-	Vk 200 m yp. Lt koski/niva/virtasuvanto. Ok habitaattia. Kirkas vesi!
2021	6.7.	Kemijoki	Lauttajoen va	65,395	Salla	Sohramojoki	3553447	7372187	25,7	-	Vk 100 m kosken alus. Lt koski/niva. Ok habitaattia. Melko kirkas vesi.
2021	6.7.	Kemijoki	Jumiskonjoen va	65,316	Kemijärvi	Vierusjoki	3543072	7372040	19,1	FPM shells *Salmo trutta*?	Vk 500 m ap. Osin lt, osin rankasti koneella perattua koskea/nivaa. Paikoin vielä jäljellä hyvää habitaattia. Vähävetinen. Melko tumma vesi.
2021	7.7.	Kemijoki	Mourujoen–Vääräjoen va	65,396	Posio	Salmijoki	3568922	7357797	23,8	-	Vk 250 m yp. Lt niva/koski/virtasuvantoa. Huippu habitaattia. Kirkas vesi.
2021	7.7.	Kemijoki	Mourujoen–Vääräjoen va	65,396	Posio	Pirttioja	3568537	7357591	24,9	-	Vk 100 m ap. Lt niva/koski. Huippu habitaattia. Kirkas vesi. Pientä puroa.
2021	7.7.	Kemijoki	Mourujoen–Vääräjoen va	65,396	Posio	Vääräjoki	3564322	7358290	25,2	-	Vk 150 m ap. Lt (osin hieman käsin perattua) koski/niva/virtasuvanto. Hyvää habitaattia. Kirkas vesi.
2021	7.7.	Kemijoki	Mourujoen–Vääräjoen va	65,396	Posio	Mourujoki	3557969	7361042	24,2	*Rutilus rutilus*	Vk 300 m ap. Lt koski/niva. Ei kovin hyvää habitaattia. Hieman samea vesi.
2021	8.7.	Kemijoki	Vilmajoen va	65,379	Salla	Pahaoja	3558151	7395709	17,9	-	Vk 250 m yp. Lt koski/niva/virtasuvanto. Erittäin hyvää habitaattia. Melko samea vesi.
2021	8.7.	Kemijoki	Vilmajoen va	65,379	Salla	Pahaoja	3559047	7395020	18,5	-	Vk 100 m yp/ap. Lt (osittain käsin perattua) koski/niva/virtasuvantoa. Ei kovin hyvää habitaattia. Samea vesi!
2021	8.7.	Kemijoki	Vilmajoen va	65,379	Salla	Pahaoja	3560437	7394165	16,4	-	Vk 100 m yp. Lt koski/nivaa. Ei kovin hyvää habitaattia. Samea vesi.
2021	8.7.	Kemijoki	Vilmajoen va	65,379	Salla	Pahaoja	3561397	7392660	21,6	-	Vk 100 m yp. Lt koski/nivaa. Pientä puroa, ei kovin hyvää habitaattia. Kirkas vesi.

Year	Date	Main river basin	Sub-catchment area	Code	Municipality	River	Coordinates (KKJ27)	Coordinates (KKJ27)	Water temp. C°	Fish species detected	Vk=Aquascoping area, meters, yp=upstream, ap=downstream, Lt=Natural river section
2021	8.7.	Kemijoki	Vilmajoen va	65,379	Salla	Seppäsenpuro	3562633	7396083	21,9	Some fish species	Vk 300 m yp. Lt koski/niva/suvanto. Ok habitaattia. Hieman tumma vesi.
2021	8.7.	Koutajoki	Kallunkijärven a	73,081	Salla	Päiviöoja	3583528	7394974	21,9	-	Vk 200 m yp. Lt koski/niva. Ei kovin hyvää habitaattia. Kirkas vesi.
2021	9.7.	Kemijoki	Lauttajoen va	65,395	Posio	Lauttajoki	3563756	7370133	21,4	Some fish species, FPMs	Vk 200 m ap. Lt nivaa/koskea/suvantoa. Kaksi raakkua löytyi. Vesi erittäin sameaa (levää).
2021	5.7.	Kemijoki	Raakunjoen va	65,315	Salla	Eskonpuro	3553380	7382218	20	-	Vk 250 m yp. Todella pientä puroa. Hiekoittunutta ja perattua (osin pois omasta uomasta).
2021	5.7.	Kemijoki	Isojärven a	65,394	Salla	Hietajoki	3557216	7381250	No record	-	vk 200 m. Heinikkoista suvantoa.
2021	6.7.	Kemijoki	Isojärven a	65,394	Salla	Siikaoja	3554815	7379233	18,5	-	Vk 300 m yp. Pitkän koskijakson jälkeen lt virtaa. Hyvä, puhdas pohja. Kirkas vesi.
2021	6.7.	Kemijoki	Isojärven a	65,394	Salla	Kalliojoki	3553032	7376670	22	-	vk 250 m yp. Melko lt ja ok, mutta ei raakkuvesityyppinen. Leveää, paikoitellen hyvää pohjaa. Tummahko vesi.
2021	6.7.	Kemijoki	Isojärven a	65,394	Salla	Haukioja	3554264	7380274	No record	-	Vk 20 m. Todella pieni, norotyyppinen. Kirkas vesi.
2021	6.7.	Koutajoki	Ala-Kitkan a	73,024	Kuusamo	Kivioja	3573930	7366157	19,9	-	Vk 300 m yp. Pieni, luonnontilainen ja pehmytpohjainen puro.
2021	6.7.	Koutajoki	Ala-Kitkan a	73,024	Kuusamo	Nurkamo-oja	3571452	7364408	No record	-	Vk 150 m ap. Pehmytpohjainen, paljon kasvillisuutta pohjalla. Rummussa vaelluseste.
2021	6.7.	Koutajoki	Ala-Kitkan a	73,024	Kuusamo	Kivioja	3576753	7363821	22,1	-	Vk 100 m yp. Lt hidasvirtainen, pehmytpohjainen, hieno puro.
2021	7.7.	Kemijoki	Mourujoen–Vääräjoen va	65,396	Kuusamo	Salmijoki	3570461	7357502	No record	-	Vk 150 m yp. Hieman perattu käsin koskialueita uittoa varten (uittokouru). Suvanto kovapohjaista.
2021	7.7.	Koutajoki	Ala-Kitkan a	73,024	Kuusamo	Laurinjoki	3579084	7361788	No record	-	Vk 100 m yp. Hiekkaista, epästabiilia uomaa.
2021	7.7.	Kemijoki	Lauttajoen va	65,395	Posio	Köykenejoki	3571972	7372019	21,8	-	Vk 300 m. Kirkas pohja, matalaa, paljon sammalta pohjalla. Tumma vesi. Rumpu on täydellinen vaelluseste.
2021	7.7.	Kemijoki	Lauttajoen va	65,395	Posio	Köykenejoki	3570234	7371119	19,8	-	Vk 250 m yp. Perattua virta-aluetta. Tumma vesi. Hyvää pohjahabitaattia.
2021	8.7.	Kemijoki	Maltiojoen alaosan a	65,465	Savukoski	Illisoja	3574246	7460334	19,5	*Salmo trutta*	Vk 150 m ap. Koskialue tien alapuolella perattu, sorapohjaa. Kosken jälkeen pehmeämpää pohjaa. Uoma kapeata ja heinikkoista.
2021	8.7.	Kemijoki	Iso-Ulmojan va	65,464	Savukoski	Ulmojanlatvaoja	3572737	7462163	15,5	*Salmo trutta*	Vk 150 m. Lt hieno mutkitellen virtaava puro. Pohja hiekkaa/soraa, heinää ja puuta.
2021	8.7.	Kemijoki	Pyhäjoen va	65,463	Savukoski	Pyhäjoki	3570241	7465503	17,5	-	Vk 150 m yp. 10 m leveätä. Pohjalla puhdasta soraa, hieman hiekkaa, paljon sammalta. Isot kivet puuttuu. Hyvää raakkuhabitaattia.
2021	8.7.	Kemijoki	Pyhäjoen va	65,463	Savukoski	Pyhäjoki	3573769	7470422	17	-	Vk 200 m yp. Pohjalla puhdasta soraa, hieman hiekkaa, paljon sammalta. Isot kivet puuttuu. Hyvää raakkuhabitaattia.
2021	9.7.	Kemijoki	Lauttajoen va	65,395	Posio	Lauttajoki	3564107	7369956	22	-	Vk 100 m yp. Ruskeavetinen, vähävetinen, lähes virtaamaton koskialue.
2021	9.7.	Kemijoki	Lauttajoen va	65,395	Posio	Lauttajoki	3564190	7370084	17,5	FPMs	Vk 100 m yp. Ruskeavetinen, rannat myös sortuneet. Pohja yllättävän puhdas, sorainen ja isokivinen.
2021	13.7.	Vienan Kemijoki	Niskajoen–Vääräjoen va	74,032	Kuusamo	Vääräjoki	3600110	7315209	20,3	-	Vk 300 m yp. Lt niva/koski. Erittäin hyvää habitaattia. Virtaamamittauspadon V-aukko ainakin ajoittainen este. Kirkas vesi.
2021	13.7.	Vienan Kemijoki	Niskajoen–Vääräjoen va	74,032	Kuusamo	Vääräjoki	3598473	7315162	18,4	*Salmo trutta*	Vk 400 m yp. Lt niva/koski. Erittäin hyvää habitaattia. Kirkas vesi.
2021	13.7.	Vienan Kemijoki	Niskajoen–Vääräjoen va	74,032	Kuusamo	Hanhioja	3599626	7313803	No record	-	Mitätön, vähävetinen puro. Ei katsottu sen enempää. Kirkas vesi.
2021	13.7.	Vienan Kemijoki	Niskajoen–Vääräjoen va	74,032	Kuusamo	Salmijoki	3598643	7312733	19,9	-	Vk 400 m yp. Lt koski/niva. Ok habitaattia. Melko kirkas vesi.
2021	13.7.	Koutajoki	Kitkajoen alaosan alue	73,021	Kuusamo	Isonjärvenpuro	3608027	7357867	20,5	*Phoxinus phoxinus*	Vk 300 m yp. Lt niva/suvanto/koski. Vaatimatonta puroa, vain paikoin ok habitaattia. Kirkas vesi.
2021	13.7.	Koutajoki	Kitkajoen yläosan a	73,022	Kuusamo	Riekamopuro	3603919	7358140	21,8	-	Vk 300 m ap. Osin perattu, pääosin lt koski/niva. Hyvää habitaattia. Kirkas vesi.
2021	13.7.	Koutajoki	Aventojoen a	73,061	Kuusamo	Hipaoja	3595263	7365940	23,8	-	Vk 150 m yp. Rankasti perattua koskea, paikoin vielä ok habitaattia. Kirkas vesi.
2021	13.7.	Koutajoki	Rysäjoen va	73,063	Kuusamo	Rysäjoki	3593614	7364063	23,7	-	Vk 200 m yp. Lt koski/niva. Erittäin hyvää habitaattia! Kirkas vesi.
2021	29.7.	Koutajoki	Hirvasjärven a	73,073	Salla	Oulankajoki	3569621	7386631	19,4	-	Vk 100 m yp. Lt koski/niva. Vain vähän habitaattia (louhikkoista). Hieman samea vesi.
2021	14.7.	Oulujoki	Kiantajärven la	59,511	Suomussalmi	Lauttapuro	3600956	7198644	21,7	Some fish species	Vk 150 m yp. Lt niva/virtasuvanto/koski. Liettynyttä pohjaa, paljon sammalat. Vain paikoin hieman habitaattia. Melko tumma vesi.
2021	14.7.	Oulujoki	Kuomanjoen va	59,519	Suomussalmi	Hiisijoki	3606532	7203387	21,7	Some fish species	Vk 150 m yp. Lt niva/koski. Ihan ok habitaattia. Hieman tumma vesi.
2021	14.7.	Oulujoki	Kuomanjoen va	59,519	Suomussalmi	Hiisijoki	3607027	7203840	22,6	*Rutilus rutilus*	Vk 200 m yp. Lt nivaa. Ihan ok habitaattia. Paljon sammalta pohjalla. Hieman tumma vesi. Rantametsä hakattu uomaan saakka.
2021	14.7.	Oulujoki	Ehronjärven va	59,518	Suomussalmi	Raatepuro	3611375	7212096	No record	-	Mitätön liru, vähävetinen. Ei katsottu sen enempää.
2021	14.7.	Oulujoki	Kiantajärven la	59,511	Suomussalmi	Saukkojoki	3613226	7228556	No record	-	Mitätön liru, joka lisäksi perattu täysin metsäojaksi. Ei tutkittu sen enempää.
2021	14.7.	Oulujoki	Akon–Juntusjärven a	59,512	Suomussalmi	Akonjoki	3608015	7231418	No record	-	Leveä, kivinen uoma, mutta ei virtausta juuri lainkaan. Pohja mudan peittämä ja vesi sameaa. Ei tutkittu sen enempää.
2021	14.7.	Oulujoki	Kiantajärven la	59,511	Suomussalmi	Kohisevanpuro	3602976	7234924	17,8	-	Vk 150 m yp. Lt nivaa. Vähävetinen uomaan nähden. Paikoin ok habitaattia. Hieman tumma vesi.
2021	15.7.	Oulujoki	Löytöjoen va	59,554	Suomussalmi	Löytöjoki	3582318	7216127	19,8	-	Vk 250 m yp. Lt virtasuvanto/niva/koski. Paikoin ok habitaattia. Kirkas vesi.
2021	15.7.	Oulujoki	Luomainjoen va	59,555	Suomussalmi	Luomainjoki	3585027	7217459	21,1	Some fish species	Vk 200 m yp. Lt koski/niva/virtasuvanto. Paikoin ok habitaattia. Hieman tumma vesi.
2021	15.7.	Oulujoki	Löytöjoen va	59,554	Suomussalmi	Löytöjoki	3584301	7215299	16,7	Some fish species	Vk 150 m yp. Lt niva/suvanto. Paikoin hyvää habitaattia. Paljon sammalta pohjalla. Kirkas vesi.

Year	Date	Main river basin	Sub-catchment area	Code	Municipality	River	Coordinates (KKJ27)	Coordinates (KKJ27)	Water temp. C°	Fish species detected	Vk=Aquascoping area, meters, yp=upstream, ap=downstream, Lt=Natural river section
2021	15.7.	Oulujoki	Saarijoen va	59,514	Suomussalmi	Saarijoki	3594172	7226589	23,7	-	Vk 150 m ap. Lt suvanto/niva/koski. Louhikkoista ja paljon sammalta pohjalla. Vain paikoin hieman ok habitaattia. Melko kirkas vresi.
2021	16.7.	Oulujoki	Hullupuron va	59,628	Suomussalmi	Leinospuro	3599649	7187566	No record	-	Rankasti kaivettua kanavaa. Ei tutkittu sen enempää. Kirkas vesi.
2021	16.7.	Oulujoki	Hullupuron va	59,628	Suomussalmi	Hullupuro	3599648	7188601	16,7	-	Vk 150 m yp. Lt niva/virtasuvanto. Hiekkaista. Paikoin ihan ok habitaattia. Melko kirkas vesi.
2021	16.7.	Oulujoki	Kangasjoen va	59,437	Suomussalmi	Kangasjoki	3592888	7188891	21,7	-	Vk 50 m yp. Lt niva. Ei juurikaan habitaattia, paljon sammalta pohjalla. Erittäin tummavetinen.
2021	16.7.	Oulujoki	Kangasjoen va	59,437	Suomussalmi	Kangasjoki	3591141	7190596	17,6	Some fish species	Vk 200 m yp. Lt niva/virtasuvanto. Iskostunutta pohjaa, mutta paikoin ihan ok habitaattia. Melko tummavetinen.
2021	27.7.	Oulujoki	Muojärven va	59,529	Suomussalmi	Kaiskonpuro	3620530	7245257	16,1	-	Vk 300 m ap. Lt (osin kaivettua kanavaa) suvanto/koski. Ei kovin hyvää habitaattia. Kirkas vesi.
2021	27.7.	Oulujoki	Hossanjoen alaosan a	59,521	Suomussalmi	Myllyjoki	3619371	7251000	12,5	-	Vk 150 m ap. Lt (osin perattua) koski/niva. Kalliopohjaa ja louhikkoa, ei juurikaan hyvää habitaattia. Hieman samea vesi.
2021	27.7.	Oulujoki	Paukuttajanjoen va	59,515	Suomussalmi	Paukuttajanjoki	3616486	7235075	16,5	Some fish species	Vk 250 m yp. Lt koski/niva. Paikoin ihan ok habitaattia. Hieman samea vesi.
2021	27.7.	Oulujoki	Lohijoen va	59,524	Suomussalmi	Lekapäänpuro	3607243	7248899	15,9	*Rutilus rutilus*	Vk 50 m ap. Lt niva/koski. Paikoin ok habitaattia. Melko samea vesi.
2021	27.7.	Oulujoki	Saarijärven a	59,523	Suomussalmi	Luomanjoki	3607063	7243741	18,9	-	Vk 150 m yp. Lt jyrkkää koskea. Paikoin ok habitaattia. Kirkas vesi.
2021	27.7.	Oulujoki	Piispajoen alaosan a	59,571	Suomussalmi	Piispajoki	3600360	7239975	19,8	-	Vk 100 m yp. Lt koskien välinen lampare, jossa hyvää habitaattia paljon. Melko puhdas sora/kivipohja. Kirkas vesi.
2021	27.7.	Oulujoki	Mustajoen alaosan a	59,561	Suomussalmi	Mustajoki	3591425	7237932	20,8	-	Vk 150 m yp. Lt koski/niva/virtasuvanto. Paikoin ihan ok habitaattia. Kirkas vesi.
2021	29.7.	Kemijoki	Ruuhijoen va	65,376	Salla	Ruuhijoki	3575772	7409996	13,2	-	Vk 250 m yp. Lt niva/koski. Huippu habitaattia. Kirkas vesi.
2021	29.7.	Kemijoki	Ruuhijoen va	65,376	Salla	Keselmäoja	3577218	7410664	No record	-	Pieni, vaatimaton ja muokattu liru. Paljon rautasakkaa pohjalla. Ei katsottu sen enempää.
2021	29.7.	Kemijoki	Aatsinginjoen alaosan a	65,482	Salla	Aatsinginjoki	3584869	7425601	17,2	*Perca fluviatilis*	Vk 100 m yp. Lt nivaa. Ei lainkaan raakkuhabitaattia. Kirkas vesi.
2021	29.7.	Kemijoki	Jaurujoen a	65,495	Salla	Jaurujoki	3558222	7425907	14,3	-	Vk 200 m yp. Lt koski. Paikoin ok habitaattia. Melko kirkas vesi.
2021	29.9.	Kemijoki	Sätsijoen va	65,477	Salla	Käärmejoki	3598933	7457752	No record	*Salmo trutta*	Vk 300 m yp+100 m ap. Syvää suvantoa/virtasuvantoa. Paikoin ok habitaattia. Paljon vesikasvillisuutta, soraa/hiekkaa. Kirkas vesi.
2021	25.8.	Kemijoki	Saukko-ojan va	65,476	Salla	Purkaoja	3601120	7465136	No record	FPMs n. 50 pcs.	Vk yht. 550 m tien yläpuolella ja Purkajärven alapuolella sekä 500 m tien alapuolella. Hiekkaista nivaa/suvantoa. Erittäin kapeata uomaa! Kirkas vesi.
2021	30.9.	Koutajoki	Onkamojoen keskiosan a	73,082	Salla	Tunturioja	3581173	7408153	No record	*Salmo trutta*	Vk 1000 m ap. Lt koskea/nivaa, alaosalla jyrkkä hienosti putoava koskijakso. Erittäin hyvää habitaattia paljon. Kirkas vesi.
2021	13.8.	Kemijoki	Ala-Suolijärven a	65,392	Posio	Karkupuro	3562429	7348684	No record	*Salmo trutta, Lota lota, Cottus gobio*	Vk (ja sähkötys) 1000 m yp. Lt koski/niva/suvanto. Erittäin hyvää habitaattia paljon. Kirkas vesi.
2021	6.7.	Kemijoki	Kemijärven a	65.31	Kemijärvi	Porttioja	3543603	7384106	No record	-	Vk 200 m yp. Lt puro, 2-3 m leveä. Korpinotko, lähes kokonaan Fontinalis-peitossa, kirkas vesi. Hieno! Lohkareita, välissä hiekkasoraa.
2021	6.7.	Kemijoki	Kemijärven a	65.31	Kemijärvi	Myllyoja	3542898	7384982	No record	-	Vk 80 m yp. Lt puro, tien yläpuolella kaksi haaraa nivaa, sitten virtasuvantoa. Hiekkaa/hiekkasoraa, vanhan sillan raunio vedessä.
2021	6.7.	Kemijoki	Kemijärven a	65.31	Kemijärvi	Myllyoja	3542097	7386998	No record	-	Vk 250 m ap. Lt hyvä joki, 3 m leveä; virtasuvannossa kaatunutta puuta & hiekottunut pohja. Kirkas vesi. Vajaa 200 m hyvää koskea erikokoisin kivin, välissä hiekkaa ja hiekkasoraa.
2021	6.7.	Kemijoki	Kemijärven a	65.31	Kemijärvi	Särkioja	3542830	7381856	No record	-	Vk 200 m yp. Kapea 1 m puro, matala 10-15 cm; Hyvä pohja täynnä erikokoista kiveä ja Fontinalista. Silti reunoilla perkuukivikoita.
2021	6.7.	Kemijoki	Jumiskonjoen va	65.316	Kemijärvi	Matkauomanoja	3545474	7378024	No record	-	Vk 180 m yp. Lt rehevä puro, 1-1,5 m lev. Osin hiekottunut pohja, jossa erikokosta kiveä ja uppopuita. Syv. 20-50 cm. Pääosin koskea, ylempänä nivapätkä.
2021	6.7.	Kemijoki	Jumiskonjoen va	65.316	Kemijärvi	Pitkälamminoja	3545980	7377503	No record	-	Vk 150 m yp. Kapea 1-1,5 m rehevä puro. Alaosan niva hiekottunut & uppopuuta; yläosan koskissa kiveä mutta matalaa (10-20 cm). Ei hyvää habitaattia.
2021	6.7.	Kemijoki	Jumiskonjoen va	65.316	Kemijärvi	Paiselamminoja	3547812	7373385	No record	-	Vk 120 m yp. Lt kapea 1 m rehevä puro; erikokoista kiveä hiekkasorapohjalla. Tien ojat tuovat mutaa/hiekkaa. Kirkas vesi, nivaa - liian matala 10-15 cm.
2021	6.7.	Kemijoki	Ala-Suolijärven a	65.392	Posio	Säynäjäjoki	3557831	7364994	No record	-	Vk 200 m yp. Lt hieno, vuolas 3 m koskinen puro. Vaihtel habitaatt, kiviä&soraa, syv. 20-40 cm; ylittävä mönkijäura ei haittaa; jopa Salmo truttaen kutuhabitaatteja.
2021	6.7.	Kemijoki	Lauttajoen va	65.395	Posio	Kivioja	3560210	7368573	No record	-	Vk 180 m yp. Lähes Lt 2 m leveä nivamainen puro, tumma vesi; erikokoisia kiviä ja soraa & Fontinalista, syv. 20-60 cm.
2021	6.7.	Kemijoki	Lauttajoen va	65.395	Posio	Majavaoja	3562897	7370712	No record	-	250 m ap. rannalta tarkasteltuna. Kuusirämeen reunustama suvantojoki, 7-8 m.; tumma ja syvä vesi, ulpukoita; EI raakkuhabitaattia.
2021	7.7.	Kemijoki	Lauttajoen va	65.395	Posio	Mustasuon-Majavasuon oja	3563392	7372503	20	-	Vk 200 m yp. Lt puro, 2-3 m leveä. Lohkareikkoa, eritt. tumma vesi; koskijaksoja, välit suvantoa. Isoja kiviä ja Fontinailsta.
2021	7.7.	Kemijoki	Lauttajoen va	65.395	Posio	Purisijalammenoja	3563448	7369413	20,5	-	Vk 150 m yp. Lt olematon pääosin <0,5 m leveä liru lohkareitten välissä; sorapohjaa!! Mutta kirkas matala vesi vähissä sorakohdilla, lisäksi kynnyksiä.
2021	7.7.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Kontio-oja	3568127	7366307	22	-	Vk 150 m ap. Lt suvantoinen jänkävirta, jossa pari lyhyttä nivaa; pohja ok hiekkasoraa nivoissa ja suvainnoissakin; paljon levää.
2021	7.7.	Kemijoki	Mourujoen–Vääräjoen va	65.396	Posio	Mourujärven Kitkanperään laskeva puro	3567214	7364434	23,5	-	Vk 120 m yp. Lt(?) isolohkareiset nivapätkät, kartalla koskina; muuten suvantoa; isoja leväisiä kiviä, EI raakkuhabitaattia.

Year	Date	Main river basin	Sub-catchment area	Code	Municipality	River	Coordinates (KKJ27)	Coordinates (KKJ27)	Water temp. C°	Fish species detected	Vk=Aquascoping area, meters, yp=upstream, ap=downstream, Lt=Natural river section
2021	8.7.	Kemijoki	Kursunjoen va	65.378	Salla	Pitkälammesta laskeva puro	3556360	7405191	No record	-	Onneton jänkäliru, EI habitaattia. Ei tutkittavissa.
2021	8.7.	Kemijoki	Kursunjoen va	65.378	Salla	Pitkälammesta laskeva puro	3556134	7404970	No record	-	Vk 50 m yp. Lt pieni 1 m leveä ryteikköpuro, hiekka/hiesupohja, ei kiviä. Ei hyvää habitaattia, tulvassa.
2021	8.7.	Kemijoki	Kursunjoen va	65.378	Salla	Kursunjoki	3556094	7404571	16	-	Vk 250 m yp. Lt koski ja välinivoja, kirkas vesi; erikokoista kiveä, sammalta ja hiekkasoraa. Optimihabitaattia!
2021	8.7.	Kemijoki	Kursunjoen va	65.378	Salla	Kursunjoki	3552885	7405054	No record	-	Noin 8 m leveä virtasuvanto, pohja hiesua/mutaa; vesi ruskehtavaa, EI habitaattia.
2021	8.7.	Kemijoki	Kursunjoen va	65.378	Salla	Kursunjoki	3552225	7405329	20	-	Vk ja rantoja myöten 300 m yp. Lt leveä virtasuvanto, 8 m. Ainoa niva muodostuu jokeen kaatuneista puista, hiekkapohja. Ei hyvää raakkuhabitaattia. Hieno harjunaluslehto rannalla.
2021	8.7.	Kemijoki	Kursunjoen va	65.378	Salla	Kursunjoki	3551590	7406188	20	-	Vk 300 m yp. Lt lveä ja kirkasvetinen joki. Sillan alusta rakennuskiveä, muuten vuolasta koskea, välipätkät nivaa. Erikokoista kiveä ja hiekkaa välissä; EI kutuhabitaattia Salmo truttaelle eikä optimaalista raakullekaan.
2021	8.7.	Kemijoki	Ala-Salmijoen va	65.377	Salla	Ala-Salmijoki	3559034	7416655	No record	-	Leveä suvantoinen jänkäjoki; >10 m leveä, EI oikeanlaista habitaattia.
2021	8.7.	Kemijoki	Ala-Salmijoen va	65.377	Salla	Ala-Salmijoki	3560566	7415676	22	-	Vk 100 m ap. Lt leveä virtasuvanto/niva; hiekkasoraa pohjalla, paljon Fontinalista; yksittäisiä isoja kiviä. Ei optimihabitaattia raakulle.
2021	9.7.	Kemijoki	Lauttajoen va	65.395	Posio	Lauttajoki	3566261	7370533	No record	FPMs	Vk 120 m yp. Lt leveähkö, sameavetinen (leväkukinta??!) koskijakso; erikokoista kiveä ja soraa väleissä. Huono näkyvyys; kaksi Mm yksilöä löytyi yläosasta ennen lumme-/ulpukkasuvantoa.
2021	30.9.	Kemijoki	Ruuhijoen va	65.376	Salla	Tuohilusikanlammenoja	3580427	7406295	No record	-	Vk 350 m yp. Lt koski/niva. Erittäin hyvää habitaattia. Hieman vähävetinen. Kirkas vesi.

3 Status of the Freshwater Pearl Mussel Populations

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3.1 Introduction

Since 2000, the present freshwater pearl mussel (later FPM) distribution and state of the populations has been investigated in three Interreg projects and in one Micro-Tacis project in the North Calotte. In 2003–2006, the presence of FPM populations was studied in old pearl fishing areas in Inari, the Pasvik Valley and Petchenga in Finland, Norway and Russia (Oulasvirta et al. 2004, Oulasvirta 2006, Oulasvirta et al. 2006), respectively. In 2007–2008, inventories were carried out in the Tornionjoki (Swedish Torneälven) river basin in Finland and Sweden (Oulasvirta et al. 2008). The main focus in these investigations was to find new unknown populations. Proper population status assessments were not carried out, but the preliminary results revealed big differences in the state of the FPM populations both between the catchment areas and between the different rivers inside the catchment areas. Most of the breeding populations were usually found from the upper parts of the river systems. However, in many rivers the recruitment rate of FPM was even in remote areas low or totally lacking.

The viability status of the northern Fennoscandian FPM populations was studied in the Interreg North project *Raakku! – Freshwater Pearl Mussel in Northern Fennoscandia* in 2011–2013 (Oulasvirta et al. 2015a). Population status of altogether 30 FPM populations in northern Finland, Sweden and Norway were investigated in that project. In addition, reasons that have led to the decline of the populations were evaluated. Most of the work was done in Finland, where knowledge of the populations was most scarce.

In Sweden and Norway, the state of the populations is monitored regularly as part of the national monitoring programmes (Naturvårdsverket 2005, Lundberg & Bergengren 2008, Larsen et al. 2000, Direktoratet for Naturforvaltning 2006, Havs- och vattenmyndigheten 2020; Miljödirektoratet 2018). In Finland, the first action plan for protecting the FPM was published in the beginning of 2021 (Ympäristöministeriö 2021). The plan includes actions at different levels from mapping the yet unknown populations to the concrete conservation measures for restoring the declined populations. The actions taken in the SALMUS project fulfil the objectives set in the national action plans in Finland, Sweden, and Norway. In this part of the project the aim was to evaluate the status of FPM populations in the cross-border river basins in the Green Belt of Fennoscandia in Finland, Norway, and Russia. In addition, areas from Sweden were included for comparison.

Field works were carried out in all three project years 2019–2021. In addition to the writers of this report, the project staff in field work included following persons:

Sakari Kankaanpää, Heikki Erkinaro, Sabrina Nykänen, Pirkko-Liisa Luhta, Eero Moilanen from Finland and Ellinor Bomark, Andreas Broman, Markku Kilpala, Mikael Sandberg, Andreas Zsoldos, Melinda dos Santos, Helen Liljendahl, Stina Gustavsson, Anja Rubach, Marcus Enberg from Sweden, and Juho Vuolteenaho from Norway.

This report presents the studies conducted in Finland and Sweden. Summary of the Norwegian results are also shown in Appendix 1. Russian results have been omitted from SALMUS reporting while the European Commission suspended the participation of Russia in all cross-border cooperation programmes after the start of the war in Ukraine.

3.2 Study area

The cross-border areas of Finland, Norway and Russia form so called Green Belt of Fennoscandia (GBF). During the cold war Iron Curtain formed a corridor of habitats with relatively low anthropogenic exploitation. Because of this history, the nature in GBF area has remained relatively untouched and contains a high diversity of species. Therefore, GBF provides a unique possibility to protect the cross-border river ecosystems and to develop sustainable blue bioeconomy in the area.

Study area consisted of the cross-border catchments in Finland, Russia, and Norway. In addition, areas from Sweden were included for comparison. Altogether 45 rivers were investigated in 14 main catchment areas in Finland, Sweden, and Norway (Fig. 26). The investigated rivers are listed in Table 6.

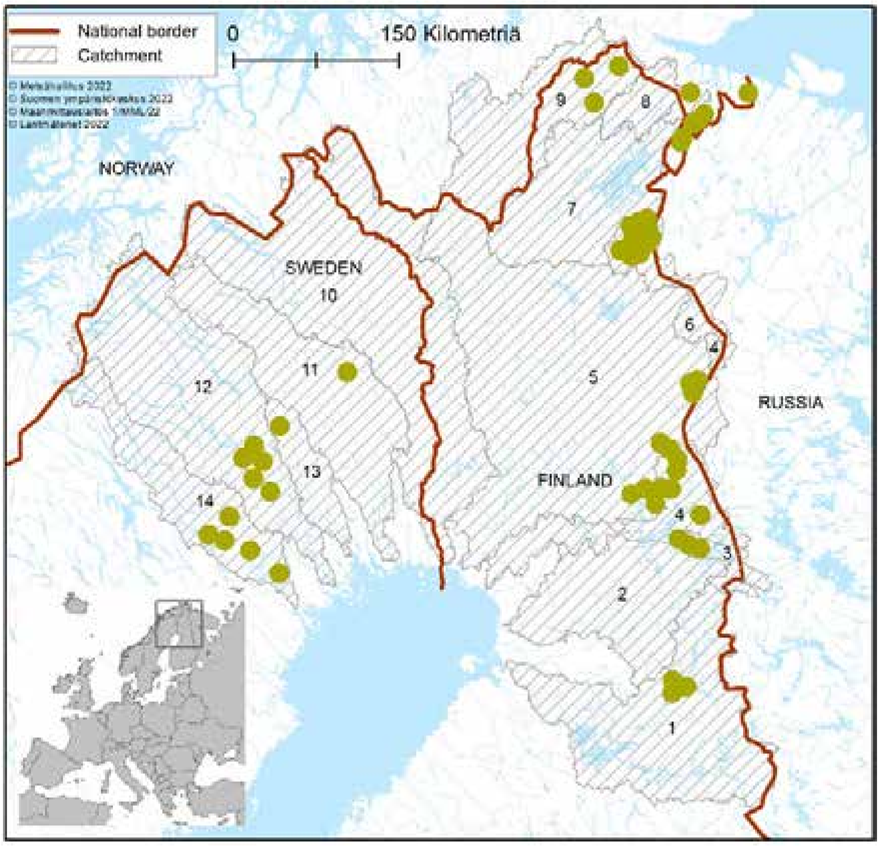

Figure 26. Project area and location of the target rivers in Finland, Sweden, and Norway. Main catchment areas: 1. Oulujoki, 2. Iijoki, 3. Carelian Kem/Vienan Kemi, 4. Koutajoki, 5. Kemijoki, 6. Lutto (Tuloma), 7. Pasvik/Paatsjoki, 8. Neiden/Näätämö, 9. Teno/Tana, 10. Torneälven/Tornionjoki, 11. Kalixälven, 12. Luleälven, 13. Råneälven, 14. Piteälven.

Table 6. Target rivers for the FPM population status assessment. *Results not presented in this report except the summary in Appendix 1.

River	Main catchment area	Country
Lutto (main channel)	Lutto (Tuloma)	Finland
Niemioja	Lutto (Tuloma)	Finland
Kolmosjoki	Lutto (Tuloma)	Finland
Pesäjärvenoja–Takkireuhkajärvenoja	Lutto (Tuloma)	Finland
Saari-Ahvenjärvenoja	Lutto (Tuloma)	Finland
Ahvenlammenoja	Lutto (Tuloma)	Finland
Nohkimaoja–Vuoksijoki	Lutto (Tuloma)	Finland
Urakkajärvenoja–Vuoksioja	Lutto (Tuloma)	Finland
Kivijoki	Lutto (Tuloma)	Finland
Rytioja	Lutto (Tuloma)	Finland
Ristimorostonjärvenoja	Lutto (Tuloma)	Finland
Sätsijoki	Kemijoki	Finland
Ahvenoja	Kemijoki	Finland
Hangasjoki–Tammakkolammenoja	Kemijoki	Finland
Köykenejoki	Kemijoki	Finland
Salmijoki	Kemijoki	Finland
Vääräjoki	Kemijoki	Finland
Porontimajoki	Koutajoki	Finland
Myllyoja	Koutajoki	Finland
Meskusjoki–Välijoki–Juomajoki	Kem	Finland
Varisjoki–Leväjoki	Oulujoki	Finland
Korpijoki	Oulujoki	Finland
Vuohččojohka	Teno	Finland
Námmájohka	Teno	Finland
Gálddašjohka	Teno	Finland
Kääntöjoki	Kalixälven	Sweden
Silpakbäcken	Luleälven	Sweden
Harrijaurebäcken	Luleälven	Sweden
Souksaurebäcken	Luleälven	Sweden
Varjekbäcken	Luleälven	Sweden
Görjeån	Luleälven	Sweden
Korsträskbäcken	Piteälven	Sweden
Ljusträskbäcken	Piteälven	Sweden
Tjartsebäcken	Piteälven	Sweden
Tvättstugubäcken	Piteälven	Sweden
Bölsmanån	Piteälven	Sweden
Rutnajoki	Råneälven	Sweden
Spurvbekken*	Pasvik	Norway
Føllelva*	Pasvik	Norway
Ørnebekken*	Pasvik?	Norway
Grense Jakobselv*	Grense Jakobselv	Norway
Neiden*	Neiden	Norway
Botnelva*	Pasvik?	Norway
Sandnes elva*	Pasvik?	Norway
Krakojokki*	Pasvik?	Norway

3.3 Methods

3.3.1 Population status assessment

The population status assessments were based on the distribution range of the mussels, population size, length (~age) distribution of the mussels, the smallest mussels found and the quality of the habitat. Since the field methods differ in detail between countries, the methods in Sweden and Finland are presented separately in chapter 3.2. All the field investigations were carried out in 2019–2021.

The state of the population was evaluated by applying Swedish criteria, in which the population status is based on the population size and proportion of juvenile mussels in the population (Table 7). The viability of the population is basically determined according to the proportion of <20 mm (~10 years) and <50 mm (~20 years) mussels in samples. The proportion of these size classes was calculated from mussel samples taken from the whole distribution range of the mussels in river.

The shell length of the mussel correlates to some extent with the age of the mussel. An obvious source of error here is the fact that the growth rate of the mussels varies between the rivers and even within the river (Aspholm 2012). According to Dunca & Mutvei (2009), the mussels of 20 mm in shell length are between 6–18 years and mussels 50 mm in length 16–27 years, depending on the growth rate of the mussels. Therefore, in this study we took also separately samples of young mussels to determine their real age by counting the annual rings on the shell. The method for determining the age of young mussels is described in chapter 3.2.

3.3.2 Field methods

3.3.2.1 Sweden

Mussel investigations – new investigations

Before the inventory of the mussel population began, the uppermost and lowermost mussel individuals of each river were located to determine the distribution range of the populations. Each distribution range was then divided into three equally long stretches and 20 x 20 metre squares were drawn onto a map on these stretches. The squares were then numbered, and six squares from each of the three stretches were chosen randomly. Coordinates from the 18 chosen sites were stored for later investigations. (Havs- och vattenmyndigheten 2016).

The 18 randomly chosen sites were investigated using an aquascope and wading trousers, following the Swedish standard method for investigating FPM populations (Havs- och vattenmyndigheten 2016). A twenty metre long transect was established, and every visible mussel within this area was counted. It is possible to shorten the transect when more than 50 mussels are found, but the transect can never be shorter than 3 metres. The width of the rivers was measured at three different places in the transect (start, middle and end) to get the mean width of the transect. The

Table 7. Criteria for determining the viability status of the FPM populations (Bergengren et al. 2010, Söderberg et al. 2009).

Class	Status
1. Viable	> 20% < 50 mm and > 0% < 20 mm (> 500 ind.)
2. Maybe-viable	> 20% < 50 mm or > 10% < 50 mm and > 0% < 20 mm (> 500 ind.)
3. Non-viable	< 20% < 50 mm (> 500 ind.) or > 20% < 50 mm (< 500 ind.)
4. Dying-out	All > 50 mm, rich occurrence (> 500 ind.)
5. Dying-soon	All > 50 mm, scarce occurrence (< 500 ind.)
6. Extinct	Earlier documented occurrence but already vanished

start and end points of the transects were marked out with spray paint on trees and stones next to the river. The coordinates for the start point were taken by GPS. The length of the smallest mussel within the transects was measured, and the 15 first randomly found mussels above or below the transects were measured for length, width, and height. These measurements were then used to determine the length distribution of the mussels within the population.

New investigations were done in the Rivers Korsträskbäcken, Görjeån (lower), Görjeån (upper), Tjartsebäcken, Souksaurebäcken and Rutnajoki.

Mussel investigations – revisit

In some of the rivers previous investigations have already been made according to guidelines of Havs- och vattenmyndigheten (2016) or earlier national methodology. Earlier methodology stated that 15 transects should be investigated compared with 18 in the latest methodology. These already existing transects were revisited and more transects were added in some rivers to get 18 transects altogether.

This was done in the Rivers Kääntöjoki, Silpakbäcken, Harrijaurebäcken, Tvättstugubäcken, Bölsmanån, Varjekbäcken and Ljusträskbäcken.

Glochidia studies

Investigation of glochidia prevalence in the host fish was performed as part of the FPM population status assessment in the rivers Kääntöjoki, Varjekbäcken, Görgeån, Ljusträskbäcken, Tjartsebäcken, Tvättstugubäcken and Bölsmanån.

Host fish studies

Investigation of the host fish abundance by electrofishing was carried out in the rivers Kääntöjoki, Silpakbäcken, Harrijaurebäcken, Souksaurebäcken, Varjekbäcken, Görgeån, Korsträskbäcken, Ljusträskbäcken, Tjartsebäcken, Tvättstugubäcken and Bölsmanån.

Water chemistry

Water chemistry was analysed from the rivers Souksaurebäcken, Görjeån and Rutnajoki.

Habitat analyses

At each site, a description of the aquatic habitat and the surrounding terrestrial environment (5 metres and 50 metres from the river) was carried out as described in Havs- och vattenmyndigheten (2016).

3.3.2.2 Finland

Mussel counts

In Finland, the field investigations were carried out basically in the same way as in Sweden (see previous chapter), with some exceptions to the method, however. The random transects were always 20 metres long and they were located into the known mussel distribution range of a river at even intervals after a random start point was determined. Instead of wading and aquascoping, the transects were investigated mainly by snorkeling (Figs 27 and 28). The coordinates of the start and end point of the transects were recorded. Moreover, the landmarks in the vicinity of the transects were written down, so that in future monitoring occasions the transects can be repeated precisely at the same sites. After that, the diver investigated the transect by swimming upstream and counting all mussels that he or she saw. The number of random transects was 4–31 per river depending on the length of the mussels' distribution range.

An alternative method, so called total count, was applied in small brooks, where the mussels were present only in a short stretch of the river. In this method basically all the mussels in the river were counted.

In the River Lutto, which is a big river, neither the 20 metres long random transects nor the total count method could be applied. Therefore, different methods had to be used in Lutto, and they are described under the results in chapter 4.2.1.

Figure 27. Aquascope was used in the shallowest transects. Here in the river Urakkajärvenoja on 31.8.2019. Measuring tape on the riverbank marks the 20 metres long line. Photo: Panu Oulasvirta.

Figure 28. Counting mussels by snorkel diving. Photo: Panu Oulasvirta.

Mussel measurements

After counting the mussels in the transect, the diver randomly collected the first 15 mussels observed for the shell length measurements (Fig. 29). Mussels for this shell measurement sample were collected in the vicinity of each random transect either upstream or downstream of it. The length measurements were used for determining the size distribution of the mussel population. In addition, the smallest observed mussel was measured.

Apart from the mussel sampling described above, we tried to find juvenile mussels (< 20 years old). If juveniles were found, their shell length was measured in the same way as with the adult mussels. In addition, we counted the annual rings on the shell and measured the length of the eroded area in the umbo part of the shell (see Fig. 30). The annual rings are not visible in the eroded area, but the age of this part, so called "umbo age", was based on a large Swedish data collected by Aliona Meret, in which the "umbo age" depends on the length of the eroded area and the growth rate of the mussel. Thus, according to number of annual rings and size of the eroded umbo area it was possible to determine the age of the mussel. When the age is compared to the shell length it was possible to determine the growth rate of the young mussels during their first years.

The age of the adult mussels was studied from 37 Finnish and from 5 Swedish mussel populations. From each population the age was determined from three mussels. The aim of age studies was to get a picture of the longevity of the mussels in different populations. The results of the age studies are described in the part "Developing conservation methods" of this report.

Figure 29. Measuring the length of the mussel. Photo: Panu Oulasvirta.

Figure 30. Annual rings are usually visible in young mussels. Eroded area in the umbo part stands out at the top of the shell. Photo: Panu Oulasvirta.

Glochidia studies

The goal of the glochidia prevalence investigation in Finland was mainly to locate new FPM populations. Results of these studies are presented in this report by Moilanen & Luhta (see "Freshwater pearl mussel inventories and development of brook restoration methods in SALMUS"). FPM glochidia were found from rivers Tammakkolammenoja, Sätsijoki and Saukko-oja. FPM was not known from Tammakkolammenoja and Sätsijoki before this study. FPM populations of Saukko-oja were investigated in 2013 (Oulasvirta et al. 2015a).

Host fish studies

The density of the FPM host fish was studied by electrofishing in rivers Välijoki, Juomajoki, Meskusjoki, Saukko-oja, Ahvenoja, Sätsijoki, Tammakkolammenoja, Hangasjoki, Vääräjoki, Lauttajoki, Köykenejoki, Salmijoki, Myllyoja, Korpijoki, Lahnajoki and Leväjoki. Results of these studies are presented separately in this report (see the section "Host fish studies").

Habitat analyses

Habitat and environment characteristics of the investigated rivers were evaluated by recording environmental parameters such as river size, water level, channel depth, bottom substrate, aquatic vegetation, amount of loose sediment, amount of wood material in the river and fish observations. If human influence in the river or in the catchment area was visible, that was also written down.

3.4 Results

Summary of the results from all investigated rivers is presented in the Appendix 1.

3.4.1 Rivers in Sweden

3.4.1.1 Kalixälven catchment

The Kalix River (in Swedish Kalixälven) is 461 km long and flows from the Kebnekaise mountain range in Kiruna municipality down to its outlet in Bothnian Bay near the town of Kalix. The main rivers in the system are River Ängesån and River Kalix, and these two main branches join at the town of Överkalix, 67 km from the coast. The catchment area covers 18,130 km^2, and River Kalix with its tributaries are protected by Natura 2000. It is also a so-called "National River" where water regulatory and other activities connected to hydropower are forbidden by Swedish law. River Kalix gets around half of its water from the River Torneälven through a bifurcation in River Tärendöälven. This is considered as the world's second largest bifurcation.

In the river Kalixälven catchment, Kääntöjoki was included as a target river for FPM population status assessments.

River Kääntöjoki

River Kääntöjoki (Fig. 31) is situated in the River Kalix catchment area in Gällivare municipality. It starts from Lake Kääntöjärvi and has its outlet into River Kalixälven. The total length of Kääntöjoki is 7.7 km and its mean width is 9.6 m. The gradient is 63 metres, from 324 metres above sea level (ASL) from the outlet of Lake Kääntöjärvi down to the outlet into River Kalixälven at 261 m ASL. The total catchment area is 86.8 km^2 and it is made up of 64.8% forest, 22.6% wetland, 11.7% surface water, 0.7% moor land and other land, 0.1% urban area and 0.1% agriculture land (SMHI SVAR VERSION 2016_3).

The environment around Kääntöjoki (50 metres on both sides of the river) is mainly

Figure 31. River Kääntöjoki. Photo: CABN.

wetland and mixed forest and the terrain is relatively flat. The close environment around the river (5 metres on both sides of the river) is dominated by grass and half grass (*Carex* sp.), brush (*Salix* sp.), herbs (meadowsweet, Filipendula ulmaria) and trees (birch, alder, spruce). The insolation is quite high in many parts of the river due to lack of shade since the number of trees in these parts is low.

The County Administrative Board of Norrbotten (CABN) has known of the occurrence of FPM in Kääntöjoki since the beginning of 1980 and has also made investigations earlier in the river. In 1993, an overall search for FPM was done with aquascope in the upper part of the river. Results showed a density of around 0.0002 individuals/m^2, and the smallest mussel that was found was 51 mm in length. In 2006, five sites were investigated with aquascope. A total of 12 mussels were found; the smallest one was 73 mm in length and the average density of mussels was 0.02 individuals/m^2. In 2013, 18 sites were investigated with aquascope within the RAAKKU! project (Oulasvirta et al. 2015a). A total of only four mussels were found within the transects and the population was estimated to be 73 individuals; the smallest one was 85 mm in length and the average density of mussels was 0.0011 individuals/m^2.

River Kääntöjoki is a part of the Torne- and Kalix River Natura 2000 areas.

Mussel investigations

The 18 random transects from 2013 were revisited between 2.–5.8. 2021 (Fig. 32). The mean depth in Kääntöjoki at the time of the investigation was 0.5 m, and the water level was around average. The air temperature was 13–18 °C, water temperature 13–16 °C, and the dominating bottom substrates were boulders/stone/gravel/sand. The water current varied between a gushing, strong current and calm water. The water colour was clear with no turbidity. The vegetation in the river was dominated by fouling algae (surface coverage 51–100%) but also mosses and vascular plants grew in the river.

The mussels were distributed over a 7 km long stretch in the river and mussels were counted on an area of 3,407 m^2. So, roughly 5% of the total mussel area was investigated. Only a total of eight mussels was found in five of the eighteen transects investigated. The estimated FPM population size was 222 individuals (Appendix 1). The mean density of the population was 0.003 individuals/m^2. The smallest mussel that was found was 41 mm in length; the other 14 measured individuals were between 49–105 mm (Fig. 33).

Overall, the conditions for FPM were good with nice gravel beds and a good water current, and a lot of trout and small salmonid fry was also observed.

Kääntöjoki has earlier been used for timber floating. From the 1990s to the beginning of 2000s ecological restoration of the river has taken place. According to earlier observations, it seems as if the restoration could have had a negative impact on the mussel population, and the number of mussels may have declined due to the measures taken.

The paucity of found FPM individuals from the investigation made in 2006 and earlier resulted in making a new investigation in Kääntöjoki by CABN in the summer of 2007. First a description of the habitats in the river was made to find the best habitat to look for the mussels. Four sites were then snorkelled in search of mussels. Nineteen mussels were found in a total investigated length of 725 metres (0.003 individuals/m^2). In June 2014, two of the sites were snorkelled again, 17 mussels were found in a total investigated length of 384 meters, smallest mussel found was 80 mm in length. On the 24th of August 2021, the two sites were snorkelled once again, and 10 mussels were found with the smallest one of 60 mm in length. The investigation in 2021 was supposed to be done in June but due to Covid-19 it had to be postponed. In August there was quite much vegetation that made

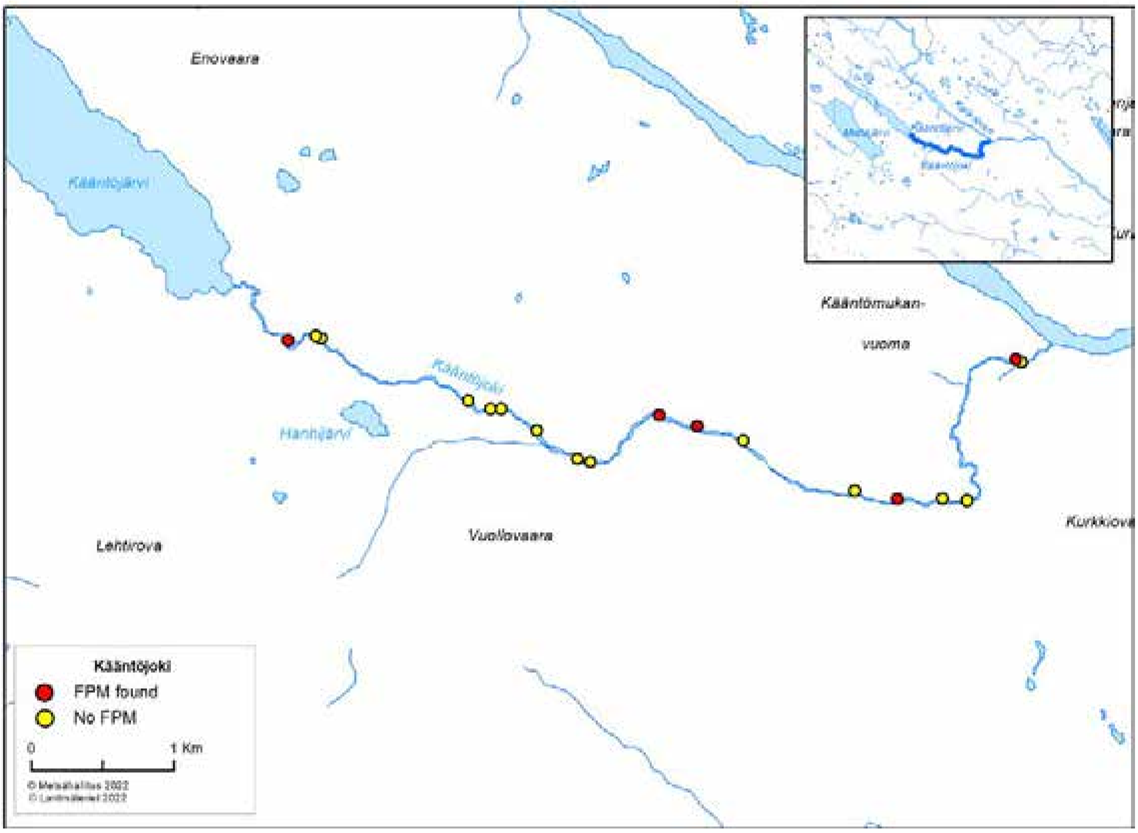

Figure 32. Random transects in the river Kääntöjoki. Small map: River Kääntöjoki marked with thicker blue line.

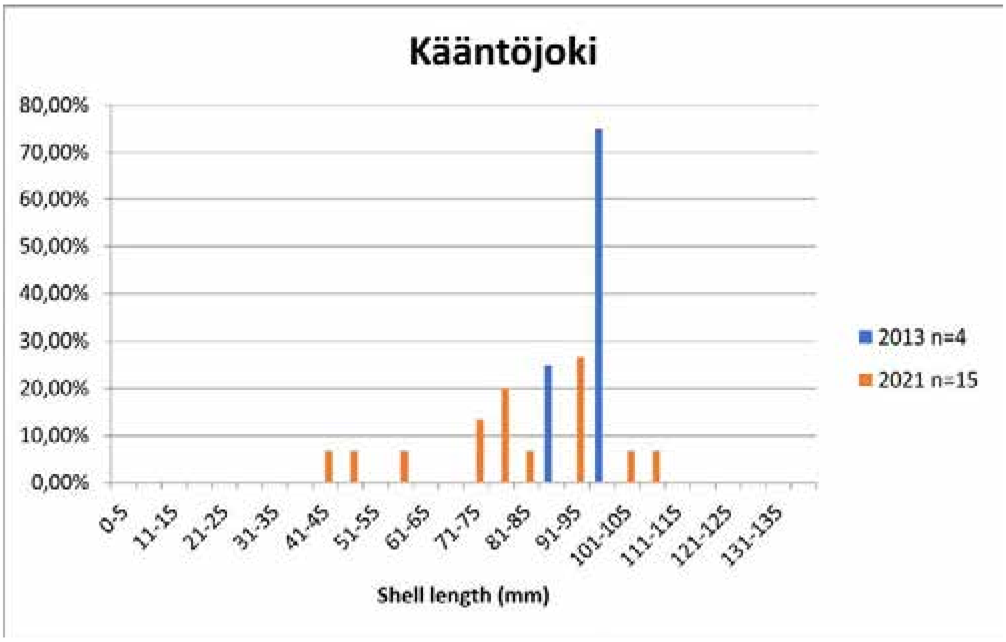

Figure 33. Size distribution of the mussels in river Kääntöjoki in 2013 and 2021.

the survey harder and maybe some mussels have been missed due to this.

The original idea was to collect mussels and move them closer to each other, but after five sites were electrofished (on 7th and 8th of June 2007) and glochidia were found on the gills of trout, the plan was changed. Trout were caught at four of the fished sites, and on two of these sites glochidia were found on 7.9% and 16.7% of the trout individuals, respectively. It was then decided that, since glochidia had been found, nothing more was to be done and the suggestion was to follow this up in the future to see whether small mussels could be found and whether the FPM population might have recovered. (Broman 2007)

On the 11th and 12th of June 2014, three of the earlier (in 2006) electrofished sites were reinvestigated. The sites were electrofished and the gills were examined by naked eye to look for glochidia. Brown trout was caught at all sites (Atlantic salmon was caught at two of the sites) and glochidia were found on 4.8%, 10% and 16.3% of the trout individuals, quite alike with the result from 2006. No glochidia were found on Atlantic salmon individuals. The total number of glochidia on the gills of the trout was low (1–10), maybe due to low numbers of mussels in the river or the fact that most of the glochidia had already dropped off due to a mild winter.

In 2015, 483 FPM individuals were moved from River Välijoki and placed at two sites in River Kääntöjoki to boost the population of the River Kääntöjoki. River Välijoki is the river between Lake Mettäjärvi and Lake Kääntöjärvi, upstream from River Kääntöjoki.

Glochidia study

Three sites with a total area of 900 m^2 were electrofished in River Kääntöjoki on 14th and 15th June 2021. The water temperature at the time of the investigation was 11.3–13.4 °C. Trout were caught at all sites and the total catch was 75 trout individuals. From this catch, 22 trout individuals (29%) were infected with glochidia larva in quite low numbers (1–10 ex.). The total number of glochidia was 49 and the mean number on the gills was only 0.64 glochidia/trout. Two Atlantic salmon individuals were also caught but neither of these fish had glochidia on their gills.

Host fish abundance

Four sites with a total area of 1,470 m^2, which corresponds to approximately 2% of the total FPM distribution area, were electrofished in River Kääntöjoki on 23rd and 24th August 2021. The water temperature at the time of the investigation was 11.1–13.4 °C. Young of the year (YOY) trout and older trout were caught at all sites and YOY salmon and older salmon were caught at two sites (Fig. 34). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM population to be functional. The mean density for YOY trout caught in River Kääntöjoki was 49.1/100 m^2 and for YOY salmon 10.4/100 m^2. Other species caught by electrofishing were common minnow, pike and burbot.

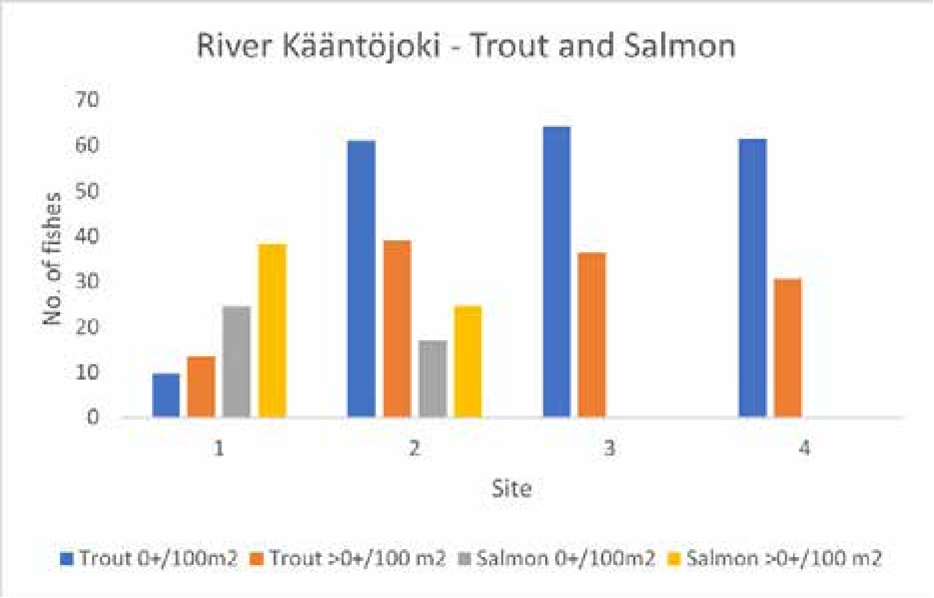

Figure 34. Number of trout and salmon caught in river Kääntöjoki using electrofishing in August 2021.

3.4.1.2 Luleälven catchment

The Luleälven River is 460 km long and rises in the mountains of the Lapponian World Heritage Area in the western part of Norrbotten County. The two main rivers in the system are the River Big Luleälven (Stora Luleälven in Swedish) and the River Small Luleälven (Lilla Luleälven), and these branches join near to the town of Vuollerim, 130 km from its outlet into the Bothnian Bay in the City of Luleå. The catchment area covers 25,240 km^2 and has an average discharge of around 500 m^3/s. River Luleälven is heavily regulated for hydroelectric power and produces around 13 TWh each year.

In the Luleälven catchment rivers Silpakbäcken, Harrijaurebäcken, Souksaurebäcken, Varjebäcken and Görjeån were included as target rivers for FPM population status assessments.

River Silpakbäcken

River Silpakbäcken (Fig. 35) is situated in the River Stora Luleälven catchment area in Jokkmokk municipality. It starts from a couple of tarns called Silpaktjärnarna and has its outlet into River Messaurebäcken which continues down to River Luleälven. The total length of Silpakbäcken is 3.5 km and its mean width is 2.9 m. The gradient is 47 metres, from 293 m ASL from the outlet of Silpaktjärnarna down to the outlet into Messaurebäcken at 246 m ASL. The total catchment area is 11.5 km^2, which is made up of 88.3% forest, 9.8% wetland, and 1.9% surface water (SMHI SVAR VERSION 2016_3). The environment around Silpakbäcken (50 metres on either side of the river) is mainly mixed forest, and the terrain is hilly. The close environment around the river (5 metres on either side of the river) is dominated by grass and half grass (*Carex* sp.), trees (birch and alder) and herbs (meadowsweet *Filipendula ulmaria*). The vegetation around the river gives good shade.

Figure 35. River Silpakbäcken. Photo: CABN.

Mussel investigations

The County Administrative Board of Norrbotten (CABN) has known of the occurrence of FPM in River Silpakbäcken since 2005. In 2013, 18 randomly chosen transects were investigated with aquascope within the RAAKKU! project (Oulasvirta et al. 2015a). The estimated FPM population size in 2013 was 17,600 individuals and the distribution range 1.3 km. The mean density of the population was 4.7 individuals/m^2. The size distribution did show that the population was mainly made up by old individuals, only 1.4% of the mussels where smaller than 50 mm in length. The smallest mussel found was 13 mm in length.

The 18 random transects from 2013 were revisited between 28th and 30th June 2021 and 15.7.2021 (Fig. 36). The mean depth in River Silpakbäcken was at the time of the investigation 0.6 m, and the water level was around average. Air temperature was 14–21 °C, water temperature 16–20 °C and the dominating bottom substrates were big boulders and fine sediment; some parts were dominated by bedrock. Water current of the study areas was variable, quite evenly distributed between strong currents and calmer parts. The water was clear with no turbidity. There was a good amount of heavy dead wood, fine detritus, and vascular plants in some parts of the river, also a lot of overwater plants, mainly bogbean (*Menyanthes trifoliata*). The vegetation in the river was dominated by filamentous algae (surface coverage 51–100%).

The mussels were distributed over 1,300 meter in the river and mussels were counted from an area of 1,028 m^2, so roughly 27% of the total mussel area was investigated. A total of 4,617 mussels was found in 17 of the 18 transects investigated. The estimated FPM population size was 18,235 individuals (Appendix 1). The mean density of the population was 4.87 individuals/m^2. The smallest mussel that was found was 16 mm in length. The size distribution (Fig. 37) did show an increase in younger individuals compared to

2013 with 30% of the mussels smaller than 50 mm, and 0.7% smaller than 20 mm in length.

The mussels are situated between wetland parts (mires) in the upper part of the river. There were high densities of mussels in some parts of the river, mainly in the slower flowing parts below white-water rapids. Small mussels were found in 13 out of 18 transects investigated. Only one transect was without mussels.

There are a few natural migration barriers for fish (falls). Overall, very little human influ-

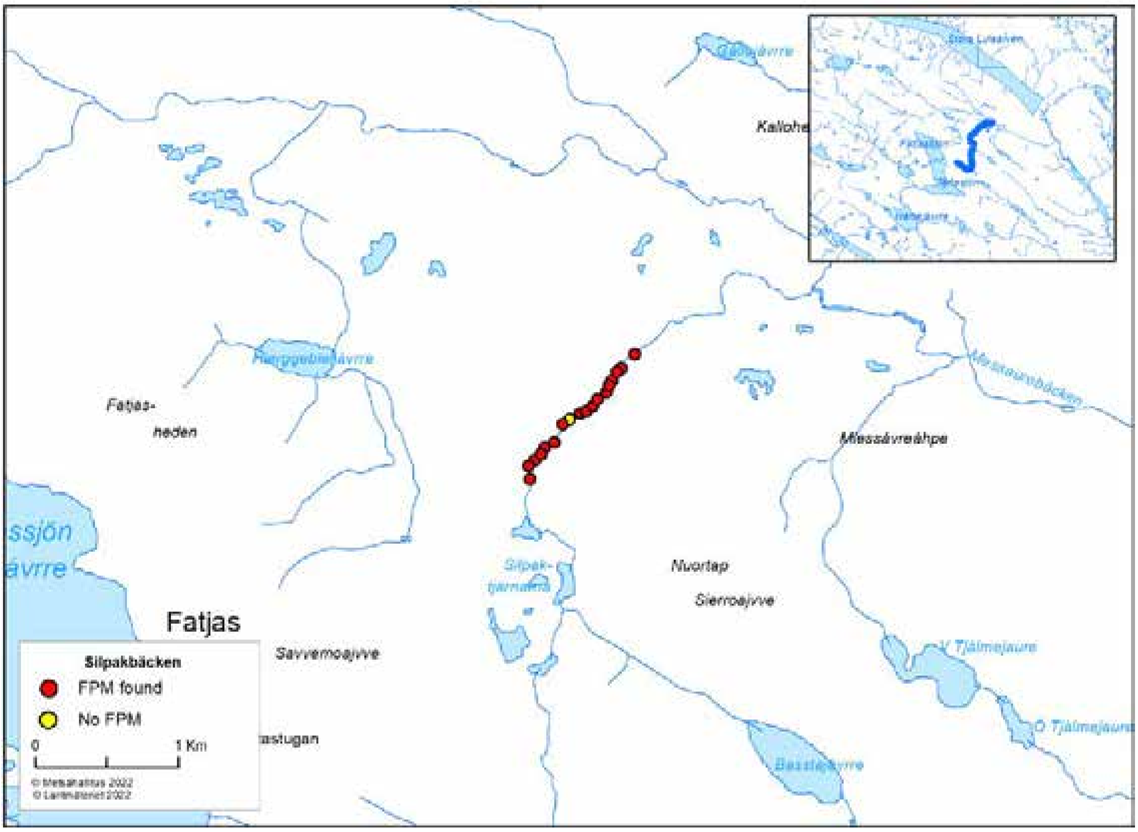

Figure 36. Random transects in river Silpakbäcken. Small map: River Silpakbäcken marked with thicker blue line.

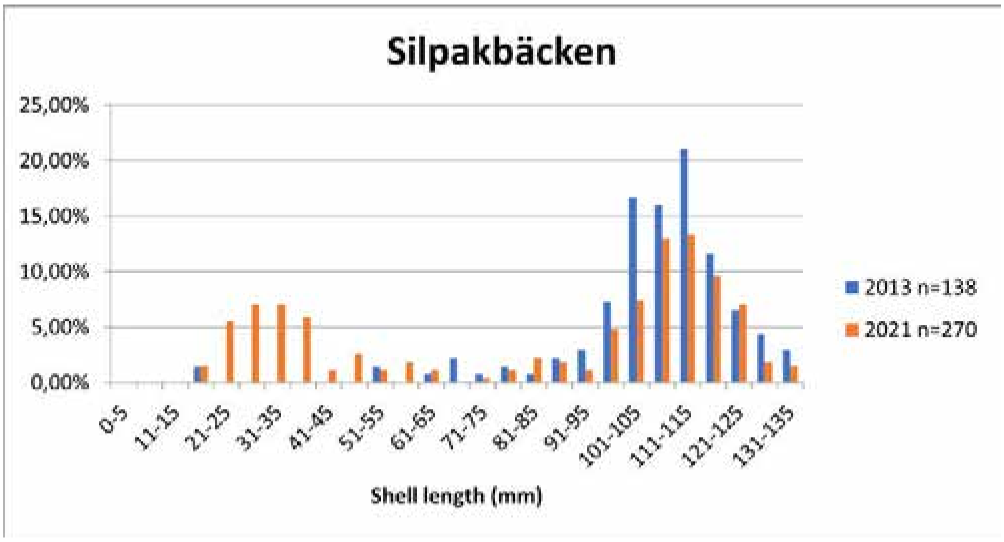

Figure 37. Size distribution of the mussels in river Silpakbäcken in 2013 and 2021.

ence was seen in and around the river, except for a powerline that crosses the river in its middle part.

Host fish abundance

Four sites with a total area of 1,150 m^2, which corresponds to approximately 31% of the total FPM distribution area, were electrofished in River Silpakbäcken on 28th and 29th August 2021. The water temperature at the time of the investigation was 6.1–6.8 °C. Young of the year (YOY) trout were caught in low numbers (2.0 and 2.5 individuals/100 m^2) at two of the sites. Older trout were caught at all sites and in higher numbers (min: 10.9 ind./100 m^2; max: 18.7 ind./100 m^2) (Fig. 38). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM population to be functional. The mean density for YOY trout caught in River Silpakbäcken (four sites) was 1.1/100 m^2 and for older trout 13.1/100 m^2. Trout was the most common species in the river, other species caught where pike and burbot.

River Harrijaurebäcken

River Harrijaurebäcken is situated in the River Luleälven catchment area in Jokkmokk municipality (Fig. 39). It starts from the Lake Harrijaure and runs in a steady inclination down to its outlet into River Lilla Luleälven. The total length of Harrijaurebäcken is 5.7 km and its mean width is 5.7 m. The gradient is 66 metres, from 280 m ASL from the outlet of Lake Harrijaure down to the outlet into River Lilla Luleälven at 214 m ASL. The total catchment area is 77.9 km^2 and this is made up of 69.9% forest, 17.4% surface water, 12.2% wetland, and 0.5% moor land and other land. (SMHI SVAR VERSION 2016_3). The environment around Harrijaurebäcken (50 metres on either side of the river) is mainly mixed forest. The close environment around the river (5 metres on either side of the river) is dominated by grass and half grass (*Carex* sp.), herbs (meadowsweet (*Filipendula ulmaria*) and brushes (*Salix* sp. and juniper). Trees are quite scarce around the river, so the insolation is quite high (shade less than 5%).

The County Administrative Board of Norrbotten (CABN) has known of the occurrence

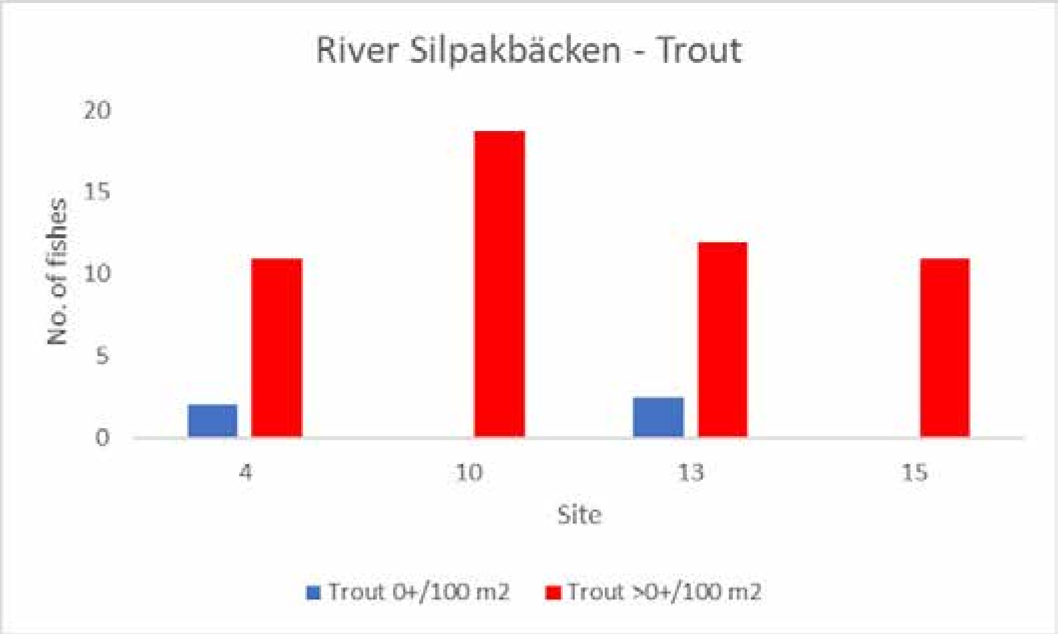

Figure 38. Number of trout caught in river Silpakbäcken using electrofishing in August 2021.

Figure 39. River Harrijaurebäcken. Photo: CABN.

of FPM in River Harrijaurebäcken since 1982. In 2013, 18 randomly chosen transects were investigated with aquascope within the RAAKKU! project (Oulasvirta et al. 2015a). The estimated FPM population size in 2013 was 1,872 individuals and the distribution range was 3 km. The mean density of the population was 0.1 individuals/m^2. The size distribution did show that the population was recruiting relatively well, with 10.5% of the mussels being smaller than 50 mm in length and the smallest mussel found being 27 mm.

The lower part of River Harrijaurebäcken is protected by biotope protection of Swedish Forest Agency since 2003, mainly for its terrestrial values.

Mussel investigations

The 18 random transects from 2013 were revisited between 12th and 14th July 2021 (Fig. 40). The mean depth in River Harrijaurebäcken at the time of the investigation was 0.7 m, and the water level was around average. The air temperature was 20–24 °C, water temperature 19–21 °C, and the dominant bottom substrates were small and large boulders with some bedrock. The water current was dominated by gushing and streaming parts, but there were also parts with slow flowing water. The water was clear with no turbidity. Vegetation in the river was dominated by fouling algae (surface coverage 51–100%) and there were also a lot of moss. The amount of dead wood and sediment was small.

The mussels were distributed over 3,000 meters in the river and mussels were counted in an area of 2,017 m^2, so roughly 12% of the total mussel area was investigated. A total of 901 mussels was found in 17 of the 18 transects investigated. The estimated FPM population size was 7,998 individuals (Appendix 1). The mean density of the population was 0.47 individuals/m^2 with the smallest mussel 16 mm in length. Size distribution did show an increase in the share of younger individuals compared to 2013 with 26% of the mussels smaller than 50 mm (Fig. 41).

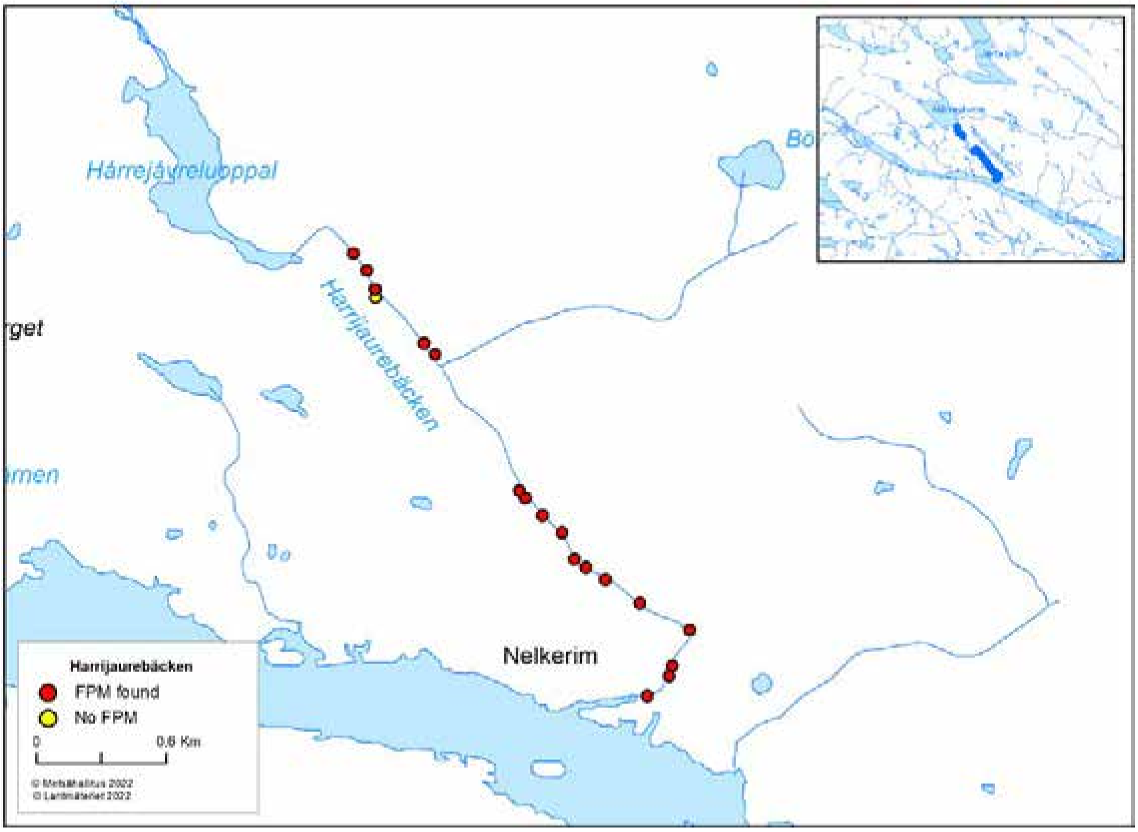

Figure 40. Random transects in river Harrijaurebäcken. Small map: River Harrijaurebäcken marked with thicker blue line.

Most mussels were found in the middle part of the river in areas where a strong current changed to more slowly flowing water. Small mussels were found in 12 out of 18 transects investigated, and only one transect was totally empty of mussels.

Host fish abundance

Four sites with a total area of 1,215 m^2, which corresponds to approximately 7% of the total FPM distribution area, were electrofished in River Harrijaurebäcken on 28th and 29th August 2021. Water temperature at the time of the investigation was 7.0–7.2 °C. Young of the year (YOY) trout were caught in low numbers (1.1 and 1.4 individuals/100 m^2) at two of the sites. Older trout were caught from all sites and in higher numbers (min: 1.2 ind./100 m^2; max: 7.4 ind./100 m^2) (Fig. 42). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM population to be functional. The mean abundance for YOY trout caught in River Silpakbäcken (four sites) was 0.64/100 m^2 and for older trout 4.43/100 m^2. European bullhead was the most abundant species in the river, another species caught was common minnow.

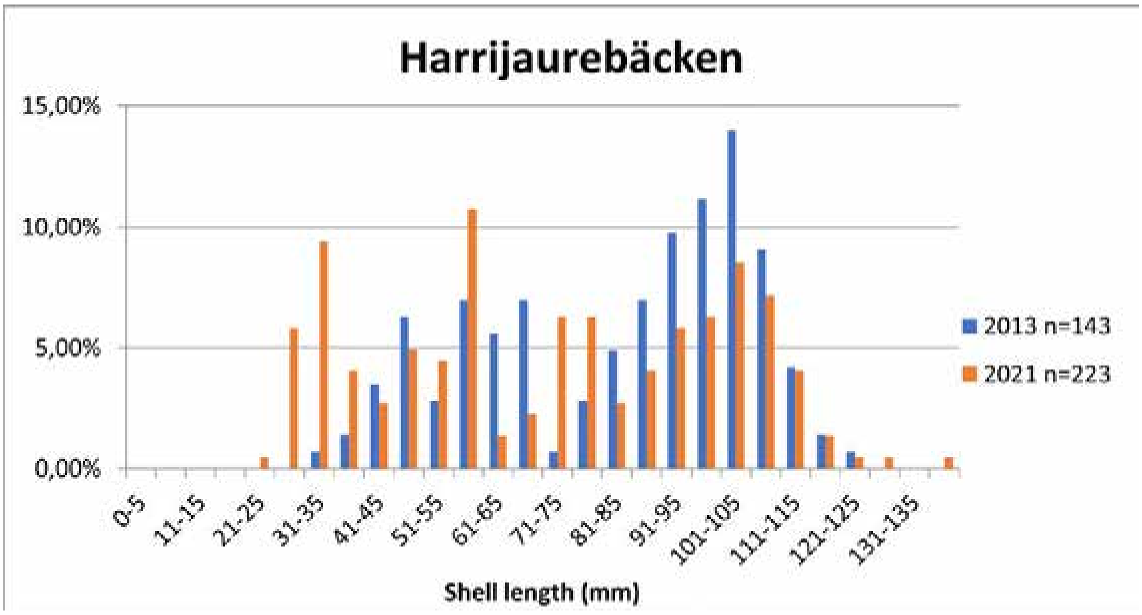

Figure 41. Size distribution of the mussels in river Harrijaurebäcken in 2013 and 2021.

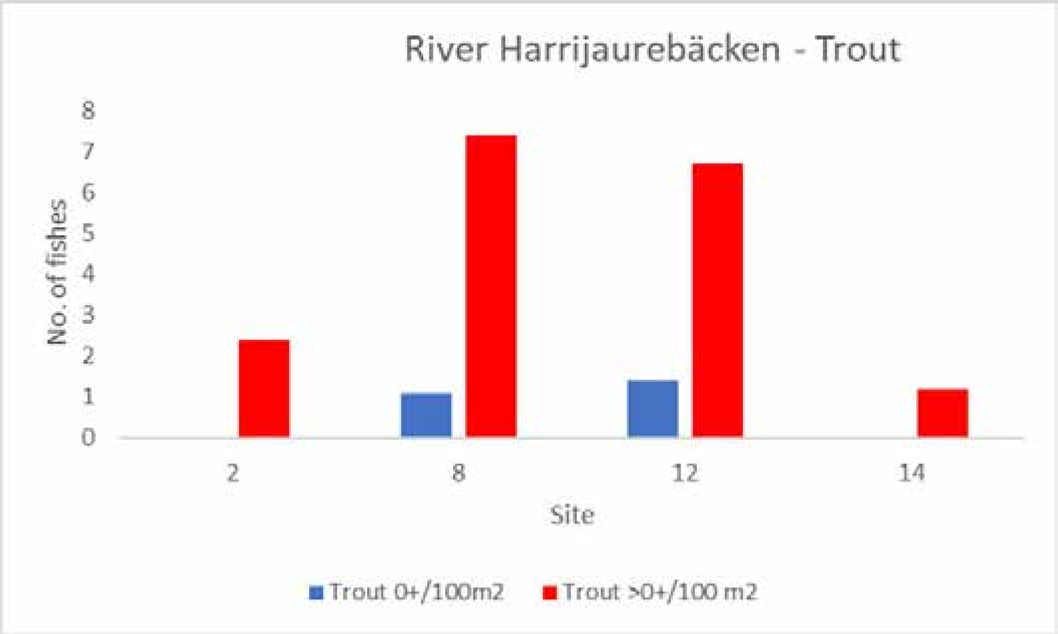

Figure 42. Number of trout caught in River Harrijaurebäcken using electrofishing in August 2021.

River Souksaurebäcken

River Souksaurebäcken is situated in the River Luleälven catchment area in Jokkmokk municipality (Fig. 43). It starts from the Lake Tjoalmejávrátja within the Sierre nature reserve and runs down to its outlet into River Stora Luleälven. The total length of Souksaurebäcken is 18.3 km and its mean width is 7.0 m. The gradient is 274 metres, from 353 m ASL from the outlet of Lake Tjoalmejávrátja down to the outlet into River Stora Luleälven at 79 m ASL. The total catchment area is 75.3 km^2 which is made up of 79.7% forest, 18.0% wetland, 2.0% surface water, and 0.3% moor land and other land (SMHI SVAR VERSION 2016_3). The environment around Souksaurebäcken (50 metres on either side of the river) is mainly mixed forest and boglands. The close environment around the river (5 metres on either side of the river) is dominated by grass and half grass but herbs and brushes are also present. The insolation into the river is neither extremely high nor low with an average shade of 6–50%, some areas along the river have even less (< 5%) shade.

The County Administrative Board of Norrbotten (CABN) has known of the occurrence of FPM in River Souksaurebäcken since 2005 when one large specimen was found. In 2019, 14 individuals were found in a stretch of 40 meters, 9 of the mussels were below 50 mm in length. A tributary to River Souksaurebäcken has a known population of 32,000 individuals (2019).

A part of the river runs within the Serri nature reserve.

Mussel investigations

18 random transects were investigated between 29th June and 1st of July 2020 (Fig. 44). The mean depth in River Souksaurebäcken at the time of the investigation was 0.5 m, and the water level was around average. The air temperature was 10–23 °C and water temperature 12–20 °C, the dominant bottom substrates were small and large boulders with stones and gravel in varying size.

Figure 43. River Souksaurebäcken. Photo: CABN.

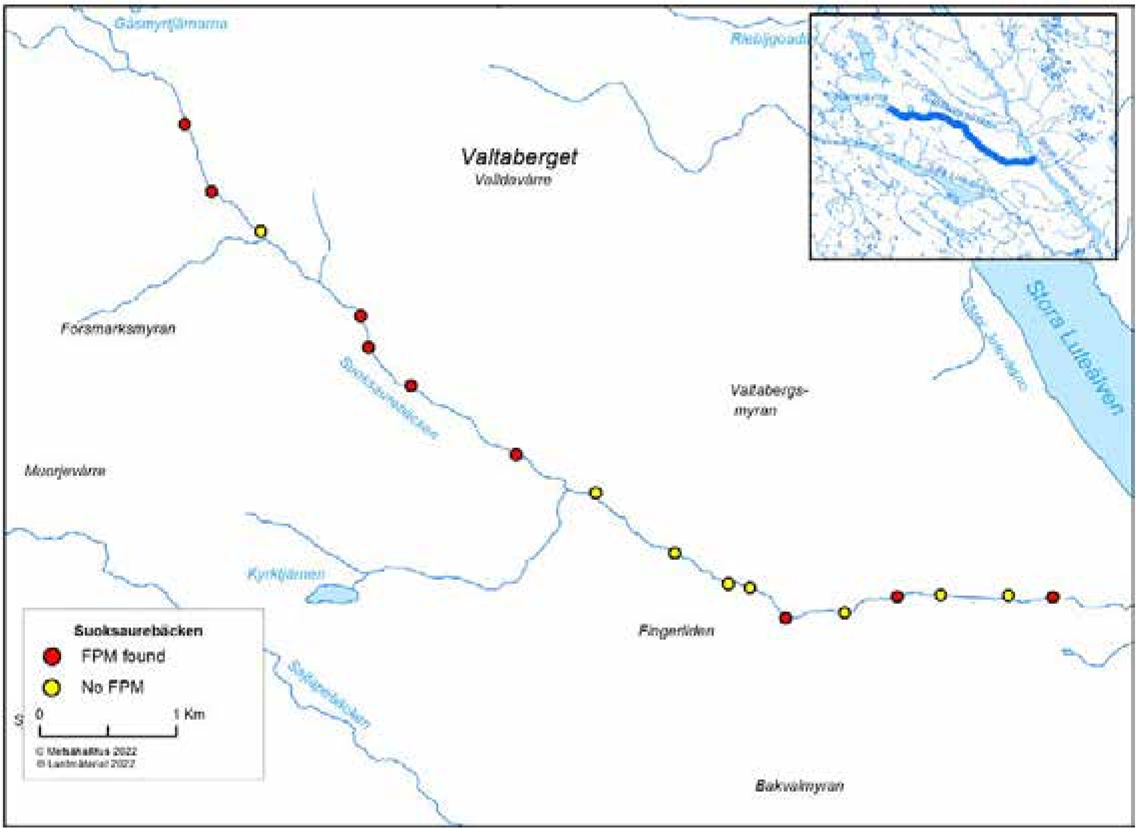

Figure 44. Random transects in river Souksaurebäcken. Small map: River Souksaurebäcken marked with thicker blue line.

The water current was dominated by gushing and streaming parts, but there were also parts with slow flowing and still water. The water was clear with no turbidity. Vegetation in the river was dominated by fouling algae (surface coverage 6–50%) and mosses were present to some extent. The amount of dead wood and detritus was small.

Mussels were distributed over an 8,500-meter-long stretch in the river and mussels were counted from an area of 2,597 m^2, so roughly 4% of the total mussel area was investigated. A total of 75 mussels were found in 9 of the 18 transects investigated. The estimated FPM population size was 1,789 individuals (Appendix 1). The mean density of the population was 0.03 individuals/m^2. The smallest mussel found was 13 mm in length. There was quite a good proportion of small mussels with 12% smaller than 50 mm and 2% smaller than 20 mm in length (Fig. 45).

Age of the juvenile mussels was studied from 15 individuals. The results show that the mussels grow in Souksaurebäcken relatively quickly so that the average shell length is 27 mm at the age of 10 years and 55 mm at the age of 20 years (Fig. 46).

Most mussels were found higher up in the river closer to the know population in the tributary, but a few mussels were also found in the lower part of the river. Small mussels were found in four of the 18 transects and no mussels at all were met in nine transects.

Host fish abundance

Three sites with a total area of 532 m^2, which corresponds to approximately 1% of the total FPM distribution area, were electrofished in River Souksaurebäcken on the 17th of August in 2020. Young of the year (YOY) trout were caught in low numbers (0.6 and 2.6 individuals/100 m^2) at two of the sites. Older trout were caught at all sites and in higher numbers (min: 5.5 ind./100 m^2; max: 7.1 ind./100 m^2) (Fig. 47). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM population to be functional.

The mean abundance for YOY trout caught in River Souksaurekbäcken (three sites) was 1.07/100 m^2 and for older trout 6.33/100 m^2. Trout was the most common species in the river and the only other species caught was European bullhead.

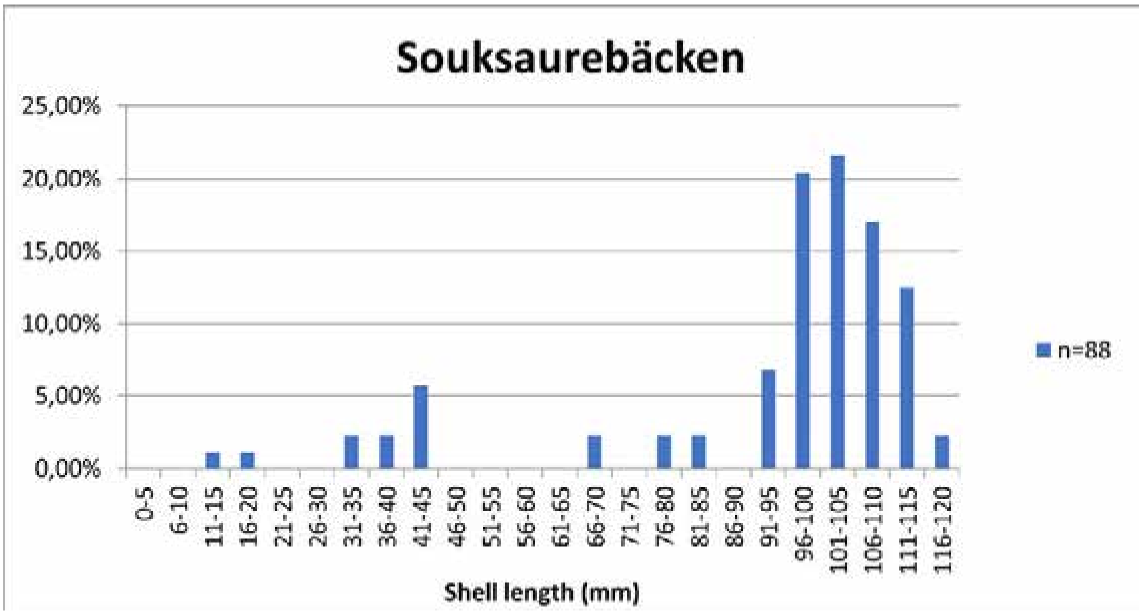

Figure 45. Size distribution of the mussels in river Souksaurebäcken in 2020.

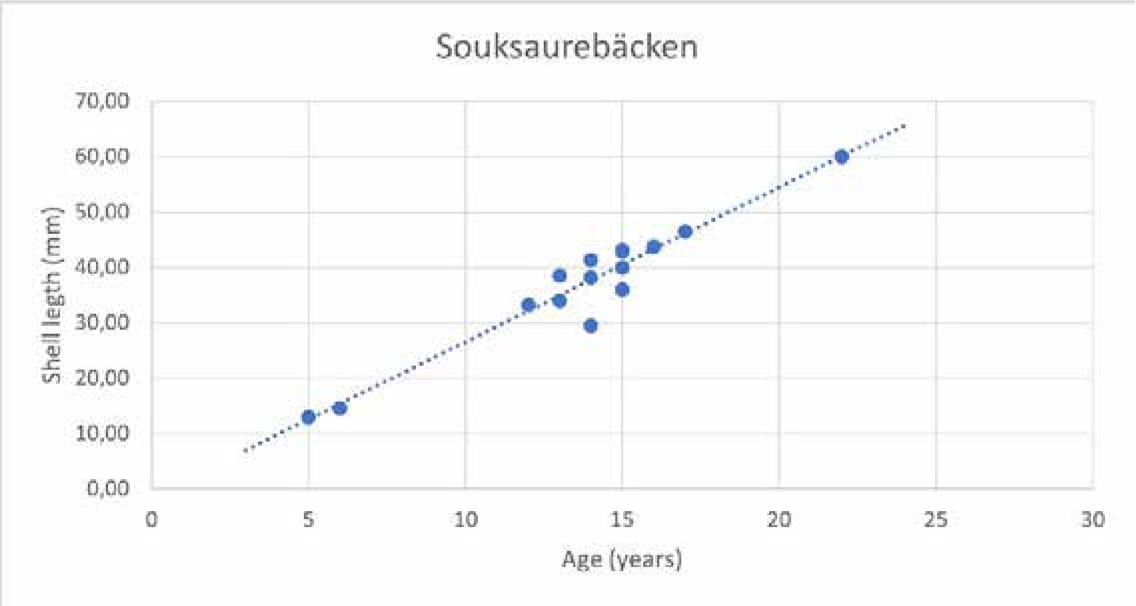

Figure 46. The growth rate of the juvenile mussels in Souksaurebäcken.

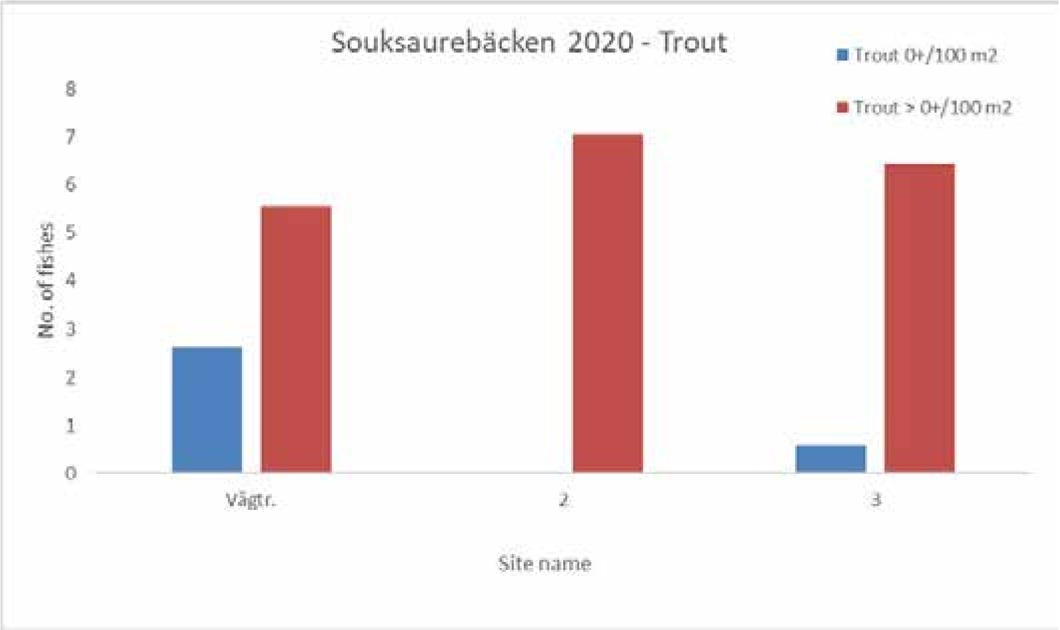

Figure 47. Number of trout caught in River Souksaurebäcken using electrofishing in August 2020.

River Varjekbäcken

River Varjekbäcken is situated in the River Luleälven catchment area in Jokkmokk municipality. It starts from the Lake Varjekträsket and runs down to its outlet into River Soinakbäcken close to Lake Soinakträsket. The total length of Varjekbäcken is 8.4 km and mean width of the river is 5.0 m. The gradient is 60 metres, from 228 m ASL from the outlet of Lake Varjekträsket down to the outlet in River Soinakbäcken at 168 m ASL. The total catchment area is 57.6 km^2 and this is made up of 69.6% forest, 25.6% wetland, 4.7% surface water, and 0.1% moor land and other land (SMHI SVAR VERSION 2016_3). The environment around River Varjekbäcken (50 metres on either side of the river) is mainly mixed forest and some boglands also surround the river (Fig. 48). The close environment (5 metres on either side of the river) is dominated by grass and half grass (*Carex* sp.) but also trees and brushes occur. The vegetation around the river gives quite good shade.

Figure 48. Age determination in River Varjekbäcken. Photo: CABN.

Mussel investigations

The County Administrative Board of Norrbotten (CABN) has known of the occurrence of FPM in River Varjekbäcken since 1993. In 2006 the population was investigated with 15 random transects by using aquascope (Fig. 49). The results showed that mussels occurred in a 5 km long stretch and the population size was estimated to be 60,500 individuals with a mean density of 2.4 individuals/m^2. Individuals less than 50 mm in length accounted for 3.9% of the population and the smallest mussel measured was 22 mm (Fig. 50). In 2017, a new survey was done and three more transects were added. The distribution range in 2017 was 7.6 km and the population size was estimated to be 141,300 individuals. Mean density was 3.7 individuals/m^2, and 2.2% of the individuals were below 50 mm in length with the smallest mussel 31 mm in length. Small mussels were found in two of the 18 transects and no mussels at all were found in two transects. Within the SALMUS project, no FPM population investigations have been done in the river Varjekbäcken.

The mean depth in River Varjekbäcken at the time of the investigation in 2017 was 0.6 m, and the water level varied between average to high. The air temperature was 11–18 °C, water temperature 10–19 °C, and the dominant bottom substrate was stone (51–100%), but boulders and sand were also found to some extent. The water current was dominated by streaming parts, but there were also a few parts with gushing and slow flowing water. The water varied between coloured and clear with no turbidity. Vegetation in the river was dominated by fouling algae (surface coverage 6–50%). The amount of dead wood and coarse detritus was moderate while there were also small amounts of fine detritus.

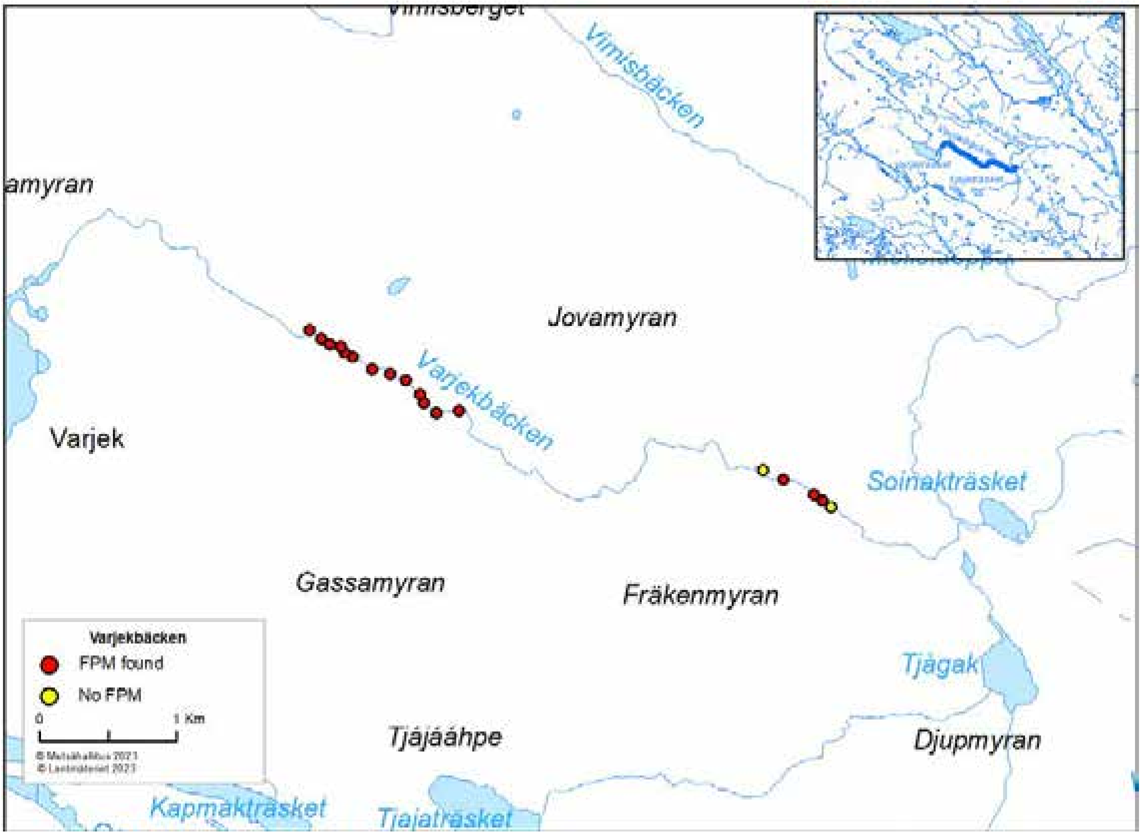

Figure 49. Random transects in river Varjekbäcken. Small map: River Varjekbäcken marked with thicker blue line.

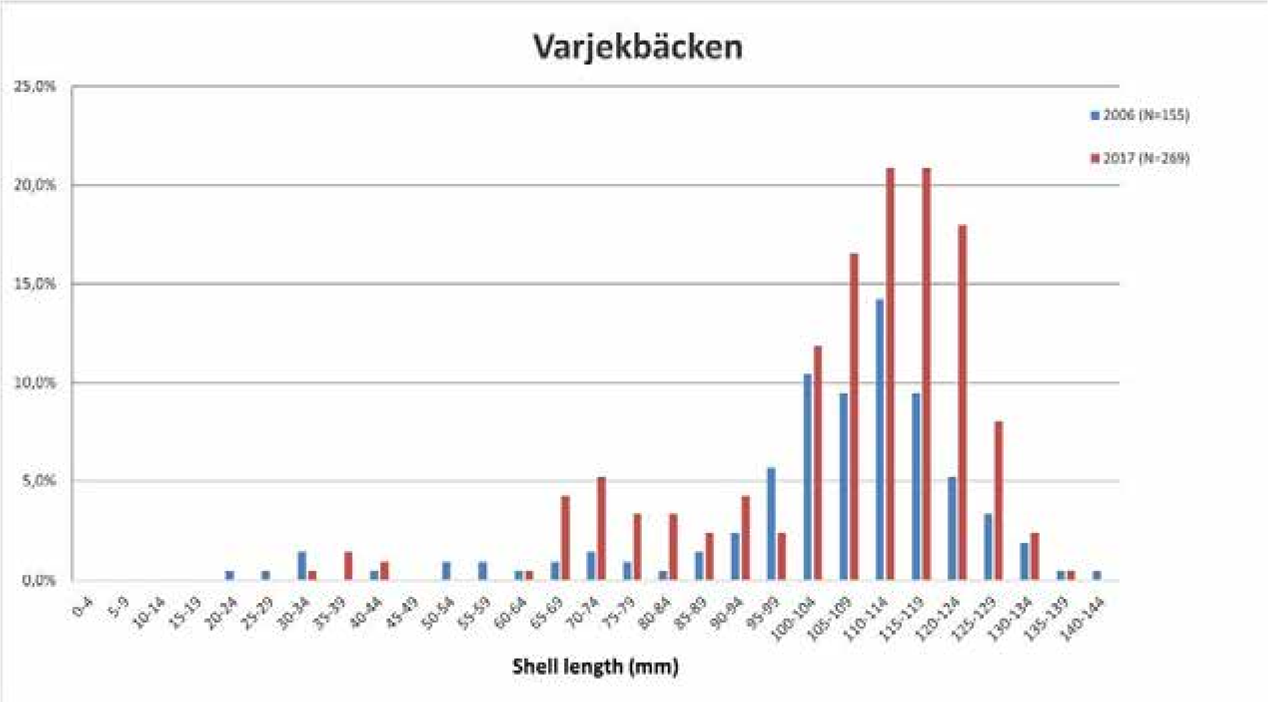

Figure 50. Size distribution of the mussels in river Varjekbäcken in 2006 and 2017.

Glochidia study

Five sites with a total area of 1,540 m^2 were electrofished in River Varjekbäcken on 18th and 19th June 2019. The water temperature at the time of the investigation was 18.2–18.5 °C. Not a single trout was caught, so there was no possibility to look for glochidia.

Host fish abundance

Four sites with a total area of 1,335 m^2, which corresponds to approximately 4% of the total FPM distribution area, were electrofished in River Varjekbäcken on 30th September and 1st November 2020. The water temperature at the time of the investigation was 7.6–8.3 °C. Young of the year (YOY) trout were only caught at one site and in low numbers (2.0 individuals/100 m^2). Older trout were also caught only at one site and in low numbers (1.0 individuals/100 m^2) (Fig. 51). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM population to be functional. The mean value for YOY trout caught in River Varjekbäcken (five sites) was 0.4 ind./100 m^2 and for older trout 0.2 ind./100 m^2. European bullhead was the most common species in the river, other species caught were burbot and perch.

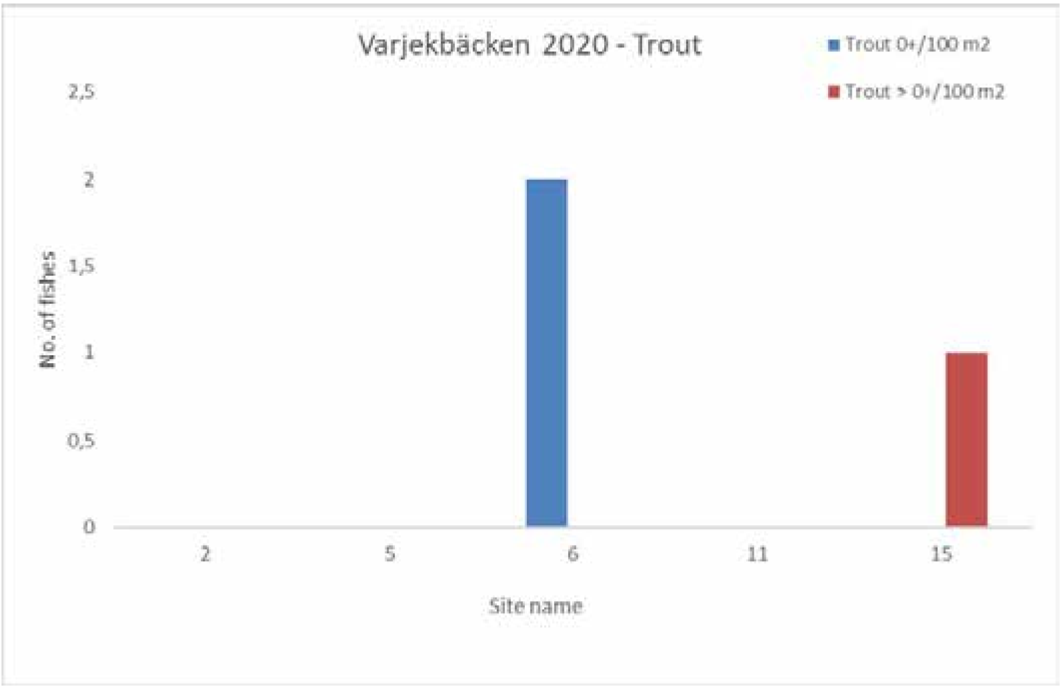

Figure 51. Number of trout caught in River Varjekbäcken using electrofishing in autumn 2020.

River Görjeån

River Görjeån is situated in the River Luleälven catchment area in Jokkmokk and Boden municipalities. It starts from the Lake Gåbddåjávrre and runs down to its outlet into River Luleälven. The total length of Görjeån is 66 km, if all lakes are included, and its mean width is 10.1 m in the upper part and 17.4 m in the lower part. The gradient is 293 metres, from 343 m ASL from the outlet of Lake Gåbddåjávrre down to the outlet into River Stora Luleälven at 50 m ASL. The total catchment area is 325.4 km^2 and this is made up of 81.2% forest, 17.1% wetland, 1.2% surface water, and 0.3% moor land and other land (SMHI SVAR VERSION 2016_3). The environment around Görjeån (50 metres on either side of the river) is mainly mixed forest in the lower part of the river while coniferous forest is more common in the upper part. The close environment around the river (5 metres on either side of the river) is dominated by brushes (*Salix* sp., alder, and juniper) but trees such as pine and birch as well as grass and half grass (*Carex* sp.) are also present. The number of trees around the river differs to some extent between the upper and lower parts, the former usually with some higher insolation (shade less than 5%) and the latter usually with a little less insolation (shade 5–50%). However, a few locations with little or no shade were present in the lower part as well.

The County Administrative Board of Norrbotten (CABN) has known of the occurrence of FPM in River Görjeån since the beginning of 1990s. FPM is also present in two tributaries of the River Görjeån. One with a small population of approximately 300 individuals (2016) and one larger population with around 18,000 individuals where the proportion of mussels smaller than 50 mm in length was even 39% (2021).

River Görjeån with its tributaries are part of a Natura 2000 site (SE0820728) and the lower part of the river is also protected by two nature reserves (Görjeån and Storspikberget). Since there are two larger lakes in the system the investigation of FPM was divided into two different parts.

River Görjeån (upper part)

The upper part of Görjeån river (Fig. 52) runs from the outlet of Lake Larvesjön down to the Lake Tjerkissjön. The stretch is 5.4 km long and FPM are distributed over the whole stretch. 21 random transects were investigated between 8th and 11th of July 2019. The mean depth in River Görjeån at the time of the investigation was 0.5 m, and the water level was around average. The air temperature was 18–22 °C. The water temperature was 14–17°C and the dominant bottom substrates were large boulders, while small boulders, stones and gravel dominated in some areas. The water current was almost exclusively streaming but a few locations had slow flowing water. The water was clear with no turbidity. Vegetation in the river was mostly dominated by fouling algae (surface coverage 51–100%) while mosses and overwater plants were dominating in some areas. The amount of dead wood and detritus varied between little and moderate in different areas.

Mussel investigations

Mussels were counted in an area of 2,959 m^2, so roughly 5% of the total mussel area was investigated. A total of 1,966 mussels was found in 12 of the 21 transects investigated (Fig. 53). The estimated FPM population size was 59,849 individuals (Appendix 1). The mean density of the population was 1.09 individuals/m^2. The smallest mussel found was 24 mm in length.

The size distribution did show quite a good recruitment rate with 13% of the mussels being smaller than 50 mm in length (Fig. 54). Small mussels were found in seven of the 21 transects and no mussels at all were found in 9 of the transects.

Most of the mussels were found in the lower part of the stretch where the habitat is more suitable. Bedrock was more common in the upper parts which makes it a less suitable habitat for the mussels. In addition, this part was also more heavily affected by actions from the timber floating era. Blasted stones and boulders were found here to a larger extent as well as sections that were straightened and cleared from boulders and stones.

Figure 52. River Görjeån upper part. Photo: CABN.

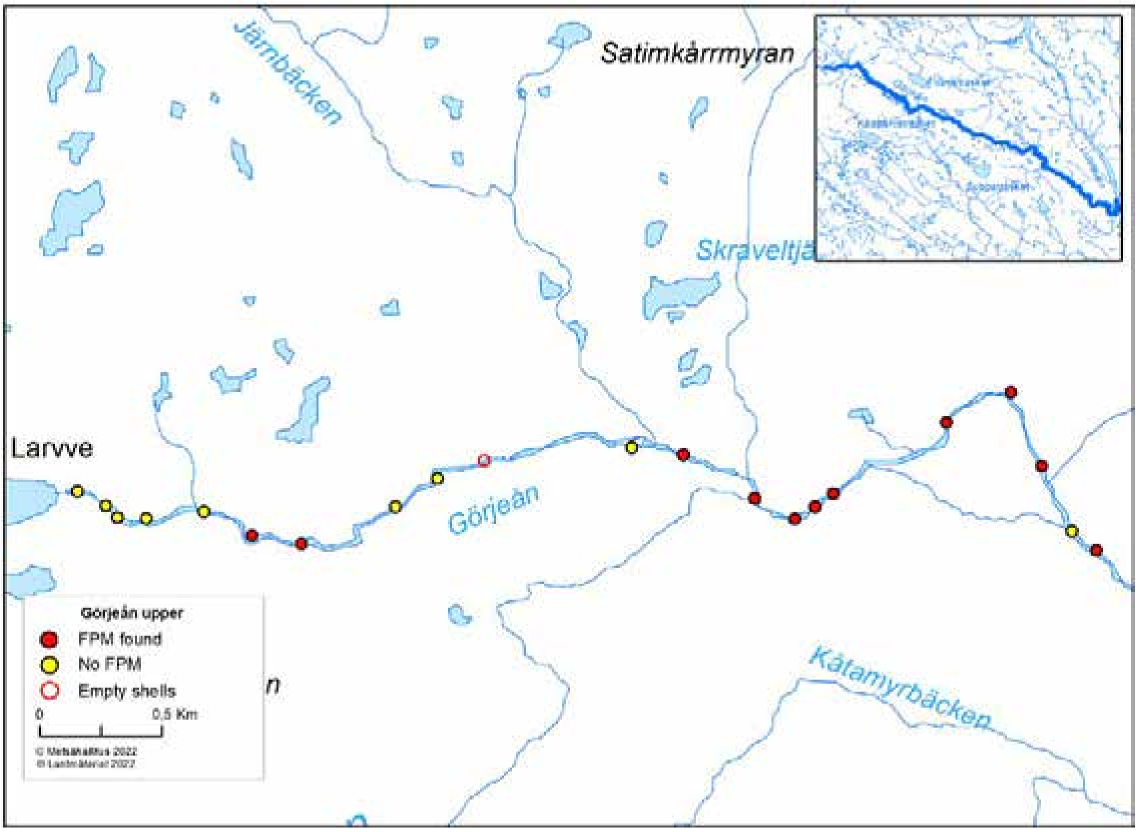

Figure 53. Random transects in river Görjeån (upper part). Small map: river Görjeån marked with thicker blue line.

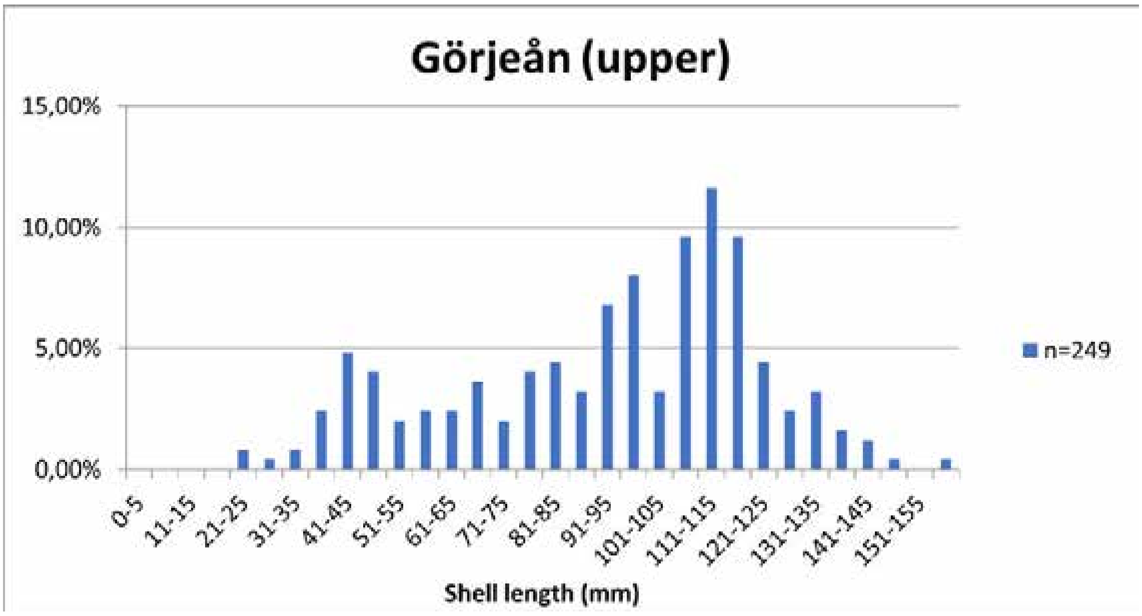

Figure 54. Size distribution of the mussels in the river Görgeån upper part in 2019.

Glochidia study

Three sites with a total area of 1,642 m^2 were electrofished in River Görjeån (upper part) on 18th and 19th June 2019. Water temperature at the time of the investigation was 17.9–18.6 °C. Trout were caught at all sites and the total catch was 13 fish. 11 brown trout individuals (85%) were infected with glochidia larva. The total number of glochidia were > 1,235 and the mean number on the gills was > 95 glochidia/trout. Four of the trout individuals had more than 100 glochidia on their gills.

Host fish abundance

Five sites with a total area of 1,650 m^2, which corresponds to approximately 3% of the total FPM distribution area, were electrofished in River Görjeån (upper part) between 19th and 20th September 2019. The water temperature at the time of the investigation was 7.0–8.0 °C. Young of the year (YOY) trout were present at all sites in low numbers (min: 1.2 individuals/100 m^2; max: 5.0 individuals/100 m^2). Older trout were caught at three sites also in quite low numbers (min: 2.6 individuals/100 m^2; max: 3.8 individuals/100 m^2) (Fig. 55). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM population to be functional. The mean abundance for YOY trout caught in River Görjeån upper part (five sites) was 2.6 ind./100 m^2 and for older trout 2.0 ind./100 m^2. Common minnow was the most abundant species in the river and the only other species caught were burbot and European bullhead.

River Görjeån (lower part)

The lower part of the river Görgeån (Fig. 56) runs from the slow flowing part Luovosädno, situated downstream Lake Måskávrre, down to River Luleälven. The stretch from Luovosädno to River Luleälven is 33 km long

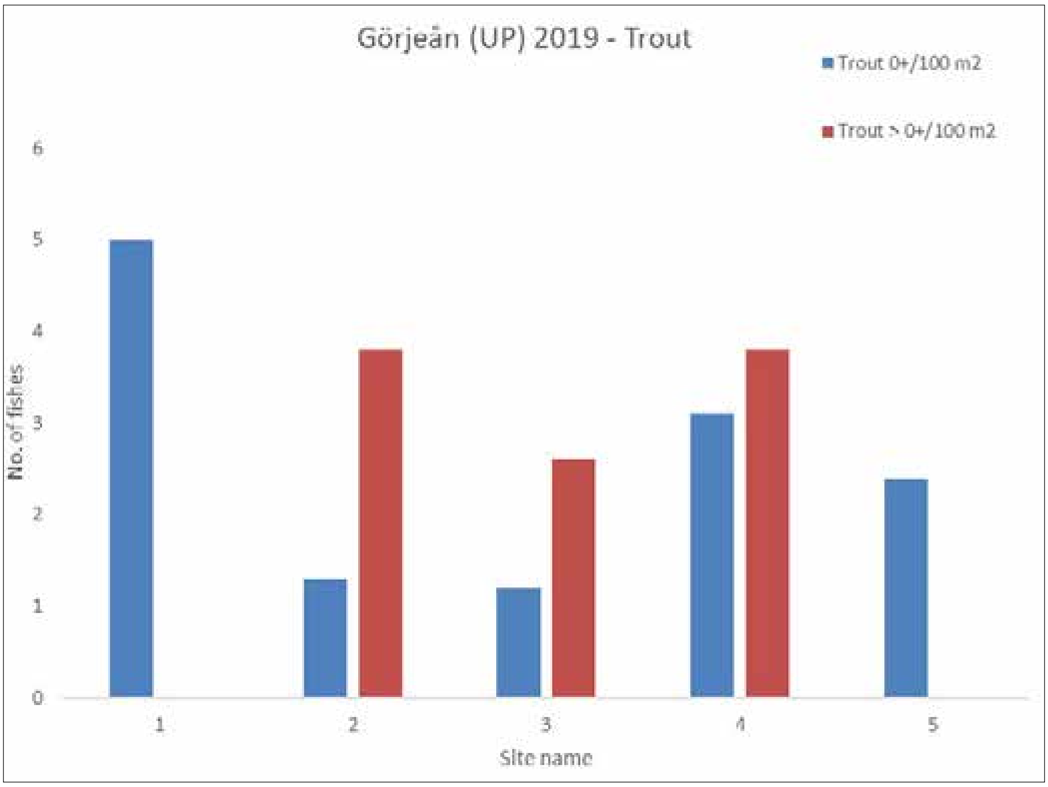

Figure 55. Number of trout caught in River Görjeån (upper part) using electrofishing in autumn 2019.

Figure 56. River Görjeån lower part. Photo: CABN.

and FPM is distributed along a 5 km long stretch in the middle/upper part of the river. 18 random transects were investigated between 6th July and 16th September 2020. The mean depth in River Görjeån at the time of the investigation was 0.5 m, and the water level was around average. Air temperature was 4–14 °C, water temperature 8–16 °C, and the dominant bottom substrates were boulders and stones. The water current is dominated by streaming parts, but there were also a few parts with slow flowing water. Water was clear with almost no turbidity. Vegetation in the river was dominated by fouling algae (surface coverage 51–100%) while mosses were common in some areas. The amount of dead wood and detritus was small.

Mussel investigations

Mussels were counted in an area of 6 060 m^2, so roughly 7 % of the total mussel area was investigated. Only 87 mussels were found in 12 of the 18 transects investigated (Fig. 57). The estimated FPM population size was 1,742 individuals. The mean density of the population was 0.02 individuals/m^2. The smallest mussel found was 44 mm in length.

The size distribution was composed based on 105 individuals and it shows that there are mainly large/older mussels in this part of the river (Fig. 58). Only 1% of the mussels were below 50 mm in length. Small mussels were found only in one of the transects.

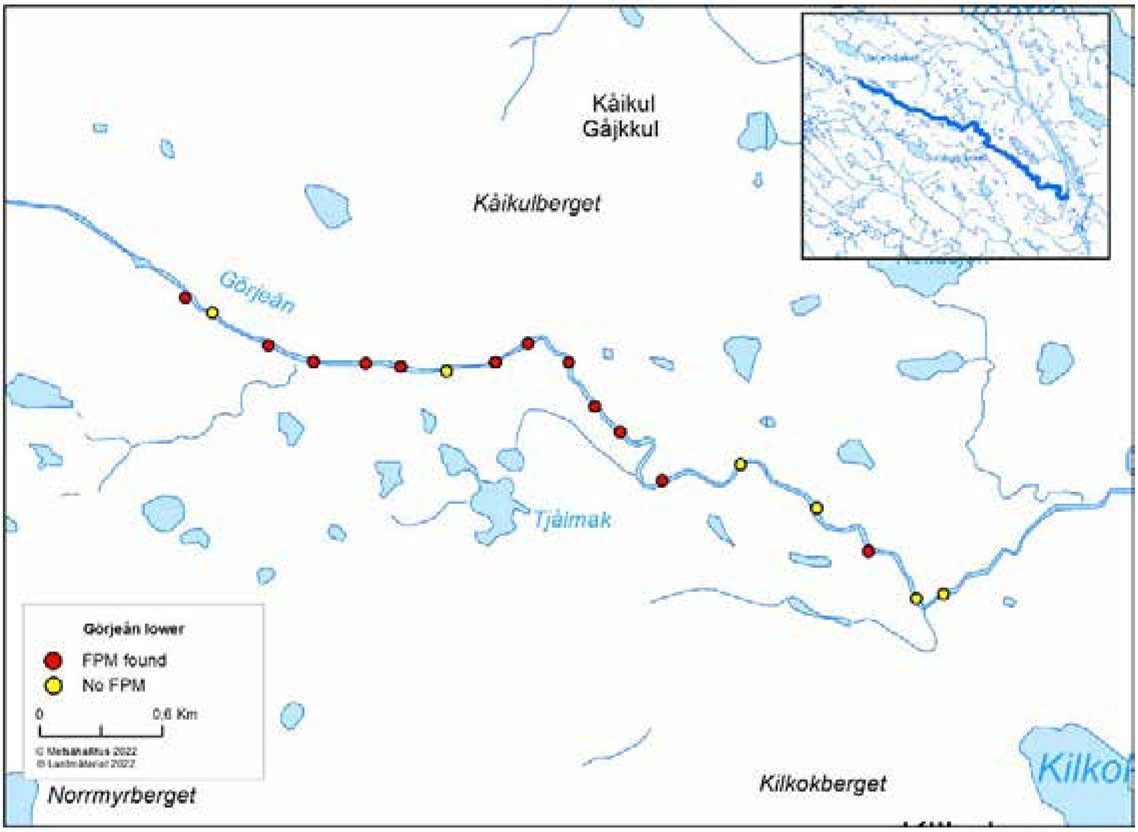

Figure 57. Random transects in river Görjeån (lower part). Small map: River Görjeån marked with thicker blue line.

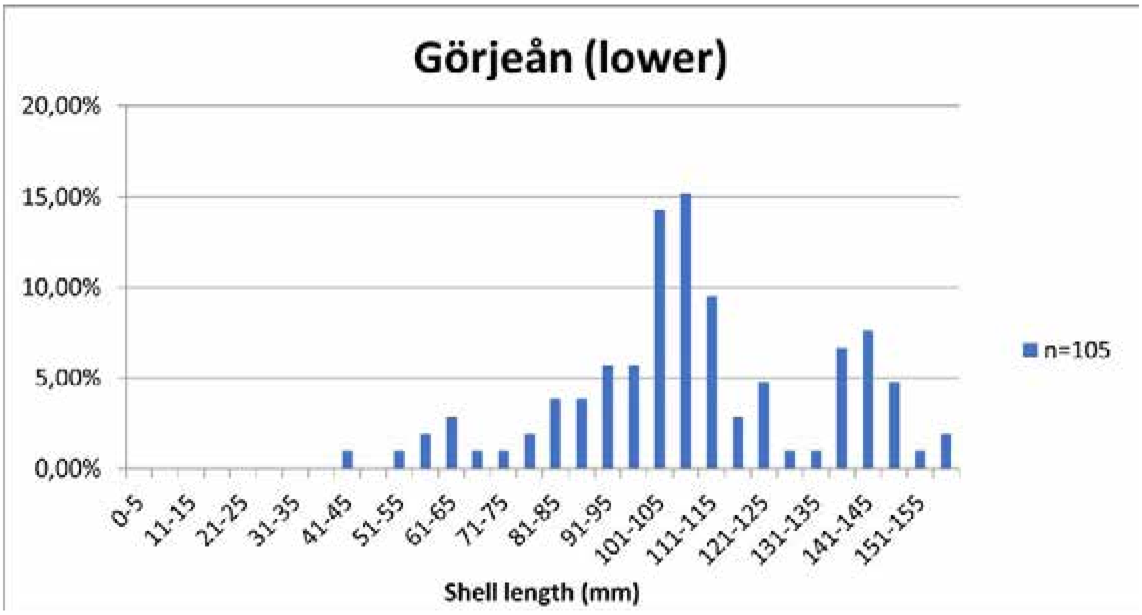

Figure 58. Size distribution of the mussels in the river Görgeån lower part in 2020.

Host fish abundance

Four sites with a total area of 1,133 m², which corresponds to approximately 1% of the total FPM distribution area, were electrofished in River Görjeån (lower part) on 4th September and 1st November 2020. The water temperature at the time of the investigation was 8.3–12.7 °C. Young of the year (YOY) trout were caught only at one site and in very low numbers (1.0 individuals/100 m²). Older trout were caught only at the same site also in quite low numbers (2.0 individuals/100 m²) (Fig. 59). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m² would be needed for a Scandinavian FPM population to be functional. The mean value for YOY trout caught in River Görjeån lower part (four sites) was 0.25 ind./100 m² and for older trout 0.5 ind./100 m². European bullhead was the most common species in the river, other species caught were burbot, common minnow and northern pike.

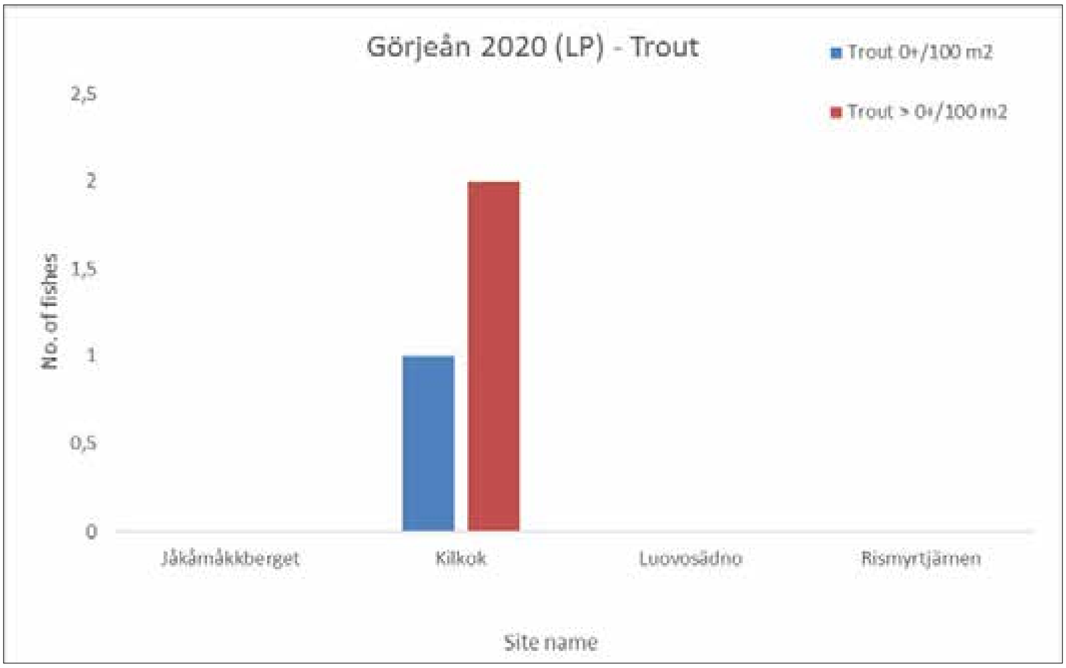

Figure 59. Number of trout caught in the River Görjeån (lower part) using electrofishing in autumn 2020.

3.4.1.3 Piteälven catchment

The River Piteälven (Swedish Piteälven) is a 410 km long river which flows from the Sulitelma mountain range close to the Norwegian border in Arjeplog municipality down to its outlet in Bothnian Bay near to town of Piteå. The main rivers in the system are River Abmoälven, River Varjisån and River Lillpiteälven. The catchment area covers 11,285 km^2, and River Piteälven and its tributaries are protected by Natura 2000 (SE0820434). It is also a so-called "National River" where water regulatory and other activities connected to hydropower are forbidden by Swedish law, although there is a hydropower plant Sikfors around 20 km upstream from the outlet. There are also some regulation dams higher up in the river.

River Korsträskbäcken

River Korsträskbäcken (Fig. 60) is situated in the River Piteälven catchment area in Älvsbyn municipality. It starts from the Lake Stor-Korsträsket and runs down through the town of Älvsbyn to its outlet into River Piteälven. The total length of Korsträskbäcken is 11.4 km and its mean width is 6.3 m. The gradient is 51 metres, from 82 m ASL from the outlet of Lake Stor-Korsträsk down to the outlet into River Piteälven at 31 m ASL. The total catchment area is 114.5 km^2 and this is made up of 78.4% forest, 5.6% agricultural land, 5,5% surface water, 5.0% moor land and other land, 3.9% urban area and 1.6% wetland (SMHI SVAR VERSION 2016_3). The environment around Korsträskbäcken (50 metres on either side of the river) is dominated by

Figure 60. River Korsträskbäcken. Photo: CABN.

mixed forest. The lower parts of the river run through urban areas with lawns, roads and residential quarters and some parts of the river are strongly affected by deforestation or other human actions. The close environment around the river (5 metres on either side of the river) is dominated by trees (fir, pine, alder, birch, and rowan), grass and half grass (*Carex* sp.) and herbs (meadowsweet and bilberries). The vegetation around the river gives good shade.

The County Administrative Board of Norrbotten (CABN) has known about the occurrence of FPM in River Korsträskbäcken since 2004 when a couple of larger individuals were found.

River Korsträskbäcken is a part of the Natura 2000 area Piteälven (SE0820434).

Mussel investigations

18 random transects were investigated with aquascope between 19th and 22nd July 2020 (Fig. 61). The mussels are distributed on a 7.1 km long stretch from the residential area Grekland in the city of Älvsbyn close to the outlet of Lake Lill-Korsträsket. The mean depth in River Korsträskbäcken at the time of the investigation was 0.4 m, and the water level was low. The air temperature was 14–18 °C, water temperature 14–16 °C, and the dominant bottom substrate was sand. Stones and gravel were also present to some extent. The water current is either streaming or slow flowing and the water was coloured with almost no turbidity. A few areas had clear water. Vegetation in the river was dominated

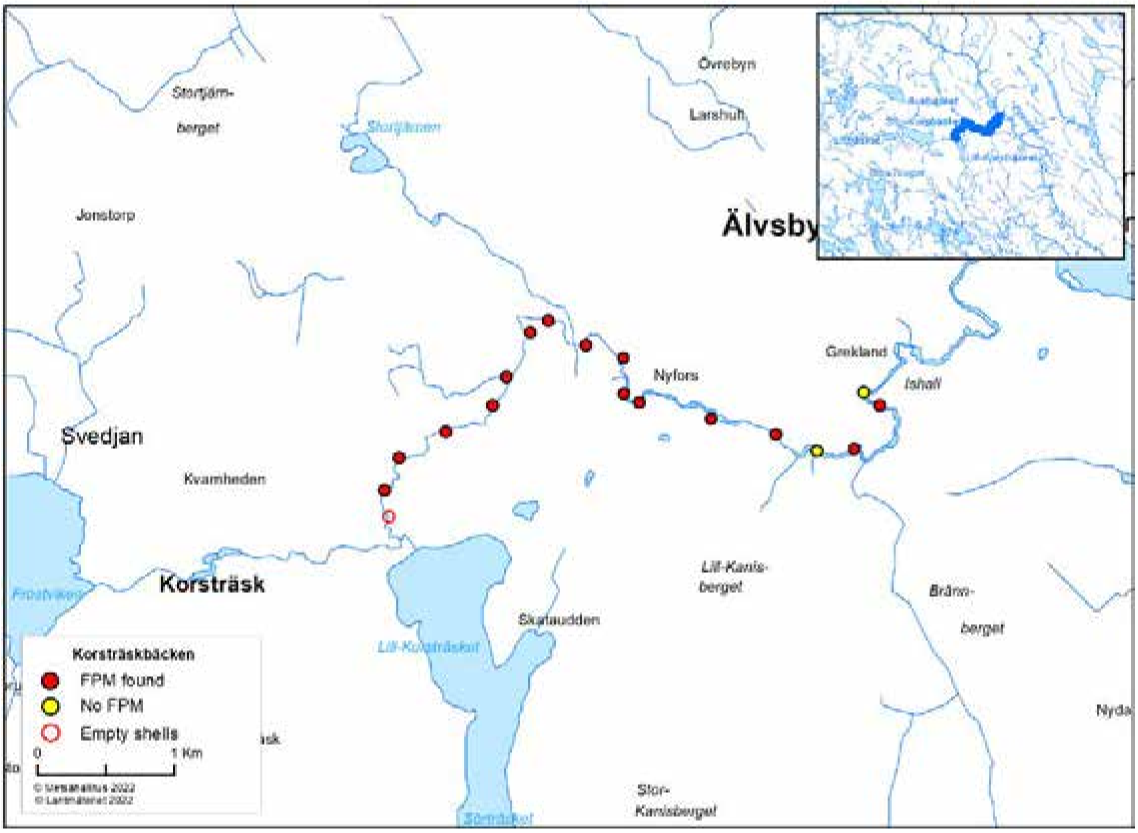

Figure 61. Random transects in the river Korsträskbäcken. Small map: River Korsträskbäcken marked with thicker blue line.

by mosses and vascular plants while fouling algae were almost absent. There was moderate to high amount of detritus and dead wood present in the river.

The majority of the investigated transects had coloured water and some of them had a lot of dense vascular plant vegetation. The transects in the town of Älvsbyn had more coloured water and a lot of trash like beer cans, bikes, and candy papers. A bit further up from Älvsbyn the river became more optimal, meandering calm stretches with sandy bottom were mixed with faster flowing parts with gravel bottom. This is where most of the mussels were found.

Mussels were counted in an area of 2,266 m^2, so roughly 5% of the total mussel area was investigated. 252 mussels were found in 15 of the 18 transects investigated. The estimated FPM-population size was 4,656 individuals (Appendix 1). The mean density of the population was 0.1 individuals/m^2 and the smallest mussel found 49 mm in length.

The size distribution shows that recruitment is scarce and that the population is mainly made up of older individuals (Fig. 62). Only 0.5% of the mussels were below 50 mm in length. No mussels at all were found in three of the eighteen investigated transects.

Host fish abundance

Four sites with a total area of 1,260 m^2, which corresponds to approximately 3% of the total FPM distribution area, were electrofished in River Korsträskbäcken on 25th August and 20th September 2021. The water temperature at the time of the investigation was 8.9–13.0 °C. No young of the year (YOY) trout were caught at any of the sites. Older trout were caught at two sites in low numbers (min: 0.5 ind./100 m^2; max: 0.8 ind./100 m^2) (Fig. 63). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM population to be functional. The mean abundance for older trout was 0.33/100 m^2. European bullhead was the most common species in the river, other species caught were common minnow, grayling and burbot.

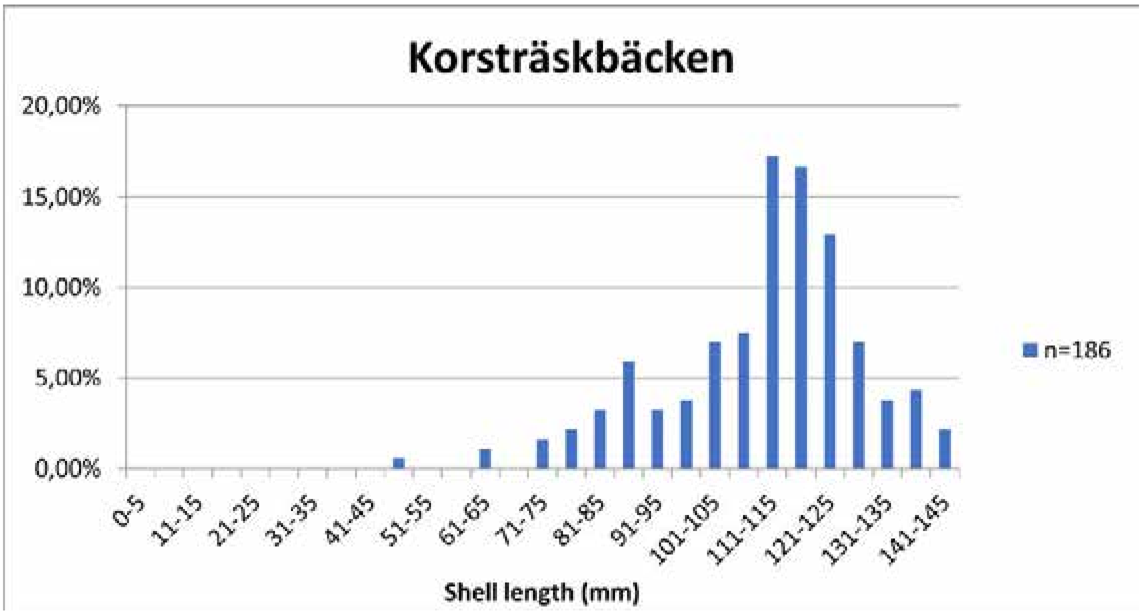

Figure 62. Size distribution of the mussels in the river Korsträskbäcken in 2020.

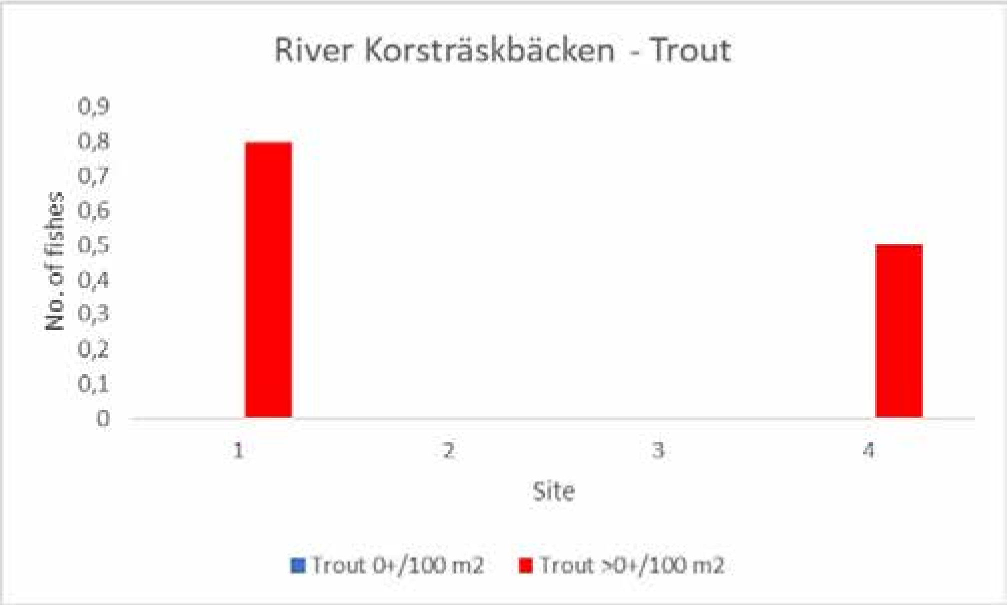

Figure 63. Number of trout caught in the River Korsträsbäcken using electrofishing in August 2021.

River Ljusträskbäcken

River Ljusträskbäcken is situated in the River Piteälven catchment area in Arvidsjaur municipality. It starts from the Lake Ljusträsket and runs down to its outlet into River Piteälven (Fig. 64). The total length of Ljusträskbäcken is 17.5 km and its mean width is 15.4 m. The gradient is 66 metres, from 281 m ASL from the outlet of Lake Ljusträsket down to the outlet into River Ljusträskbäcken at 215 m ASL. The total catchment area is 217.7 km^2 and this is made up of 83.0% forest, 13.2% wetland, 3.3% surface water and 0.5 % moor land and other land (SMHI SVAR VERSION 2016_3). The environment around River Ljusträskbäcken (50 metres on either side of the river) is mainly coniferous forest but mixed forest and boglands are also present. The close environment around the river (5 metres on either side of the river) is dominated by grass and half grass and brushes (alder, juniper, and birch). The insolation is neither very high nor very low (shade mostly around 5–50%, but there are some areas with a shade < 5%).

Mussel investigations

The County Administrative Board of Norrbotten (CABN) has known of the occurrence of FPM in River Laxtjärnbäcken since 2004 when WWF made a larger investigation. In 2012 CABN revisited the 15 transects from 2004 and did then discover that the distribution area of the FPM reached much higher up in the river, a total of 10 km. One more transect was added higher up in the river (Fig. 64) and the estimated FPM population size in 2012 was 759,631 individuals. The mean density of the population was 4.9 individuals/m^2. The size distribution did show that the population was recruiting relatively well, with 16.1% of the mussels being smaller than 50 mm in length with the smallest mussel found 17 mm. The FPM population in River Ljusträskbäcken has not been investigated within SALMUS but is included in CABN regional monitoring program of FPM. The latest investigation, done in 2018, showed similar results as in 2012 with a population of 791 988 individuals (Appendix 1), with a mean density of 5.1 individuals/m^2, 16.2% of individuals being smaller than 50 mm in length and the smallest mussel with a

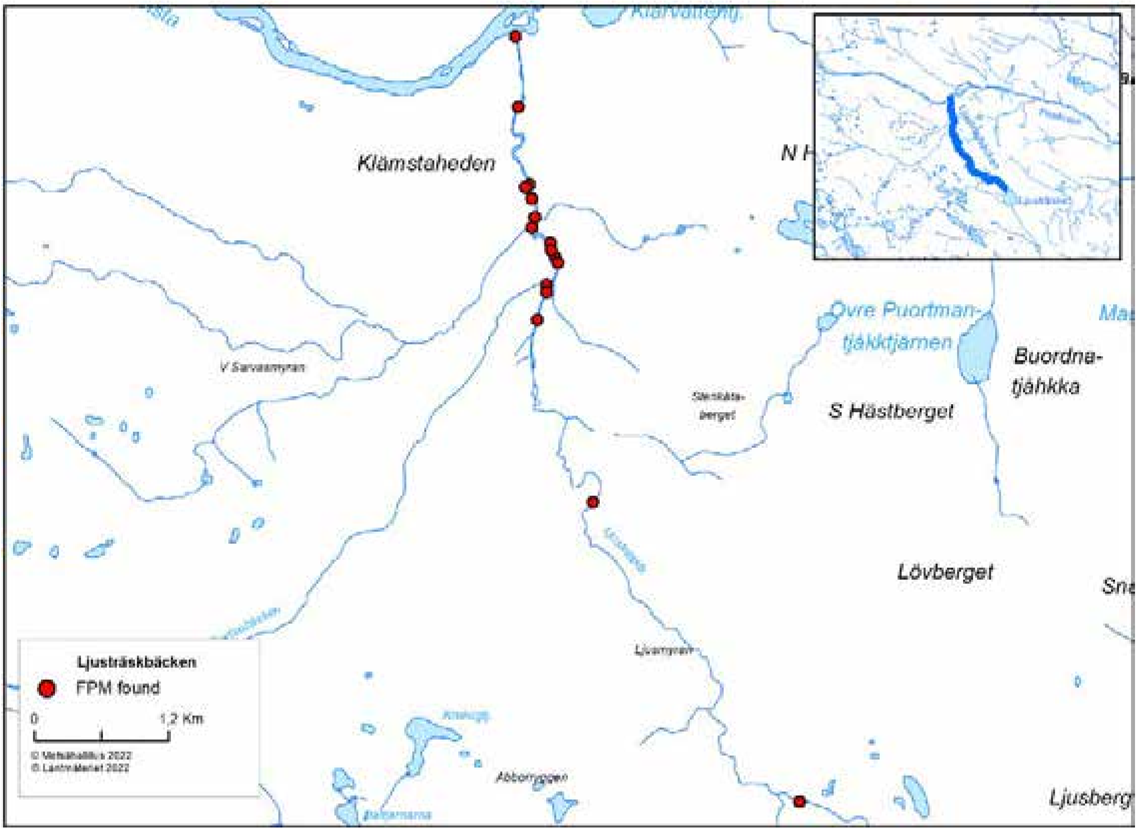

Figure 64. Random transects in the river Ljusträskbäcken. Small map: River Ljusträskbäcken marked with thicker blue line.

length of 15 mm (Fig. 65). Small mussels were found in all except one of the investigated transects and none of the transects were lacking mussels. Six tributaries running to River Ljusträskbäcken have FPM populations and this can be considered as a core area for FPM in the River Piteälven catchment area.

Age of the juvenile mussels was studied from 20 individuals. The average shell length at the age of 10 years was 26 mm long and 48 mm at the age of 20 years (Fig. 66). The result for 20-year-old mussels is a bit unreliable, because the data included only one mussel that was over 15 years old.

The mean depth in River Ljusträskbäcken at the time of the investigation in 2018 was 0.5 m, and the water level varied between average to high. Air temperature was 13–19 °C, water temperature 14–17 °C, and dominant bottom substrates were stones, boulders, and sand. The water current was almost exclusively streaming, and water varied between coloured and clear, most often without turbidity. Vegetation in the river was dominated by fouling algae (surface coverage 6–50%) and vascular plants. The amount of dead wood and sediment was small.

River Laxtjärnbäcken is part of the Natura 2000 area Piteälven (SE0820434), and work is going on within CABN to form a nature reserve in this area based on its freshwater habitat values, mainly due to the large size of local FPM population and occurrence of this species in several adjacent rivers.

Glochidia study

Five sites with a total area of 1,600 m^2 were electrofished in River Ljusträskbäcken on 12th and 13th June 2019. The water temperature at the time of the investigation was 12.3–14.4 °C. Only a total of four brown trout were caught at one site. All four trout individuals were

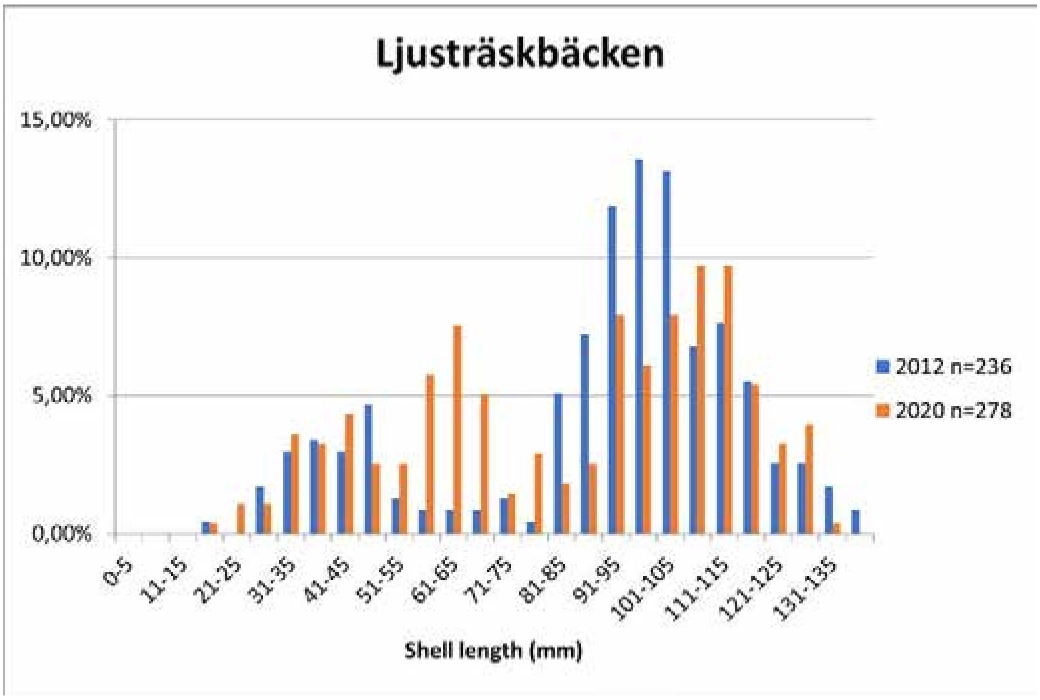

Figure 65. Size distribution of the mussels in Ljusträskbäcken in 2012 and 2020.

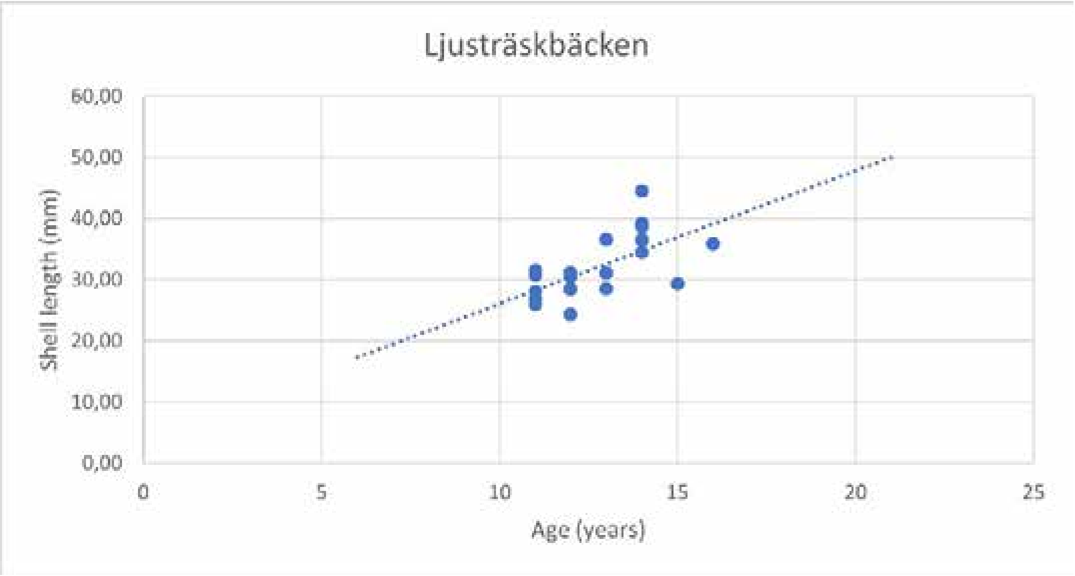

Figure 66. Growth rate of young mussels in River Ljusträskbäcken. Age class 15–20 years was mostly missing from the sample, which makes the estimate unreliable between 15–20 years.

infected with glochidia larva. The total number of glochidia were 116 (9–58 glochidia/trout) and the mean number on the gills were 29 glochidia/trout. Inspection of glochidia is shown in Fig. 67.

Host fish abundance

Five sites with a total area of 1,487 m^2, which corresponds to approximately 1% of the total FPM distribution area, were electrofished in River Ljusträskbäcken on 1st and 2nd September 2021. The water temperature at the time of the investigation was 10.2–10.6 °C. Young of the year (YOY) trout were caught at two out of the five sites in low numbers (min: 1.3 individuals/100 m^2; max: 3.4 individuals/100 m^2). Older trout were caught at three sites, also in low numbers (min: 1.2 ind./100 m^2; max: 1.8 ind./100 m^2) (Fig. 68). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM population to be functional. The mean abundance for YOY trout caught in River Ljusträskbäcken (five sites) was 0.9 ind./100 m^2 and for older trout 1.0 ind./100 m^2. European bullhead was the most common species in the river, other species caught were common minnow, grayling, burbot, northern pike and European brook lamprey.

Figure 67. Investigation of glochidia larvae on gills of brown trout in the River Ljusträskbäcken in June 2019. Photo: Patrik Olofsson, CABN.

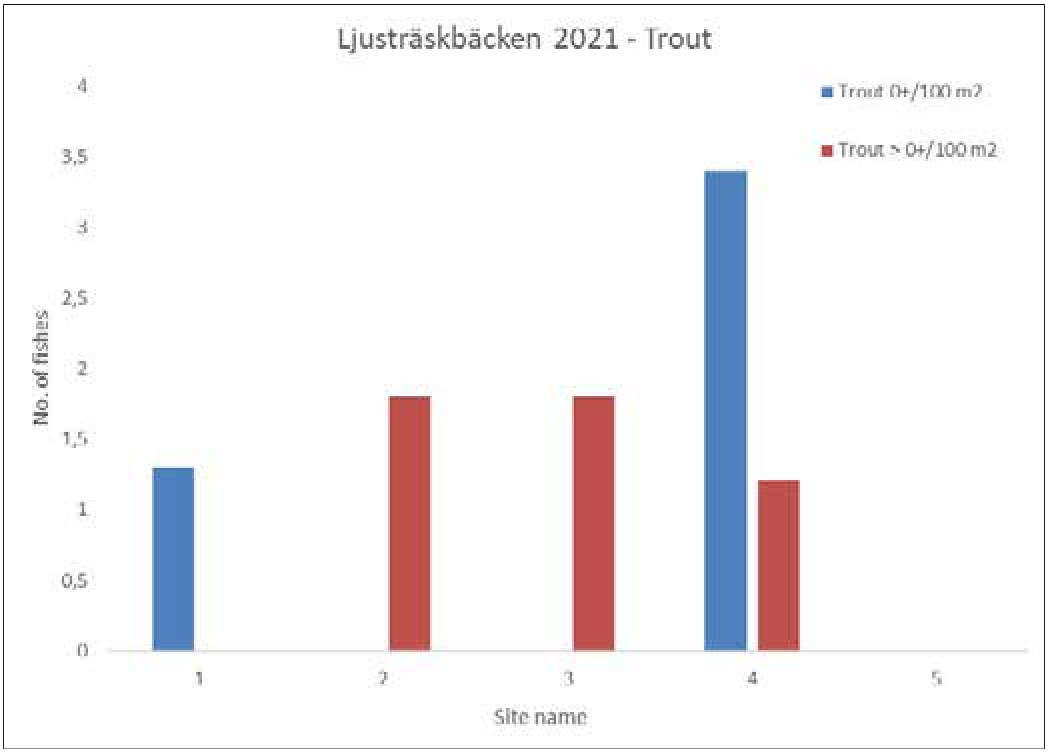

Figure 68. Number of brown trout caught in the River Ljusträskbäcken using electrofishing in September 2021.

River Tjartsebäcken

River Tjartsebäcken is situated in the River Piteälven catchment area in Arvidsjaur municipality. It starts from the Lake Holmträsket and runs down to its outlet into River Laxtjärnbäcken. The total length of Tjartsebäcken is 17.5 km and its mean width is 10.1 m. The gradient is 132 metres, from 367 m ASL from the outlet of Lake Holmträsket down to the outlet into River Ljusträskbäcken at 235 m ASL. The total catchment area is 64.8 km^2, and this is made up of 92.6% forest, 5.5% wetland and 1.9% surface water (SMHI SVAR VERSION 2016_3). The environment around Tjartsebäcken (50 metres on either side of the river) is mainly coniferous forest. The close environment around the river (5 metres on either side of the river) is dominated by trees (pine, spruce, and birch) and brushes (juniper) (Fig. 69). The insolation is neither very high nor very low (shade mostly 5–50%), but there are some areas with a shade < 5%.

The County Administrative Board of Norrbotten (CABN) has known of the occurrence of FPM in River Tjartsebäcken since 1994 when two larger individuals were found below the bridge close to Lake Laxtjärnen, the second bridge upstream. In 2017 an eDNA sample was taken upstream the bridge and it turned out positive for FPM. Within the SALMUS project we did not find any mussels above the bridge. Other investigations during 2021 revealed a yet unknown population of FPM in a tributary to River Tjartsebäcken upstream the bridge so most likely the positive eDNA from 2017 came from that river. For other rivers in this area with FPM, see River Ljusträskbäcken above.

River Tjartsebäcken is part of the Natura 2000 area Piteälven (SE0820434).

Mussel investigations

13 random transects were investigated between 16th and 21st July 2019 (Fig. 70). The mussels are distributed along a 3.1 km long

Figure 69. River Tjartsebäcken. Photo: CABN.

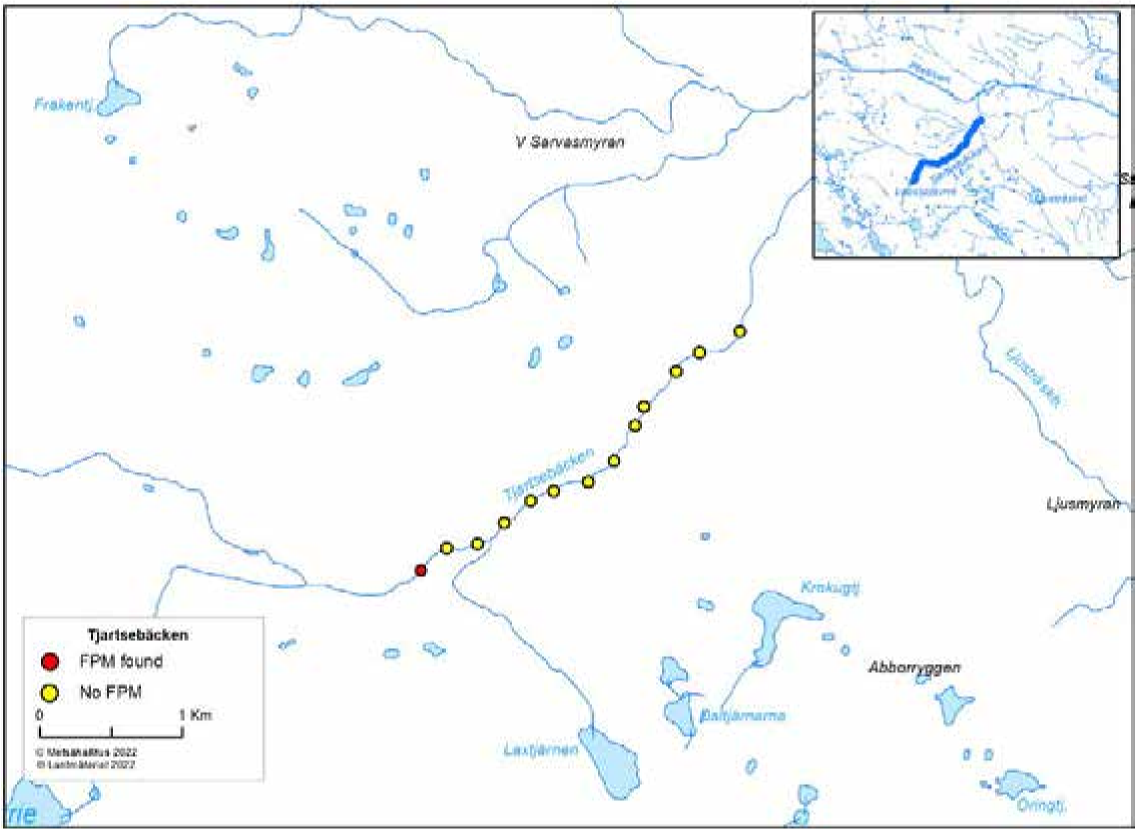

Figure 70. Random transects in the river Tjartsebäcken. Small map: River Tjartsebäcken marked with thicker blue line.

stretch below the bridge close to Lake Laxtjärnen and downstream. The mean depth in River Tjartsebäcken at the time of the investigation was 0.4 m, and the water level was around average. The air temperature was 11–17 °C, water temperature 12–13 °C, and the dominant bottom substrates were large and small boulders together with gravel and stones. The water current was mostly streaming but there were also a few areas with slow flowing water. The water was clear with no turbidity. Vegetation in the river was dominated by fouling algae (surface coverage 6–50% or even up to 51–100%), overwater plants were also quite common in some areas. The amount of detritus was small to moderate and relatively good amount of dead wood was also to be found in the river. Some locations in River Tjartsebäcken were strongly affected by the clearing of boulders and stones since the timber floating era.

Mussels were counted in an area of 2,097 m^2, so roughly 7% of the total mussel area was investigated. Only one mussel was found in one of the 13 transects investigated. The estimated FPM population size was eleven individuals (Appendix 1). The mean density of the population was as low as 0.0004 individuals/m^2. The smallest mussel found was 77 mm in length.

Only three mussels were measured for length, so no size distribution was possible to create for this population.

Glochidia study

Four sites with a total area of 1,200 m^2 were electrofished in River Tjartsebäcken on the 12th of June 2019. The water temperature at the time of the investigation was 9.1–13.3 °C. Trout were caught at all sites and the total catch was 18 trout. Six trout (33%) were infected with glochidia larva in low numbers. The total number of glochidia was 48 and the mean number on the gills was 2.7 glochidia/trout (min: 0; max: 14).

Host fish abundance

Four sites with a total area of 723 m^2, which corresponds to approximately 2% of the total FPM distribution area, were electrofished in River Tjartsebäcken on 18th September 2019. The water temperature at the time of the investigation was 6.6–7.7 °C. Young of the year (YOY) trout were caught at three of the sites in quite low numbers (min: 1.0 individuals/100 m^2; max: 3.2 individuals/100 m^2). Older trout were also caught at three sites in low numbers (min: 1.7 ind./100 m^2; max: 3.5 ind./100 m^2) (Fig. 71). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM population to be functional. The mean abundance for YOY trout caught in River Tjartsebäcken (four sites) was 1.6 ind./100 m^2 and for older trout 1.8 ind./100 m^2. European bullhead was the most common species in the river, another species caught was common minnow.

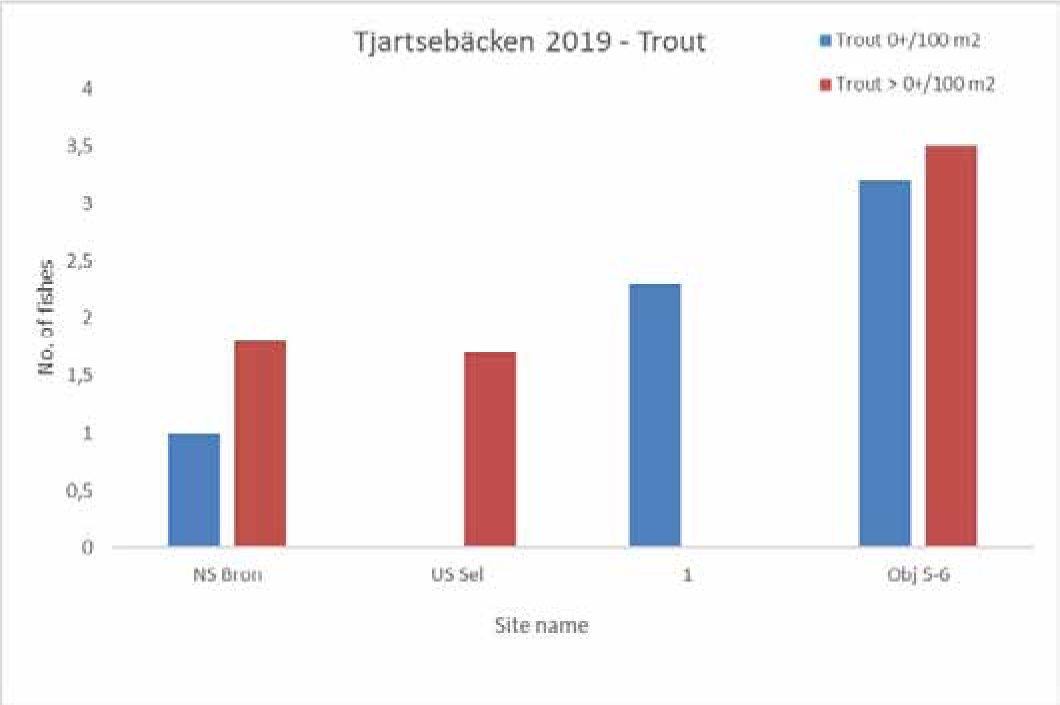

Figure 71. Number of trout caught in the River Tjartsebäcken using electrofishing in 2019.

River Tvättstugubäcken

River Tvättstugubäcken (Fig. 72) is situated in the River Piteälven catchment area in Jokkmokk municipality. It starts from the small tarn Tvättstugutjärnen and runs down to its outlet into River Telebäcken. The total length of Tvättstugubäcken is 2.3 km and its mean width is 1.1 m. The gradient is 44 metres, from 258 m ASL from the outlet of Tvättstugutjärnen down to the outlet into River Telebäcken at 214 m ASL. The total catchment area is 6.1 km^2 and this is made up of 92.9% forest, 6.4% wetland and 0.7% surface water (SMHI SVAR VERSION 2016_3). The environment around River Tvättstugubäcken (50 metres on either side of the river) is mainly mixed forest and boglands. The close environment around the river (5 metres on either side of the river) is dominated by grass and half grass, brushes, and trees. Herbs are also present to some extent. The vegetation around the river provides good shade.

The County Administrative Board of Norrbotten (CABN) has known of the occurrence of FPM in River Tvättstugubäcken since 2004, when WWF made a larger investigation with 15 random transects. The results from 2004 showed that the mussels were distributed over a stretch of 1.2 km and the population size was estimated to 15,674 individuals. Mean density was 13.0 individuals/m^2, 5.9% of the mussels were smaller than 50 mm in length and the smallest individual was 24 mm. It is also known that FPM occurs in River Telebäcken and in a small river close to Tvättstugubäcken called Pärlskalsbäcken (meaning "Pearl shell creek" in English) with an estimated population of 26,804 individuals (2020).

River Tvättstugubäcken is part of the Natura 2000 area Piteälven (SE0820434).

Mussel investigations

Tvättstugubäcken was investigated with aquascope between 3rd and 24th June 2020 (Fig. 73). The investigation showed that FPM occurs almost all the way from Lake Tvättstugtjärnen down to the outlet. The distribution range was 2,240 m. The 15 transects from 2004 were revisited and three more transects were added. The mean depth in River Tvättstugubäcken at the time of the investigation was 0.2 m, and the water level was around average. The air temperature was 13–29 °C, water temperature 13–23 °C, and the dominant bottom substrates were stones, sand, and gravel in varying sizes. The water current was mostly streaming but some parts of the river were gushing or slow flowing. Water was clear without turbidity. There was not much vegetation in the river, some mosses and vascular plants were present at some locations. The amount of detritus was small to moderate and only little heavy dead wood was to be found, light dead wood was more prevalent.

Mussels were counted in an area of 306 m^2, so roughly 12% of the total mussel area was investigated. Altogether, 1,867 mussels were found in seventeen of the eighteen transects

Figure 72. River Tvättstugubäcken. Photo: CABN.

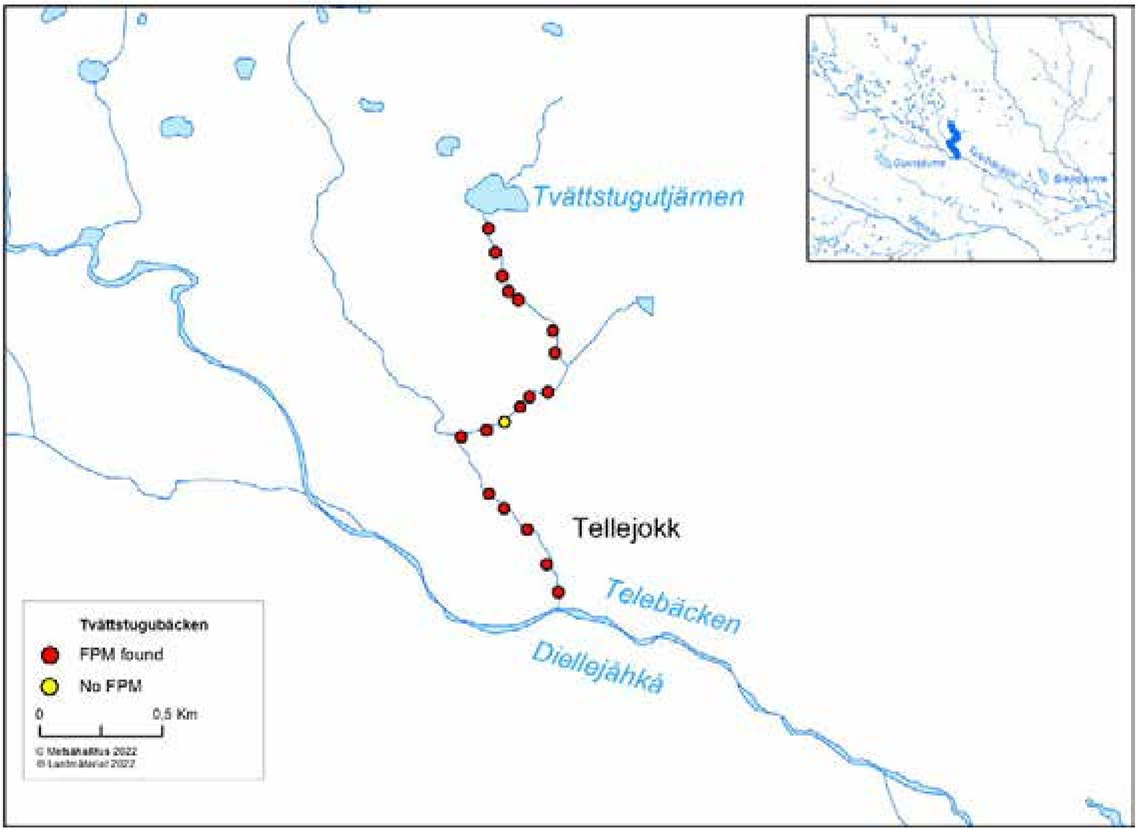

Figure 73. Random transects in the river Tvättstugubäcken. Small map: River Tvättstugubäcken marked with thicker blue line.

investigated. The estimated FPM population size was 20 792 individuals (Appendix 1). The mean density of the population was 8.6 individuals/m^2 and the smallest mussel found 40 mm in length.

The size distribution shows that recruitment is poor and that the population is mainly made up of older individuals (Fig. 74). Only 0.8% of the mussels were below 50 mm in length. Small mussels were found in three of the eighteen transects and only one transect had no mussels at all.

Glochidia study

Four sites with a total area of 299 m^2 were electrofished in River Tvättstugubäcken on the 11th of June 2019. The water temperature at the time of the investigation was 11.1–13.8 °C. Trout were caught at all sites and the total catch was 30 trout. Of them, 22 trout individuals (72%) were infected with glochidia larva. The total number of glochidia was 612, hence the mean number on the gills was 20.4 glochidia/trout. Two trout individuals had more than 100 glochidia larva on their gills.

When electrofishing for the host fish abundance survey was done in autumn (6th of September) of 2019, all trout individuals caught from two study sites were also examined for the presence of glochidia. A total of 59 trout was caught at both sites and all fish had glochidia on their gills (100%). The total number of glochidia was 3,500 and the mean number on the gills was 59.3 glochidia/trout. Nine trout individuals had more than 100 glochidia larva on their gills.

Host fish abundance

Four sites with a total area of 756 m^2, which corresponds to approximately 31% of the total FPM distribution area, were electrofished in River Tvättstugubäcken on 4th and 5th September and on 16th and 17th September 2019. Water temperature at the time of the investigation was 7.1–12.6 °C. Young of the year (YOY) trout were caught at three of the four sites in high numbers (min: 14.9 individuals/100 m^2; max: 101 individuals/100 m^2). Older trout were caught at all sites and in quite high numbers (min: 15.4 ind./100 m^2; max: 25.3 ind./100 m^2) (Fig. 75). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM popula-

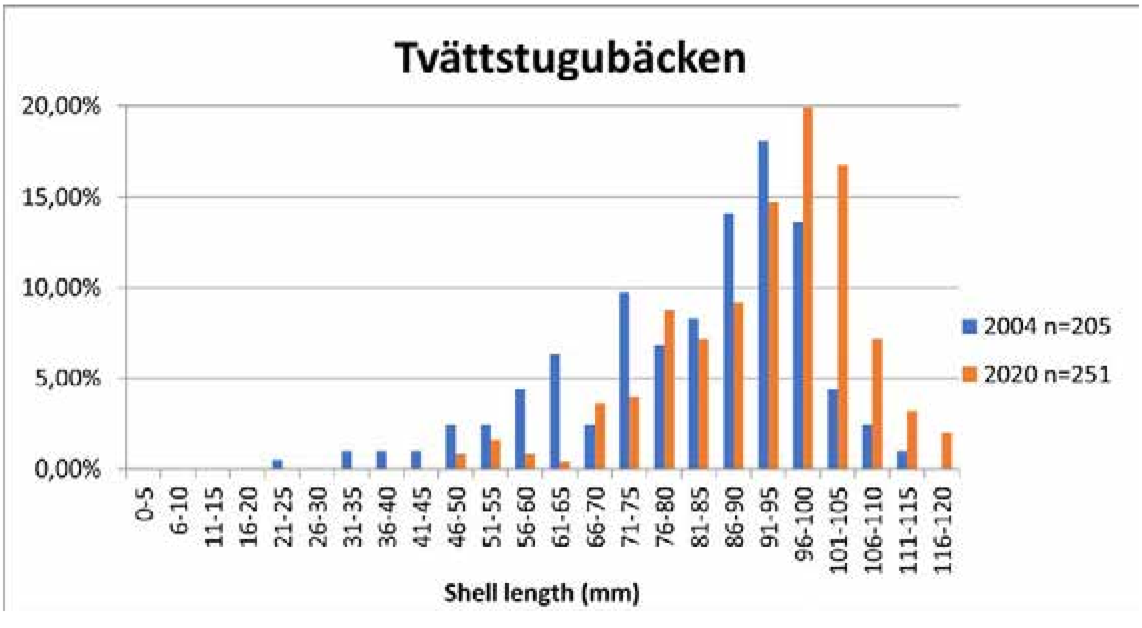

Figure 74. Size distribution of the mussels in Tvättstugubäcken in 2004 and 2020.

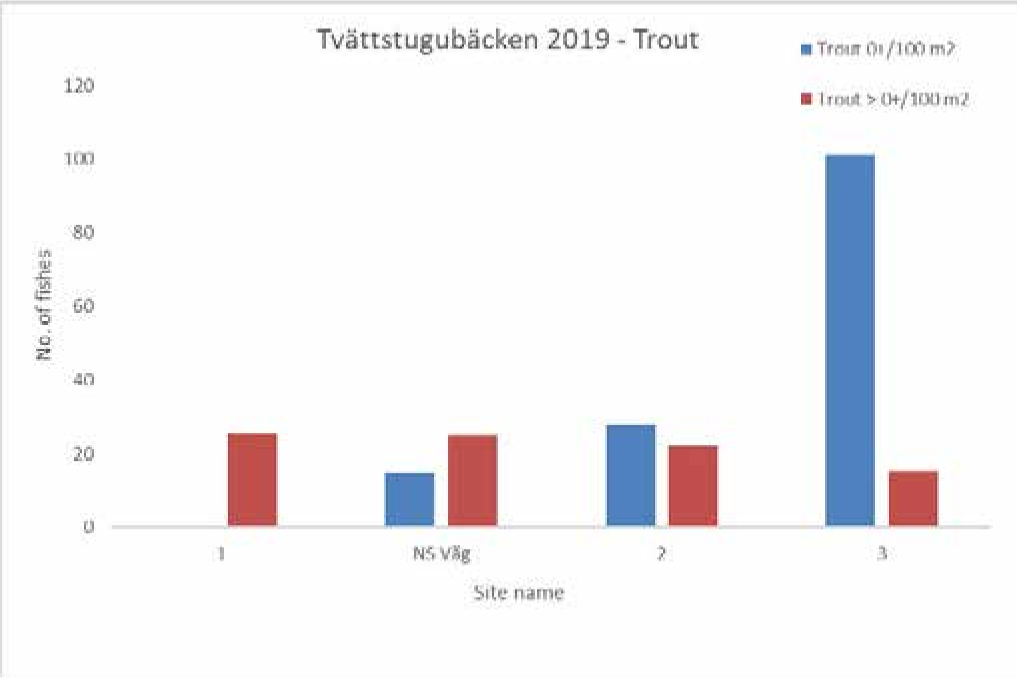

Figure 75. Number of trout caught in River Tvättstugubäcken using electrofishing in September 2019.

tion to be functional. The mean abundance for YOY trout caught in River Tjartsebäcken (four sites) was 36.0 ind./100 m^2 and for older trout 21.9 ind./100 m^2. Trout were the most common species in the river, other species caught were European bullhead and European brook lamprey.

River Bölsmanån

River Bölsmanån is situated in the River Piteälven catchment area in Älvsbyn municipality (Fig. 76). It starts from the small lake Lilltjärnen and runs down to its outlet into the River Piteälven (Fig. 73). The total length of Bölsmanån is 5.0 km and its mean width is 5.5 m. The gradient is 80 metres, from 200 m ASL from the outlet of Lake Lilltjärnen down to the outlet into the River Piteälven at 120 m ASL. The total catchment area is 43.7 km^2 and this is made up of 77.7% forest, 12.2% wetland, 9.7% surface water and 0.4% moor land and other land (SMHI SVAR VERSION 2016_3). The environment around River Bölsmanån (50 metres on either side of the river) is mainly mixed forest and some areas are affected by deforestation. The close environment around the river (5 metres on either side of the river) is dominated by grass and half grass, herbs, and brushes. Trees are also present to some extent (birch, spruce, alder). Vegetation around the river provides good shade.

The County Administrative Board of Norrbotten (CABN) has known of the occurrence of FPM in River Bölsmanån since 2004, when WWF made a larger investigation of 17 random transects. The results from 2004 showed that the mussels were distributed over a stretch of 4 km and the population size was estimated to be 135,972 individuals. Mean density was 6.2 individuals/m^2, 0.4% of the mussels were smaller than 50 mm in length and the smallest mussel was 43 mm.

River Bölsmanån is part of the Natura 2000 area Piteälven (SE0820434).

Mussel investigations

Bölsmanån (Fig. 76) was investigated with aquascope between 15th and 17th July 2020. The distribution range was 3,800 m. The 17 transects from 2004 were revisited and one more transect was added (Fig. 77). The

Figure 76. River Bölsmanån. Photo: CABN.

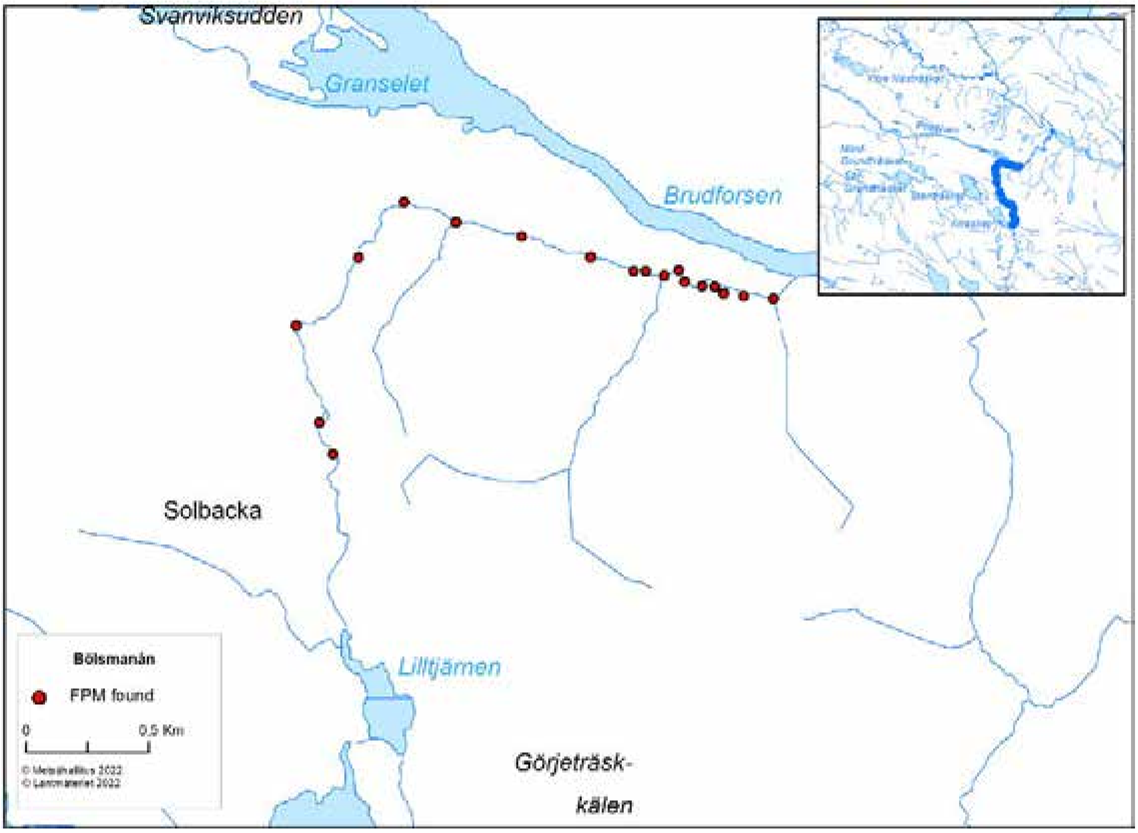

Figure 77. Random transects in the river Bölsmanån. Small map: River Bölsmanån marked with thicker blue line.

mean depth in River Bölsmanån at the time of the investigation was 0.6 m, water level was around average. The air temperature was 14–23 °C, water temperature 19–22 °C, and the dominant bottom substrates were boulders, stones, sand, and fine sediment. The water current was dominated by streaming parts, but a few areas with gushing and slow flowing water were also present. Water was clear with no turbidity. Vegetation in the river was dominated by mosses (surface coverage 6–50 %) and some vascular plants. The amount of dead wood was mostly small while a few areas had moderate to high quantities. The amount of detritus was also small.

Mussels were counted in an area of 1,407 m^2, so roughly 7% of the total mussel area was investigated. Altogether 3,146 mussels were found in the eighteen transects investigated. The estimated FPM population size was 110,356 individuals (Appendix 1). Mean density of the population was 5.3 individuals/m^2. The smallest mussel found was 11 mm in length.

The size distribution showed a more favourable pattern than in 2004, although young individuals were not very abundantly present. 8.7% of the mussels were below 50 mm in length (Fig. 78). Small mussels were found in ten of the eighteen transects and none of the transects were totally lacking mussels.

Glochidia study

Five sites with a total area of 1,535 m^2 were electrofished in River Bölsmanån on the 10th of June 2019. The water temperature at the time of the investigation was 17.3–17.5 °C. Only one trout was caught, a four-year-old trout with more than 100 glochidia larvae on its gills.

In connection of electrofishing for the host fish abundance study between 2nd and 3rd September 2019, only two trout individuals were caught, and they were examined also for glochidia. Both fish had glochidia on their gills. The total number of glochidia was 37 (10 and 27) and the mean number on the gills accordingly 18.5 glochidia/trout.

Host fish abundance

Five sites with a total area of 1,243 m^2, which corresponds to approximately 2% of the total FPM distribution area, were electrofished in River Bölsmanån on 2nd and 3rd September 2019. The water temperature at the time of the investigation was 13.3–16.0 °C. Young of the year (YOY) trout and older trout were both caught only at one site, not the same

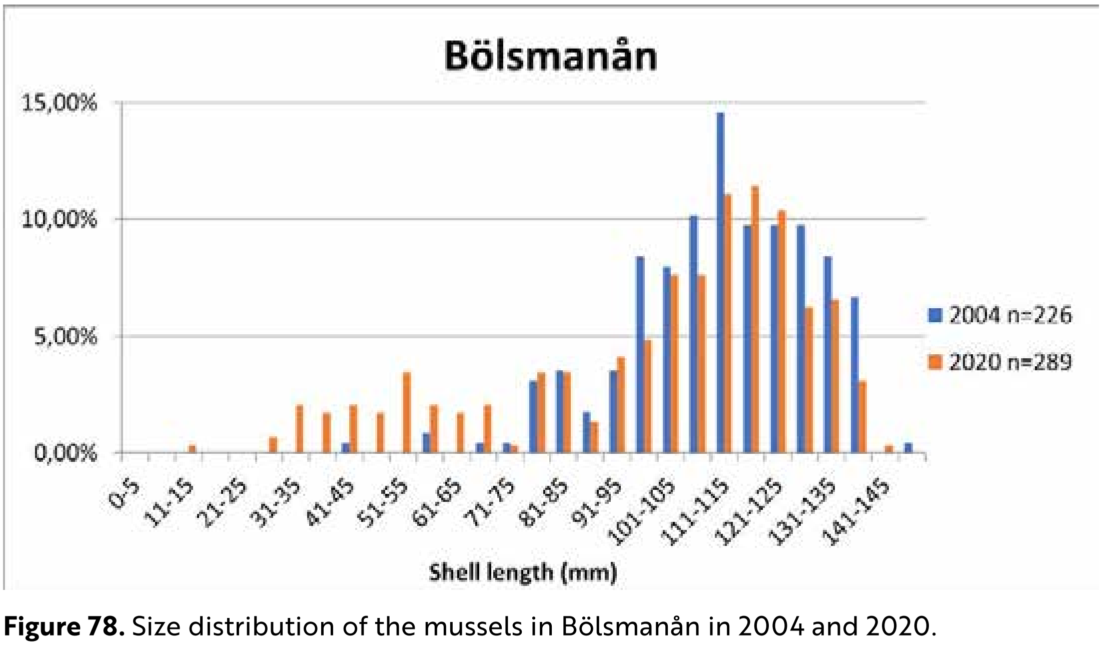

Figure 78. Size distribution of the mussels in Bölsmanån in 2004 and 2020.

one, and in very low numbers (Fig. 79). Above all, YOY fish are important for the recruitment of new mussels and according to Havs- och Vattenmyndigheten (2020) a minimum abundance of five YOY per 100 m^2 would be needed for a Scandinavian FPM population to be functional. The mean abundance for YOY trout caught in River Bölsmanån (five sites) was 0.2/100 m^2 and for older trout 0.12/100 m^2. The most common species in the river was common minnow. Other species caught were European bullhead, brook lamprey, and burbot.

Water temperature

According to Dunca & Mutvei (2009), FPM does not grow when water temperature is below +5 °C. In the case of River Bölsmanån during 2019–2020, the period with water temperature below +5 °C was approximately 7.5 months (Fig. 80).

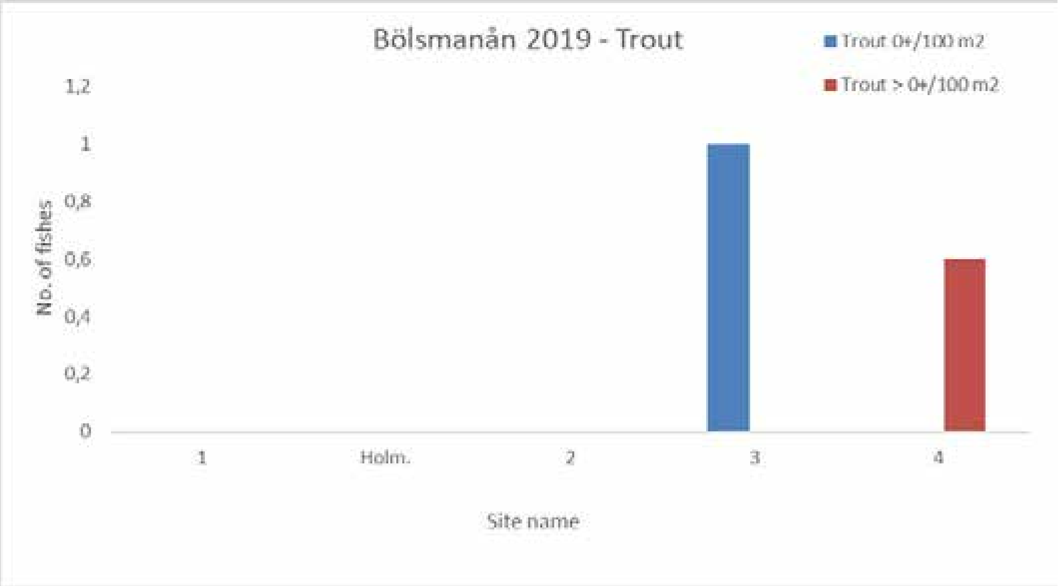

Figure 79. Number of trout caught in River Bölsmanån using electrofishing in autumn 2019.

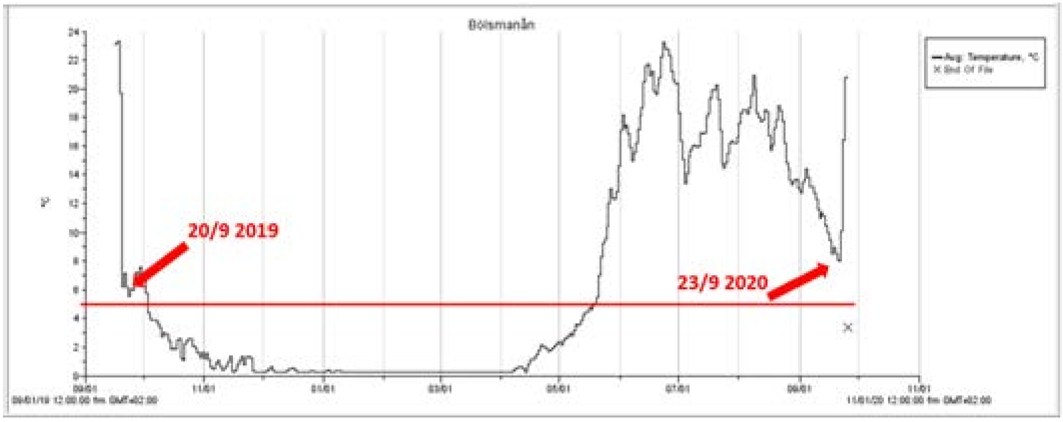

Figure 80. Water temperature in the River Bölsmanån 2019-2020. Arrows indicate start and stop of the measurement.

3.4.1.4 Råneälven catchment

The River Råneälven (Swedish Råneälven) is 210 km long and flows from the Lake Råneträsket south of the mountain Dundret in Gällivare municipality down to its outlet in Bothnian Bay near to the town of Råneå. The river flows first 150 km mainly through uninhabited forests and mires. In the last 50 km from the Lake Valvträsket onwards the surroundings are more of agricultural use. The catchment area covers 4,207 km^2. River Råneälven and its tributaries are protected by Natura 2000 (SE0820431). It is also a so-called "National River" where water regulatory and other activities connected to hydropower are forbidden by Swedish law.

River Rutnajoki

River Rutnajoki (Fig. 81) is situated in the River Råneälven catchment area in Gällivare municipality. It starts from the Lake Rudnájávrre and runs down to its outlet into River Råneälven. The total length of Rutnajoki is 10.0 km and its mean width is 14.2 m. The gradient is 56 metres, from 386 m ASL from the outlet of Lake Rudnájávrre down to the outlet into River Råneälven at 330 m ASL. The total catchment area is 109.2 km^2 and this is made up of 57.4% forest, 34.8% wetland, 5.8% surface water and 2.0 % moor land and other land (SMHI SVAR VERSION 2016_3). The environment around River Rutnajoki (50 metres on either side of the river) is mainly mixed forest and some boglands also surround the river. The close environment (5 metres on either side of the river) is dominated by grass and half grass, brushes, and herbs. The insolation is neither very high nor very low (shade around 5–50%, but there are some areas with < 5%).

The County Administrative Board of Norrbotten (CABN) has known of the occurrence of FPM in River Rutnajoki since 2018, when 24 FPM (five smaller than 50 mm in length) were found in connection to restoration

Figure 81. River Rutnajoki. Photo: CABN.

of the river within the LIFE ReBorN project (ReBorN).

River Rutnajoki is a part of the Natura 2000 area Råneälven (SE0820431).

Mussel investigations

18 random transects in Rutnajoki were investigated with aquascope between 13th and 16th June 2020 (Fig. 82). The distribution range was 2,640 m. The mean depth in River Rutnajoki at the time of the investigation was 0.5 m, and the water level was around average. The air temperature was 12–21 °C, the water temperature was 13–15 °C, and the dominant bottom substrates were boulders, but also stones and gravel were common. The water current was dominated by gushing and streaming parts. The water was clear with almost no turbidity. The vegetation in the river was dominated by fouling algae (surface coverage 51–100%) but mosses and vascular plants were also present to a certain extent. The amount of dead wood and detritus was small.

Mussels were counted on an area of 4,851 m^2 so roughly 13% of the total mussel area was investigated. 50 mussels were found in the eighteen transects investigated. The estimated FPM population size was 332 individuals (Appendix 1). The mean density of the population was low, 0.009 individuals/m^2. The smallest mussel found was 47 mm in length.

The size distribution showed a weak recruitment with only 1.3% of the mussels below 50 mm in length (Fig. 83). Small mussels were not found in any of the eighteen transects investigated and eight of the transects were lacking mussels.

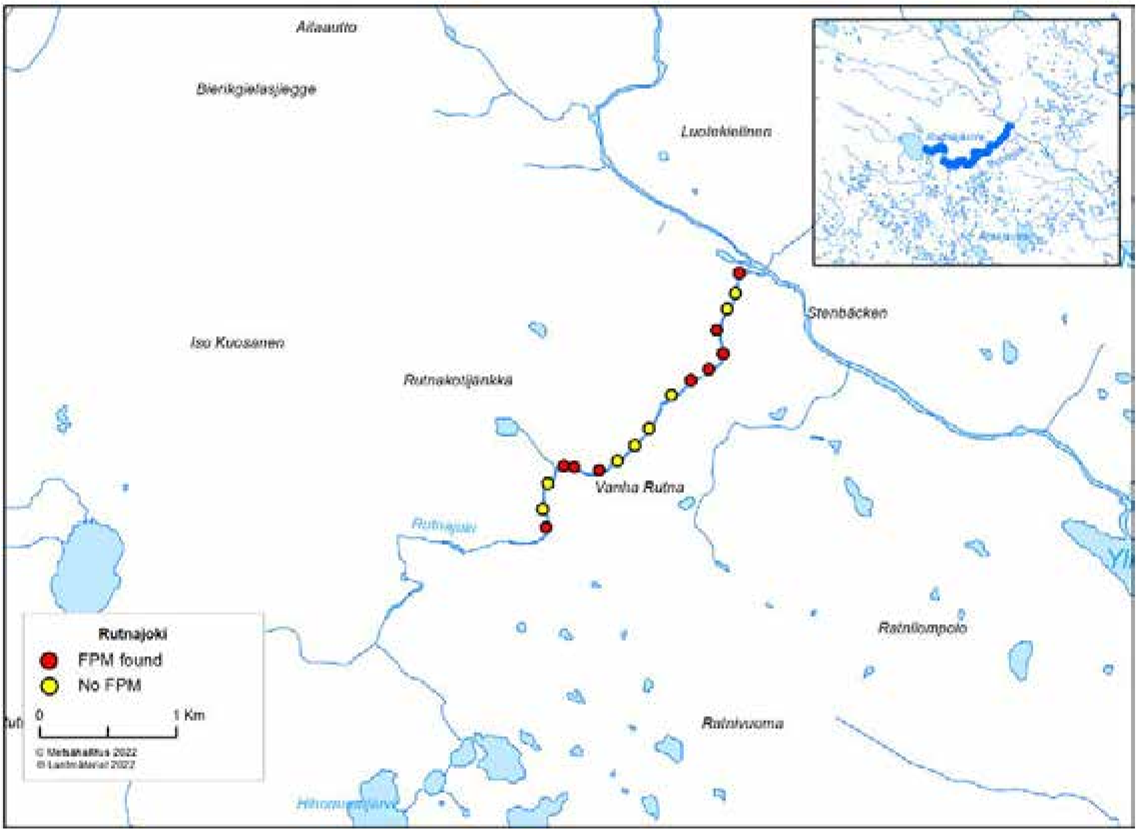

Figure 82. Random transects in river Rutnajoki. Small map: River Rutnajoki marked with thicker blue line.

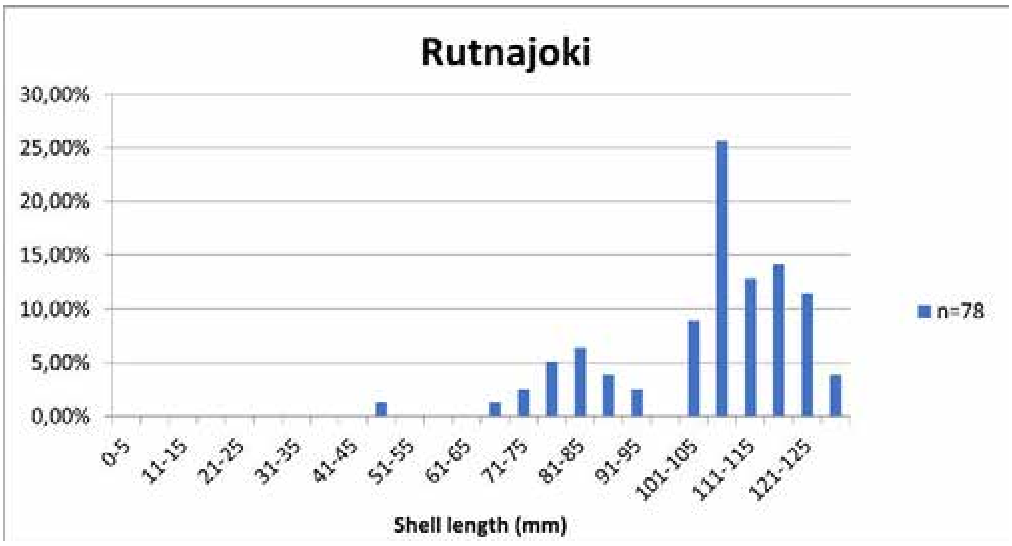

Figure 83. Size distribution of the mussels in Rutnajoki in 2020.

3.4.2 Rivers in Finland

3.4.2.1 Lutto (Tuloma) catchment

River Lutto is the upper part of the river Tuloma catchment. Major part of the catchment is in Russian territory and the Tuloma river itself meets the sea near the City of Murmansk, Russia. In Finland, Lutto has its origins in the Saariselkä mountain range from where it runs around 70 km before it crosses the Finnish-Russian border. At the border the river is already over 100 metres wide. The total catchment area on the Finnish side covers 1,578 km^2 (Ekholm 1993). The main tributary on the Finnish side is River Suomujoki, which runs from south to the Lutto. Other bigger tributaries in Finland are Kulasjoki, Nohkimaoja-Vuoksijoki, Kolmosjoki and Hirvasjoki (Fig. 84). Tributaries that join to river Lutto in Russian territory, but whose headwaters are in Finland are Kivijoki, Jaurujoki, Anterijoki and Nuortti. If their catchments are included, the total area of the Lutto catchment in Finland covers more than 3,000 km^2.

In the past, the Lutto and its tributaries were famous pearl fishing areas (Oulasvirta et al. 2006). Currently, the FPM is known from 26 different rivers in the Lutto drainage system. FPM populations in the Lutto system have been investigated by the working group of WWF Finland from 1970s and by Alleco and Metsähallitus field teams in 2003–2005 and 2011–2013 (Valovirta 1997, Oulasvirta et al. 2006, Oulasvirta ym. 2015a, Arino & Autio, unpublished field notes from 1979–1982). The Lutto main channel FPM population had been investigated only in small parts, but the rough estimate by Valovirta (1997) for the population was 120,000 mussels in the lower course of the Lutto main channel. The number of mussels in the whole drainage area in Finnish side has been estimated to be 600,000–1,000,000 individuals (Oulasvirta et al. 2006). The upper limit of the distribution in the main channel is just below the Lake Luttolompolo, and the lower limit in Finland is at the national border. The distribution in Russia is mostly unknown. According to Golubev & Golubeva (2010), the main channel of the Lutto on the Russian side has in average FPM population densities of one mussel/m^2 and the juvenile mussels are missing. On the other hand, the FPM population in River Kola, which is the main tributary of River Tuloma, is in good shape (Golubev & Golubeva 2010).

Especially in the main channels of the Lutto and Suomujoki rivers, the major prob-

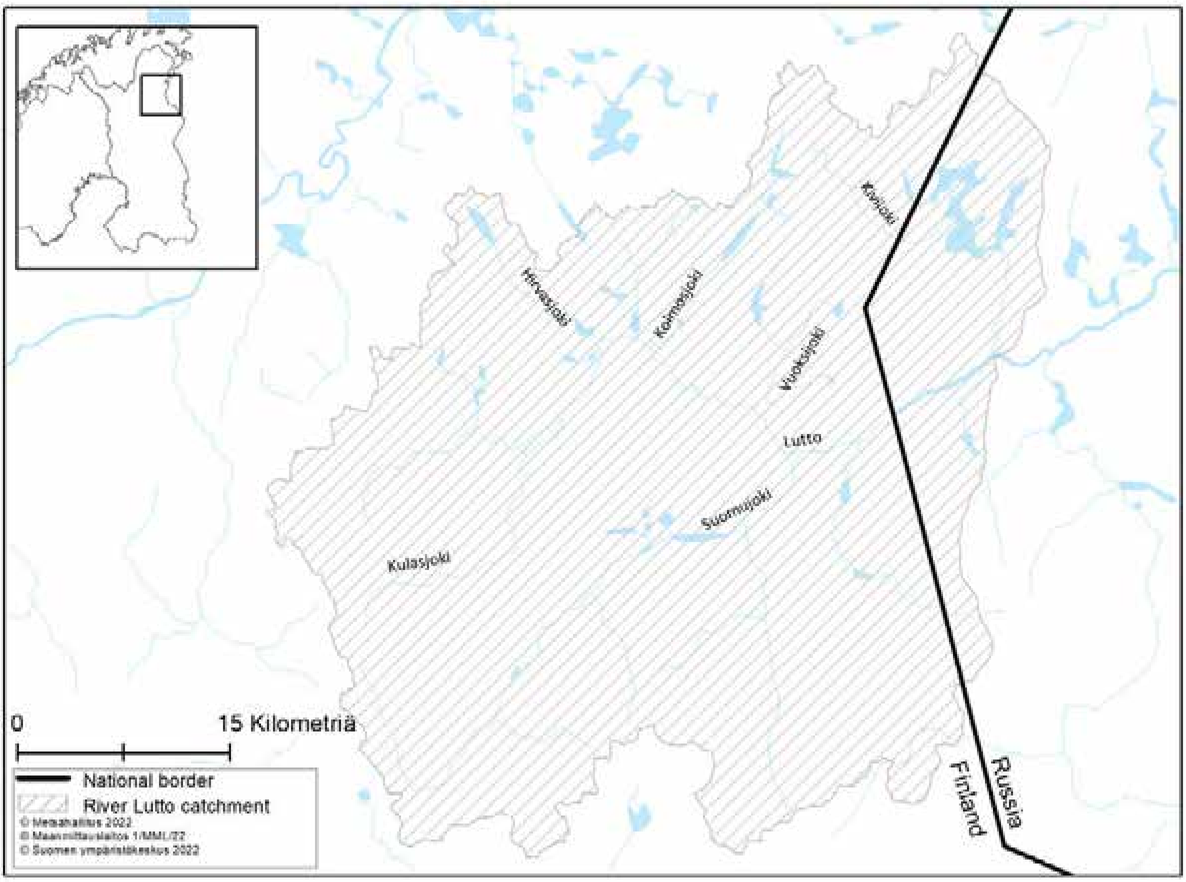

Figure 84. River Lutto catchment area in Finland.

lem for FPM recruitment is the Upper Tuloma hydropower plant, that has prevented salmon from ascending to the Lutto's Finnish parts since its construction in the 1960s. The results of host fish experiments carried out in the University of Jyväskylä show that FPM in old salmon rivers, such as Rivers Livojoki and Lutto, prefer Atlantic salmon as their host to brown trout (Salonen et al. 2016). Another main problem are the forestry operations, which threaten FPM also in smaller tributaries.

The population status of FPM was studied in seven rivers in the Lutto catchment during the Interreg North Raakku! -project in 2011–2014 (Oulasvirta et al. 2015a). In the SALMUS project, 11 target rivers were chosen to FPM population status assessments in the Lutto drainage area. These were Niemioja in the municipality of Sodankylä and Kolmosjoki, Urakkajärvenoja–Vuoksioja, Nohkimaoja–Vuoksijoki, Kivijoki, Rytioja, Ristinmorostonjärvenoja, Saari-Ahvenjärvenoja, Takkireuhkajärvenoja–Pesäjärvenoja, Ahvenlammenoja and the Lutto main river in the municipality of Inari. Most of the river basins are not included to any nature conservation area. Only exceptions are the lower course of River Niemioja and lower parts of Lutto main channel, that are inside the Urho Kekkonen National Park (FI1301701) and the headwaters of River Kolmosjoki and the lowest part of River Pesäjärvenoja, that belong to the Tsarmitunturi Wilderness Natura 2000 area (FI1300205).

River Lutto

The main channel of Lutto was one of the main target rivers in the SALMUS project. Field works in river Lutto were focused on the known mussel area down from Lake Luttojärvi (162 metres above sea level) until the Finnish border zone, 350 metres from the nation border. During this around 45 km long stretch, the river drops down around 50 metres. Investigations in Lutto river were carried out in all project years 2019, 2020 and 2021.

Due to the big size of the Lutto river we were obligated to apply here different methods compared to other rivers. The investigation here was carried out in three stages. First, in 2019, we conducted a preliminary survey of the mussels on the whole area (Fig. 85). The objective of this survey was to find out the overall distribution range of the mussels and to find possible key areas, where the mussels are more abundant. The mussels were observed in 2019 mainly from the inflatable boat by an aquascope (Fig. 86). Only the rapid areas were investigated by snorkel diving. By this way we covered the whole 45 km river stretch from Luttojärvi lake to border zone. The investigation was done in 16.–30.8.2019. The method was quite rough in precision, because the bottom area that could be observed from the boat/snorkelling was narrow. However, the method gave the desired result, since after the investigations two FPM key areas was found. One key area was in the upper part of the distribution range between the Lake Luttojärvi and mouth of the tributary of Kulasjoki. Another key area was close to the national border downstream from the mouth of River Suomujoki (Fig. 85). Between these two key areas there is a ca. 34 km long twisting river stretch, where mussel densities are very low. We noticed that the mussels in this area were mainly situated in a narrow lane at the outer edge of the rive bends, where the bottom substrate was usually coarser gravel than the fine sand prevailing elsewhere in the channel.

Studies in 2020 were focused on the upper key area (Fig. 87). 28 transects across the river were established to the ca. 4.2 km river

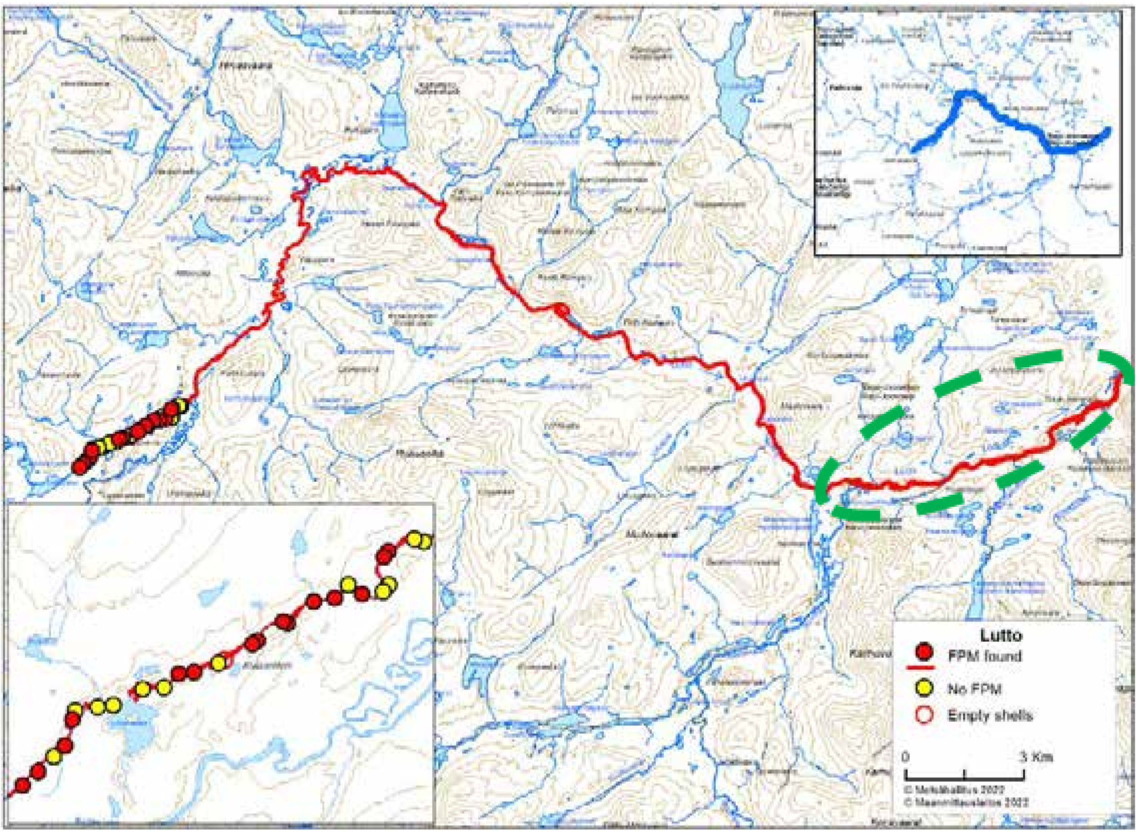

Figure 85. Investigated area in the river Lutto main channel. Constant red line: area investigated from the inflatable boat or by snorkel diving. Red and yellow dots: cross-river transects in the upper key area. Lower key area is marked with a green circle.

stretch between the lake Luttojärvi and the outlet of river Kulasjoki (Fig. 85). The transects were marked with lead weighted bottom rope and after that the mussels were counted by a diver from a metre wide area both sides of the transect (Fig. 88). The 2020 counts were conducted in 17.–18.8.2020.

Figure 86. In the preliminary mapping of the river Lutto in 2019 the mussels were mainly observed from the inflatable boat with an aquascope. Photo: Panu Oulasvirta.

Figure 87. River Lutto in its upper course, that was the uppermost key area for the mussels. Photo: Panu Oulasvirta.

Figure 88. Transect line across the river Lutto main channel in the upper course. A diver follows the lead weighted bottom rope and counts mussels from a one-metre-wide area both sides of the rope. Photo: Panu Oulasvirta.

In 2021 we again had to apply different methods, because the Lutto river is in the lower key area near the nation border already 50–100 meter wide (Fig. 89). Here the transects across the river were out of the question. Instead, the mussel counting was performed by five parallel divers that drifted down the river following the current (Fig. 90). Each of the divers counted all the mussels from a two-meter-wide lane from the bottom. This was possible to do although the depth of the river was in some places more than three meters, because of the good transparency of the water in River Lutto. The number of mussels in each of the parallel transects was recorded at 140–260 metre intervals. The total length of the investigated area was 7,140 metres. In the data analysing, the total number of mussels was extrapolated according to the number of observed mussels and river width on that river stretch. The expedition to the Lutto river in 2021 took place on 10th and 11th of August.

The total number of mussels in Lutto main river in Finnish side was estimated to be 41 100 individuals (Appendix 1). Major part of the population, 34,300 mussels in estimation, was situated in the lower key area between the river Suomujoki and border zone. In the upstream key area between the lake Luttojärvi and the mouth of river Kulasjoki the estimated number of mussels was 4,300 individuals. The middle part of the river was estimated to contain only around 2,500 mussels. However, the latter result is only indicative in size, since the method on that area was so rough.

No juvenile mussels were detected from river Lutto. This means that the viability class of the population is *dying*. The result is alarming, when we note that only in 1990s the size of the FPM population in the lower course of Lutto was estimated to be 120,000 individuals (Valovirta 1997). The conclusion is that the population is aging and decreasing rapidly. In the Interreg North project in 2013 the mussels were counted from a transect across the river in the upstream area. The result from the two metres wide and 20 metres long transects was 143 mussels. We repeated the counting in the same transect in 2019. The result was 88 mussels, in other words the number of mussels had decreased by 38% in six years. It is not possible to draw reliable conclusions from a single monitoring transect, but the result is to some extent indicative of the rate of decline.

Figure 89. River Lutto main channel near the national border. The width of the river here is more than 100 metres. The hills behind are in Russian territory. Photo: Panu Oulasvirta.

Figure 90. Aerial view of the divers drifting down river Lutto near the national border in 2021. Each diver counted mussels from a 2 metre wide transect on the bottom. Photo: Antti Tenetz.

River Niemioja

River Niemioja is a tributary of river Lutto. It is a 60–150 cm wide brook, flowing straight to Lutto from the lake Niemijärvi (area ca. 9.7 ha; 154 m above sea level). The length of the brook is 2.3 km and it descends about 29 m on its way. Catchment area is ca. 3 km^2. Besides lake Niemijärvi, two smaller lakes are situated above it, lake Niemilampi (2.11 ha) and a nameless lake (1.24 ha). So, lakes make 4.2% of the Niemioja catchment area.

The lower part of River Niemioja, around 300 meters, belongs to the Urho Kekkonen National Park Natura area (FI1301701). Rest of the catchment is not protected, and it is affected by large-scale forestry activities of the surrounding areas (Figs 91 and 92). Large clearcuts were performed in this area in the 1980s. Most evidently due to northern climate and extremely wide clearcut areas, the forests in Niemioja catchment have not yet recovered. In river Niemioja, the consequences of those clearcuts and forest roads (Fig. 92) can still be seen as sedimented channel bottoms in the upper catchment above the lake Niemijärvi and also about halfway of the stream course down from the lake (Fig. 93).

The upper course of Niemioja is also deeper, and the main flow type is current. In deeper parts submerged plants covered the bottom almost totally, while in shallow rapid areas plants were replaced by filamentous green algae at some sites (Fig. 94). A river stretch of about 150 m in length ran in practice underground, under big rocks and grass, making mussel counting impossible. Empty shells, found downstream from this section, indicate that freezing may occur during winter in this river section.

The river changes abruptly in its middle course. Here the river is much shallower and rapids are the main river habitat (Fig. 95). Filamentous algae are replaced by water moss. The bottom substrate here is almost free from sediment. Many young mussels inhabited this river section in 2021 (Fig. 96).

Figure 91. Niemioja and old clearcuts on its banks. Photo: Heikki Erkinaro.

Figure 92. Old forestry trace through the FPM stream in the middle of mussel area is still used nowadays by ATVs. Photo: Heikki Erkinaro.

Figure 93. Sedimented habitats in the upper course of Niemioja. Sediments provide nutrients for rooted plants. Plant roots and sediment clogged bottom makes habitat unfavourable for FPM. Photos: Aune Veersalu.

Figure 94. Filamentous algae prevail in the rapids of Niemioja upper course. Photo: Heikki Erkinaro.

Figure 95. The lower course of Niemioja is shallow, rapids being the main flow type. Population study during SALMUS project in 2021 was made by snorkeling, as young mussels under stones and riverbanks were hard to detect with aquascope. Photo: Heikki Erkinaro.

Figure 96. The bottom substrate is cleaner in the lower course of Niemioja and many young mussels were observed during SALMUS investigations in 2021. The smallest one measured was 9 mm in length. Photos: AuneVeersalu and Heikki Erkinaro.

The occurrence of FPM in Niemioja is mentioned in LUOMUS (Finnish Museum of Natural History) archives from the last century. An FPM shell sample from Niemioja is also in possession of the museum (leg. I. Valovirta). In 2005, a living FPM population in Niemioja was confirmed in the Interreg Kolartic Project "The existence and state of the populations of freshwater pearl mussel in the parts of the North Calotte" (Oulasvirta et al. 2006; Oulasvirta 2006) by Juho Vuolteenaho and Terho Myyryläinen. At that time, almost the entire population (1,073 individuals) was found from the 50-metre-long river stretch in the middle course of the river.

In the SALMUS project, river Niemioja was investigated with the total count method in 7.–8.9.2021. The survey covered the whole river except for a 150 m long stretch down from lake Niemijärvi (Fig. 97). The uppermost part was not investigated, because no living mussels – only shells and moving sediment – was found in a 100 m long section a bit downstream from the lake. In total, 9,592 mussels were counted in the 1.8 km long river stretch (Appendix 1). The number of mussels decreases in the lowermost course, ca. 400–300 metres before the outlet to Lutto river. Only one mussel was found from this part of Niemioja which already belongs to the Urho Kekkonen National Park.

The proportions of mussels less than 20 mm and 50 mm were 2.9% and 39.4%, respectively (Appendix 1). Small-sized young mussels were common (Fig. 98). Therefore, it was also possible to calculate the growth curve for the young mussels (Fig. 99). The results show that the mussels of the Niemioja population grow relatively quickly so that they are in average 28 mm long at the age of 10 years and 69 mm long at the age of 20 years. However, the estimate of the growth rate between 15 to 20 years is quite rough, since only two mussels were measured from that age group.

Because of the big proportion of young mussels, the Niemioja FPM population can be classified as *viable* (Appendix 1). The viability class stays the same regardless of the estimation principle used, i.e., if it is based on the proportion of the < 20 mm and < 50 mm individuals or on the proportion of the ≤ 10yr and ≤ 20yr old mussels (Table 8).

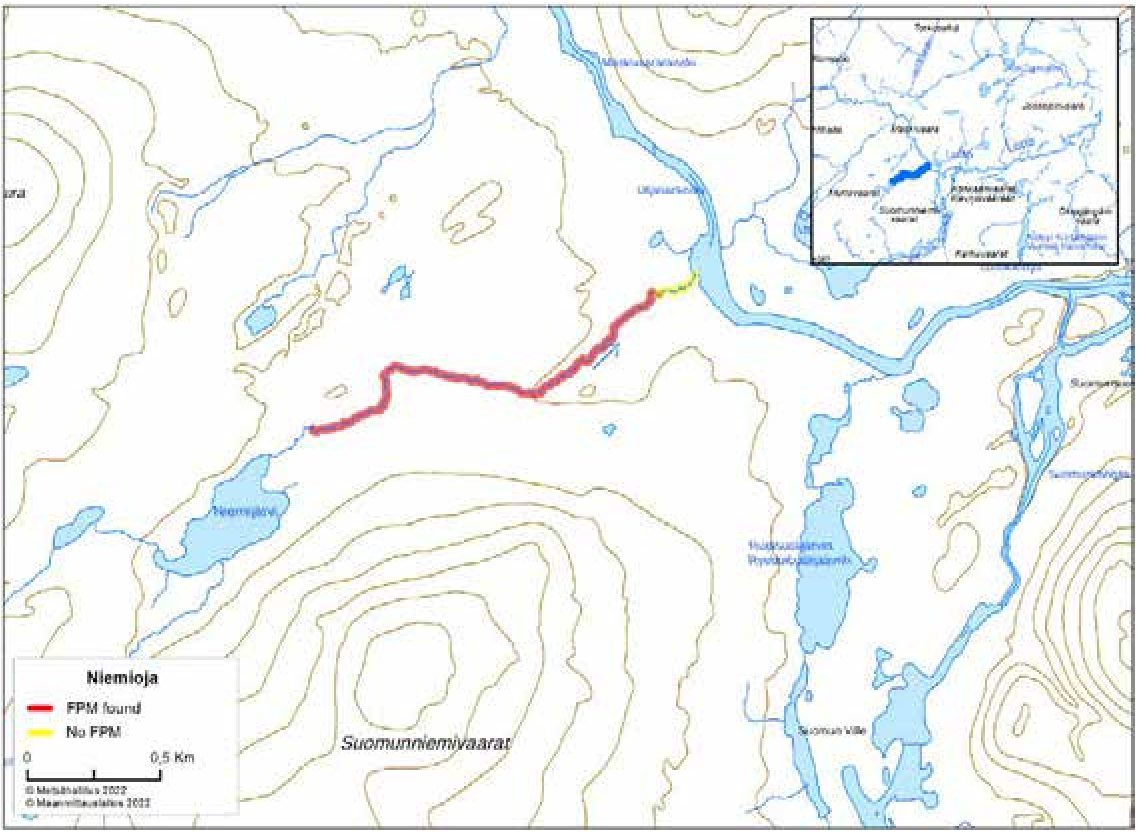

Figure 97. Investigated area (total count) in river Niemioja. Small map: thicker blue line marks river Niemioja.

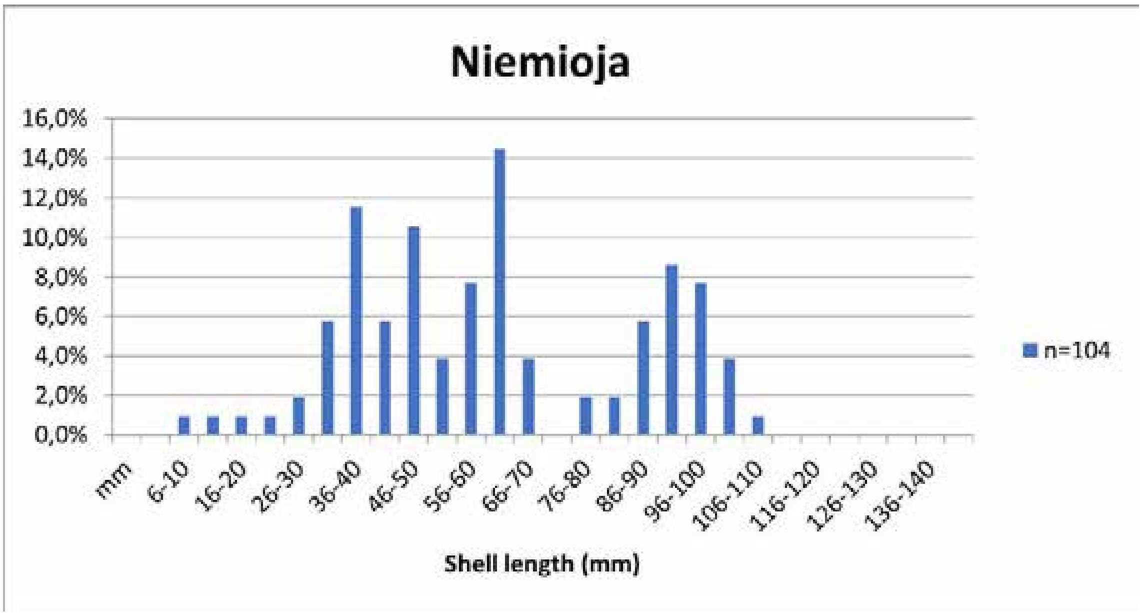

Figure 98. Size distribution of the mussels in river Niemijoki. Mussels that are ≤20 years old are in average smaller than 69 mm. This age group of young mussels stands out clearly.

Compared to the 2005 data, it seems that the population has grown considerably. Moreover, the distribution range in 2021 covered almost the whole river. In 2005, no juvenile mussels were detected but in 2021 juveniles were abundant. The reason for the good recruitment success in the river Niemioja FPM population between 2005 and 2021 is unknown. One possibility is that the population is recovering from the negative effects caused by the forest clearcuts of the 1980s. Good recruitment of young mussels during the last two decades is clearly visible also in the size distribution graph in Figure 98.

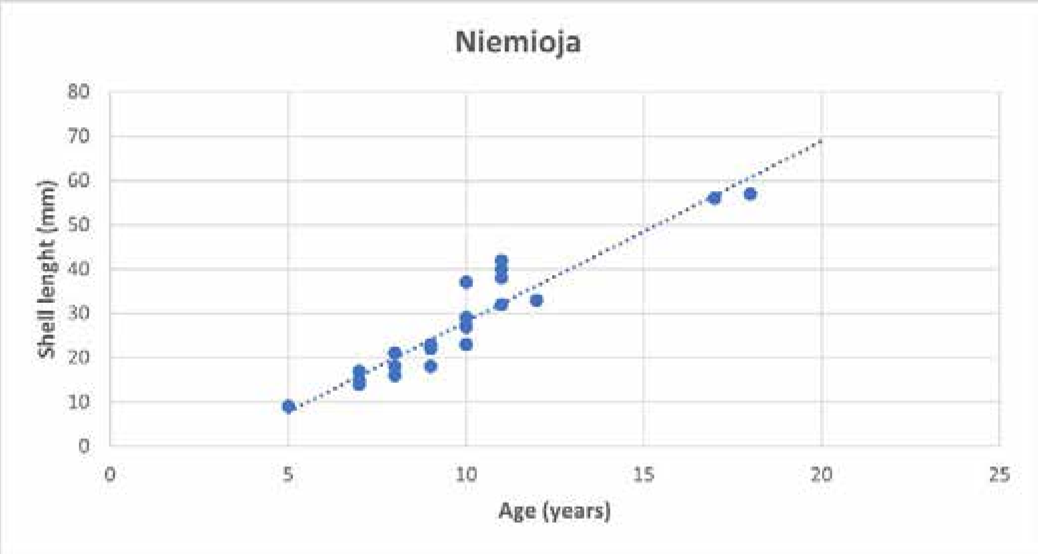

Figure 99. Growth rate of the juvenile mussels in river Niemioja.

Table 8. Percentages of < 20 mm and < 50 mm mussels and percentages of ≤ 10 yrs and ≤ 20 yrs mussels from those populations where age data of the young mussels was available. For comparison, in the last two columns the viability of the population is estimated according to the size of the mussels and according to the real age of the mussels. The viability class changed in rivers Ljusträskbäcken and Nohkimaoja–Vuoksijoki when real age data was used. * The populations did not fully fit the criteria in Table 7.

River	% <20 mm	% <50 mm	% ≤10yr	% ≤20yr	Viability (size)	Viability (age)
Sätsijoki	1	28	1	28	Viable	Viable
Kivijoki	2	31	2	33	Viable	Viable
Niemioja	3	39	5	68	Viable	Viable
Urakkajärvenoja–Vuoksioja	1	20	7	20	Viable	Viable
Ljusträskbäcken	0.4	16.2	2.16	37.05	Maybe-viable	Viable
Souksaurebäcken	2.30	12.5	2.3	12.5	Maybe viable	Maybe viable
Bölsmanån	0.003	8.7	1	9.3	Maybe viable*	Maybe viable*
Nohkimaoja–Vuoksijoki	0	14	5	14	Non-viable	Maybe viable
Kolmosjoki	0	2	> 0	6.4	Non-viable	Maybe viable*
Tvättstugubäcken	0	0.8	0	1.2	Non-viable	Non-viable
Köykenejoki	0	> 0	0	> 0	Non-viable	Non-viable

River Kolmosjoki

Kolmosjoki (Fig. 100) is a tributary of river Lutto. The origin of the river is in lakes Pieni-Arttajärvi (215 m above sea level) and Iso-Arttajärvi (204 m above sea level) ca. 16 km north from Lutto. In between there is a 3 km long lake Kolmosjärvi (181 m above sea level). A smaller lake Kolmoslompolo (156 m above sea level) is located in the lower course. The catchment area covers in total 95.23 km^2 out of which 4.82% are lakes (Ekholm 1993). The upper parts of the catchment are included into the Natura 2000 area Tsarmitunturi Wilderness (FI1300205).

FPM is known from the river Kolmosjoki already from the pearl fishing era (Matti Huru, an old pearl fisher, personal communication). Prelimary studies in the river were conducted during the Interreg Kolarctic project in 2003–2005 (Oulasvirta et al. 2006, Oulasvirta 2006). The FPM, including young mussels, were met in many locations, but not in high densities. The distribution range of the mussels is over 14 km in length.

In this study, 24 random transects were established to the Kolmosjoki river. However, two of the transects were not investigated, because they could not be reached. From the investigated transects, 17 were located below lake Kolmosjärvi and five transects in the upper course upstream from Kolmosjärvi lake (Fig. 101). The transects were investigated in 28.6. and 13.–15.8.2020.

FPM was found from all the transects investigated above the Lake Kolmosjärvi (Fig. 101). Downstream from lake Kolmosjärvi only 5 out of 17 transects contained alive mussels. Two transects contained dead shells and 10 transects were without FPM. The estimated number of mussels for the whole Kolmosjoki was 36,547 individuals (Appendix 1). The mean density of the population was 0.5 individuals/m^2.

Major part of the Kolmosjoki FPM population consisted of adult mussels (Fig. 102). The smallest found specimen was 21 mm in shell length and the proportion of ≤ 50 mm mussels was 1% (Appendix 1). Based on these figures the population was classified as *non-viable*. However, the growth rate of the juvenile mussels in Kolmosjoki population is rather high so that mussels of 10yr old are in average 29 mm in shell length and mussels of 20yr old already 70 mm in length (Fig. 103). If the proportion of young mussels is based on these measured size class criteria, the proportion ≤ 10yr mussels would be > 0% and the proportion of ≤ 20yr old mussels 6.4% (Table 3). According to the Nordic classification the viability class would still be *non-viable*, although these figures do not quite fit into the criteria presented in Table 7.

Figure 100. River Kolmosjoki in its middle course. Here an inflatable kayak was used when moving between transects. Photo: Panu Oulasvirta.

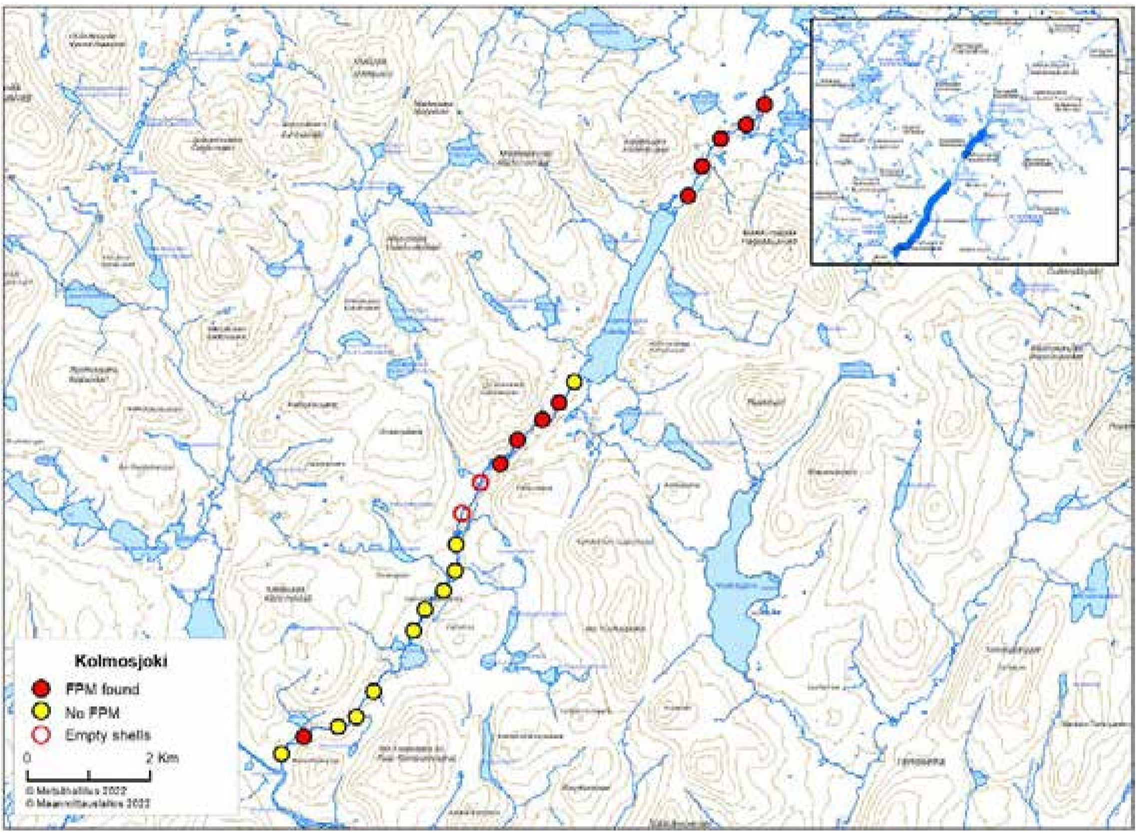

Figure 101. Random transects in river Kolmosjoki. Small map: River Kolomosjoki marked with a thicker blue line.

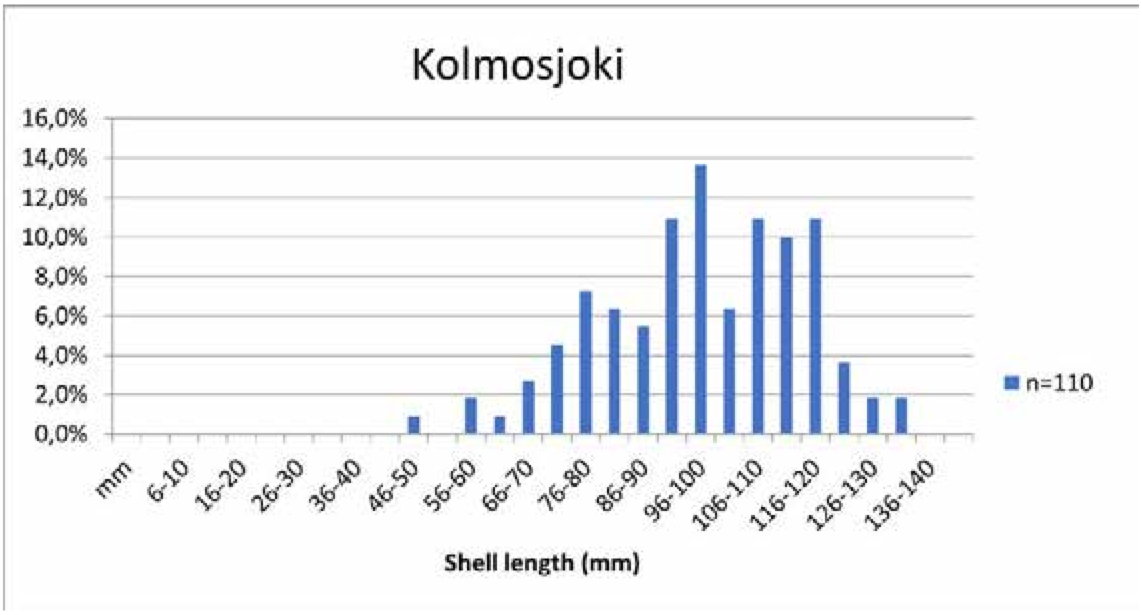

Figure 102. Size distribution of the mussels in River Kolmosjoki. Mussels that are ≤ 20 years old are in average smaller than 70 mm.

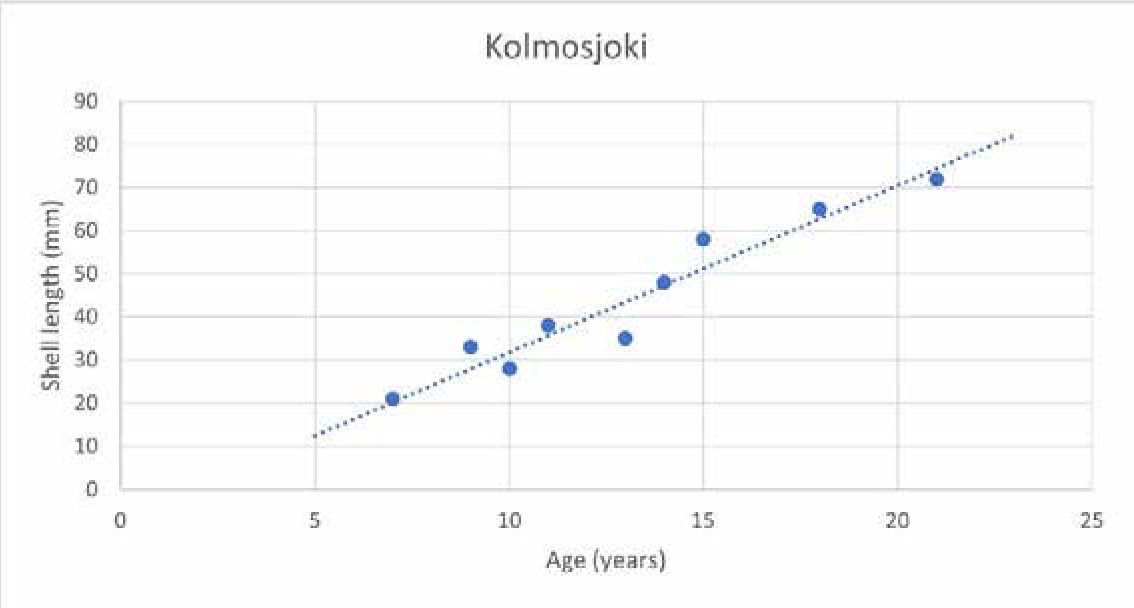

Figure 103. Growth rate of the juvenile mussels in River Kolmosjoki.

River Saari-Ahvenjärvenpuro

Saari-Ahvenjärvenpuro is a tributary of river Kolmosjoki. It is a small brook, only 50–100 cm in width. It starts from a 11.1 ha lake Saari-Ahvenjärvi (214 m above sea level). Further upstream, lake Saari-Ahvenjärvi headwaters include a couple of little brooks and a 1.29 ha lake. Saari-Ahvenjärvenpuro river flows 2.3 km to River Kolmosjoki through two ponds, the upper one is 0.5 ha and lower one, Palonrajalampi, is 0.9 ha. The brook falls 41.7 m on its way from Saari-Ahvenjärvi lake to Palonrajalampi (Fig. 104) and less than 10 more metres in the last 500 metres run from lake Palonrajalampi to Kolmosjoki (Fig. 105). The catchment area is 2.9 km^2, out of which 4.5% are lakes. In autumn 2021, forest clear-cuts were performed near the river channel. Sediment flow to the river was visible from the forest road, next to the brook. Heavy forest machines had driven over the stream in several places between Saari-Ahvenjärvi and Palonrajanlampi (Fig. 106).

The FPM population in Saari-Ahvenjärvenpuro was found and its limits in an around 400 metres river stretch between lake Palonrajalampi and river Kolmosjoki determined in 29.08.2021 by A. Veersalu (Metsähallitus). Additional investigations between lakes Saari-Ahvenjärvi and Palonrajalampi were made on October 12, 2021. Mussels were not found from this part of the river (Fig. 107). The size of FPM population was estimated by total count method, using aquascope.

The mussel count showed that Saari-Ahvenjärvenpuro hosts a small FPM population. Only 28 FPM individuals were detected from the whole river (Appendix 1). The actual size of the population is probably bigger, because the investigation was done using an aquascope, which is not an optimal method

Figure 104. Upper course of the Saari-Ahvenjärvenpuro brook is mostly featured by steep shallow rapids. It slows down about 300 metres before Palonrajalampi (right picture: in the background, upper right corner). Moving fine sediment partly covers bottom substrate in this stream part. Photos Aune Veersalu.

Figure 105. The FPM population of Saari-Ahvenjärvenpuro is located between Palonrajalampi and Kolmosjoki, where the creek flows twisting and more slowly than in the upper course. Surrounded by pine forests, the banks of the stream flowing in depression are dominated by *Molinia caerulea* (purple moor-grass). Photos: Aune Veersalu.

Figure 106. Forestry machines crossed Saari-Ahvenjärvenoja at several sites in Autumn 2021. Mud from a forest road is heading towards the stream (lighter area behind trees) after water originated from a slope spring has run along the road for some 150 m. Photos: Aune Veersalu.

for finding mussels, especially when they are under the banks or buried into the gravel.

The mussels were not measured, except for one juvenile of 31 mm in length (Fig. 108). Also two other mussels about the same size were detected. All other mussels were adults.

The little size of this small brook and the prevailing substrate types indicate that Saari-Ahvenjärvenpuro may serve as a "kindergarten" for the river Kolmosjoki FPM population. Mussels were found only at the lower course of the river, below lake Palonrajalampi. The area is influenced by repeated forestry activities and above the Lake Palonrajalampi no mussels were found. There, in the upstream area, the amount of fine particle silt was higher than in the lower course already in August 2021, before the clearcuts taking place in September 2021. Apparently Lake Palorajanlampi acts as a sediment trap, enabling survivable conditions for the downstream population. After the recent massive disturbance in autumn 2021 this small, just found population of Saari-Ahvenjärvenpuro appears to be in great danger of extiction.

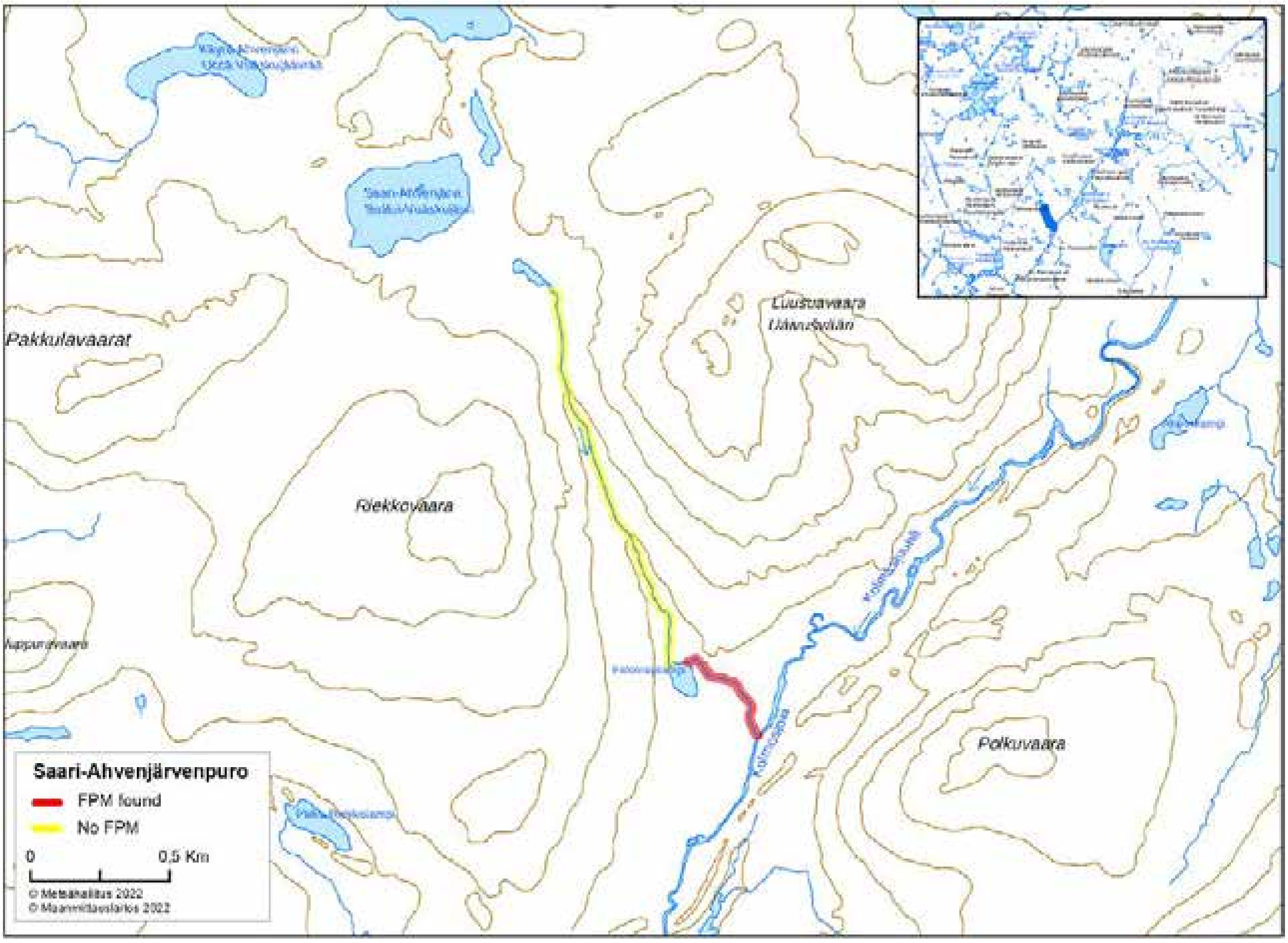

Figure 107. Investigated area in river Saari-Ahvenjärvenpuro. All mussels were found from the lower course of the river. Small map: Saari-Ahvenjärvenpuro marked with a thicker blue line.

Figure 108. Stones and gravel are main substrates in Saari-Ahvenjärvenoja FPM area, downstream from Palonrajalampi. In some parts organics make up to 50% of substrate. Last slowly flowing part before river Kolmosjoki is muddy. Using aquascope, some younger mussels were observed (3 out of total 28 FPM individuals counted), all of them with the size of about 3 cm. Photos: Aune Veersalu.

River Takkireuhkajärvenoja–Pesäjärvenoja

Takkireuhkajärvenoja and Pesäjärvenoja belong to the same river continuum being a tributary of river Kolmosjoki. Upper part of the river is called Takkireuhkajärvenoja and the lower part, below lake Pesäjärvi, Pesäjärvenoja. Headwaters of Takkireuhkajärvenoja consist of lake Takkireuhkajärvi (in Sami language: Mááccuhkápulohjävri, 20.81 ha) with some springs flowing to it. A small brook flows 600 metres from Lake Takkireuhkajärvi (247.9 m above sea level) to a small, 0.79 ha pond and 1.58 km from this to lake Pesäjärvi (Ruáhujävri), 202 m above sea level, falling 45.4 m on its way. The catchment area of Takkireuhkajärvenoja is in total 3.96 km^2. The lower part, Pesäjärvenoja flows from Lake Pesäjärvi (34.37 ha) to River Kolmosjoki and is 1.58 km long. Pesajärvenoja catchment area, including Takkireuhkaoja, is 7.87 km^2 in total. The area is not protected, except for the lowest 50 metres of Pesäjärvenoja, that is inside the Tsarmitunturi Wilderness Natura 2000 area (FI1300205). Main anthropogenic disturbance sources in the area are forestry and forest roads.

The FPM population was found from Pesäjärvenoja in 2006 by Metsähallitus (M. Mela, V. Mikkonen, T. Myyryläinen). The sub-population in Takkireuhkajärvenoja was confirmed and the distribution range (ca. 1 700 metres) determined during the SALMUS project by A. Veersalu and S. Kankaanpää (Metsähallitus). The investigations showed that the FPM population is divided in two parts – one in the upper part of the Takkireuhkajärvenoja and the other one in the lower course of the Pesäjärvenoja. Between these two sub-populations there is a stretch of river with no FPM (Fig. 109).

The distribution range and size of Pesäjärvenoja sub-population was determined in 7.8.2019 by total count method (Fig. 110). Takkireuhkajärvenoja sub-population was investigated in 8.10.2020 and 11.–13.10.2021 by total count method, using an aquascope and snorkeling (Fig. 111).

In total, 855 mussels were counted from Takkireuhkajärvenoja and 81 mussels from

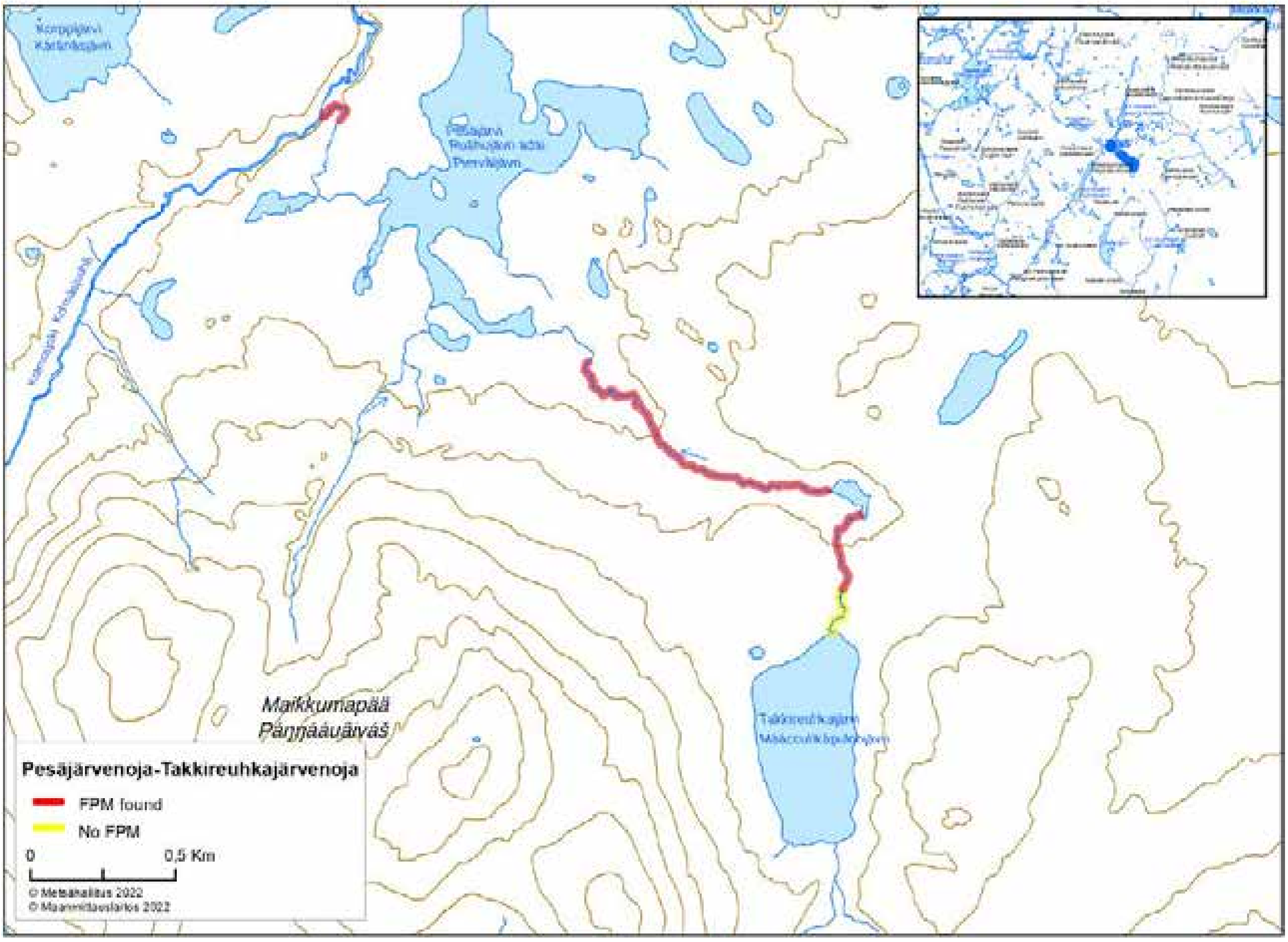

Figure 109. Investigated area (total count) in river Pesäjärvenoja (upper line) and in Takkireuhkajärvenoja (lower lines). Small map: River Pesäjärvenoja and Takkireuhkajärvenoja marked with a thicker blue line.

Figure 110. Most juvenile FPM were found from the lower part of Pesäjärvenoja. Photos: Aune Veersalu.

Pesäjärvenoja (Appendix 1). In Pesäjärvenoja the mussels were found only from the lowermost 160 m long river stretch before the brook joins to river Kolmosjoki. Since many of the mussels in river Pesäjärvenoja were small juveniles (smallest found mussel 20 mm in shell length), it is possible that the brook serves as a juvenile habitat for the Kolmosjoki river mussels, just like described above for the river Saari-Ahvenjärvenoja. The smallest mussel found in Takkireuhkajärvenoja was 44 mm in length and the proportion of mussels ≤ 50 mm 3.6% (Appendix 1). The size distribution of randomly collected 56 mussels in Takkireuhkajärvenoja are shown in Fig. 112. The overall viability class of the Takkireuhkajärvenoja–Pesäjärvenoja FPM population is *non-viable*, although parts of it, i.e., Pesäjärvenoja, could be considered as *viable*. It is however questionable, whether Pesäjärvenoja mussels can be considered as own population or if they are part of the river Kolmosjoki FPM population.

Figure 111. S. Kankaanpää surveying river Takkireuhkajärvenoja and gathering mussels for measurement in October 2021. Air and water temperatures are already freezing. Photos: Aune Veersalu.

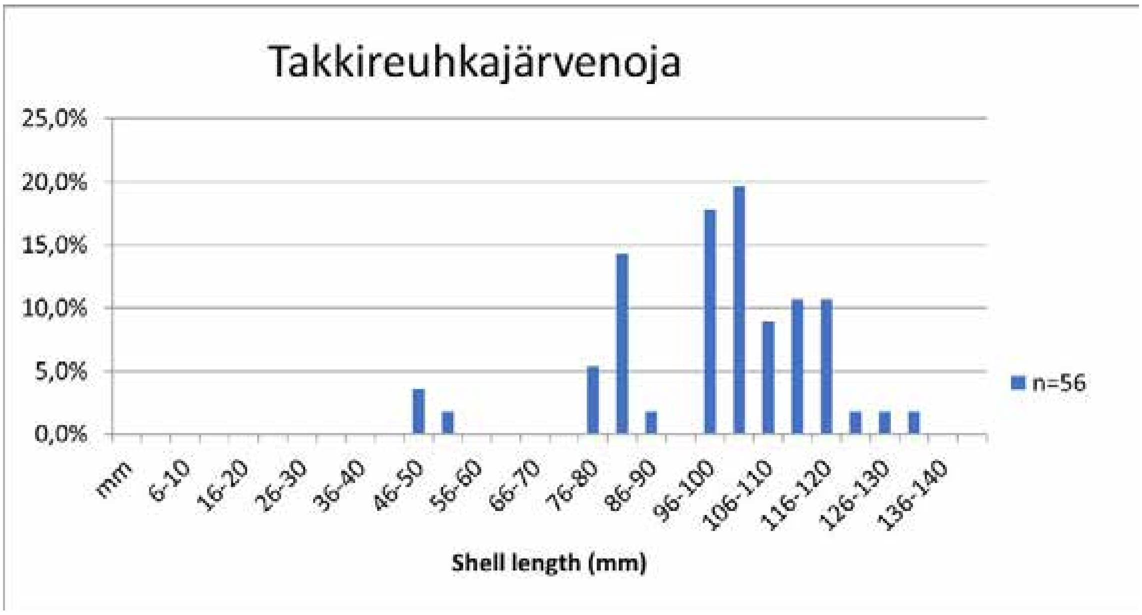

Figure 112. Size distribution of the mussels in the river Takkireuhkajärvenoja.

River Kivijoki

River Kivijoki (Fig. 113) gets it water from lake Joenyhtymäjärvi (173 m above sea level) and several tributaries. It runs to Kivilompolo lake at the Finnish-Russian national border and from the border the river flows in Russian territory to the lake Madsašjaur. The downstream river from Lake Madsašjaur has its outlet in the Lutto main river in Russia.

FPM was found from River Kivijoki during the Interreg Kolarctic project in 2005 (Oulasvirta 2006). In that project river was preliminary investigated by snorkeling it downstream from the outlet of the tributary of Hanhioja to the Russian border. Altogether 737 mussels were counted from that river stretch.

In this study, 24 random transects were established to the area from lake Joenyhtymäjärvi to the national border (Fig. 114). Length of the investigated area is around 5 km. The transects were investigated in 7.–9.8.2021. In all, 11 out of the 24 transects contained FPM. The estimated number of mussels for the whole Kivijoki was 3,442 individuals (Appendix 1). The mean density of the population was 0.17 individuals/m^2.

According to the results, it seems that the Kivijoki FPM population has grown notably since 2005. However, the results of 2005 and our study are not totally comparable, because of the different methods. In 2005, the mussels were counted when swimming down the river. By this method the counting is never as accurate compared to the counting upstream. Moreover, the investigated area was shorter in 2005. Still, part of the population growth is probably true, because the proportion of juvenile mussels in Kivijoki was in 2021 very high. It indicates that the recruitment of new mussel generations has been successful recently. Young year classes stand up well in the size distribution chart in Fig 115. The proportion of ≤ 20 mm mussels was 2.17% and the proportion of ≤ 50 mm mussels 31.16%. With these figures the population could be classified as *viable*.

Figure 113. River Kivijoki 7.8.2021. Photo: Panu Oulasvirta.

Due to the abundance of juvenile mussels, we could also determine the growth curve for the young mussels. The growth rate in Kivijoki represents so-called normal growth rate (see Dunca & Mutvei 2009). The shell length of the ≤ 10yr mussels were in Kivijoki in average 21 mm and the ≤ 2 0yr mussels 55 mm (Fig. 116).

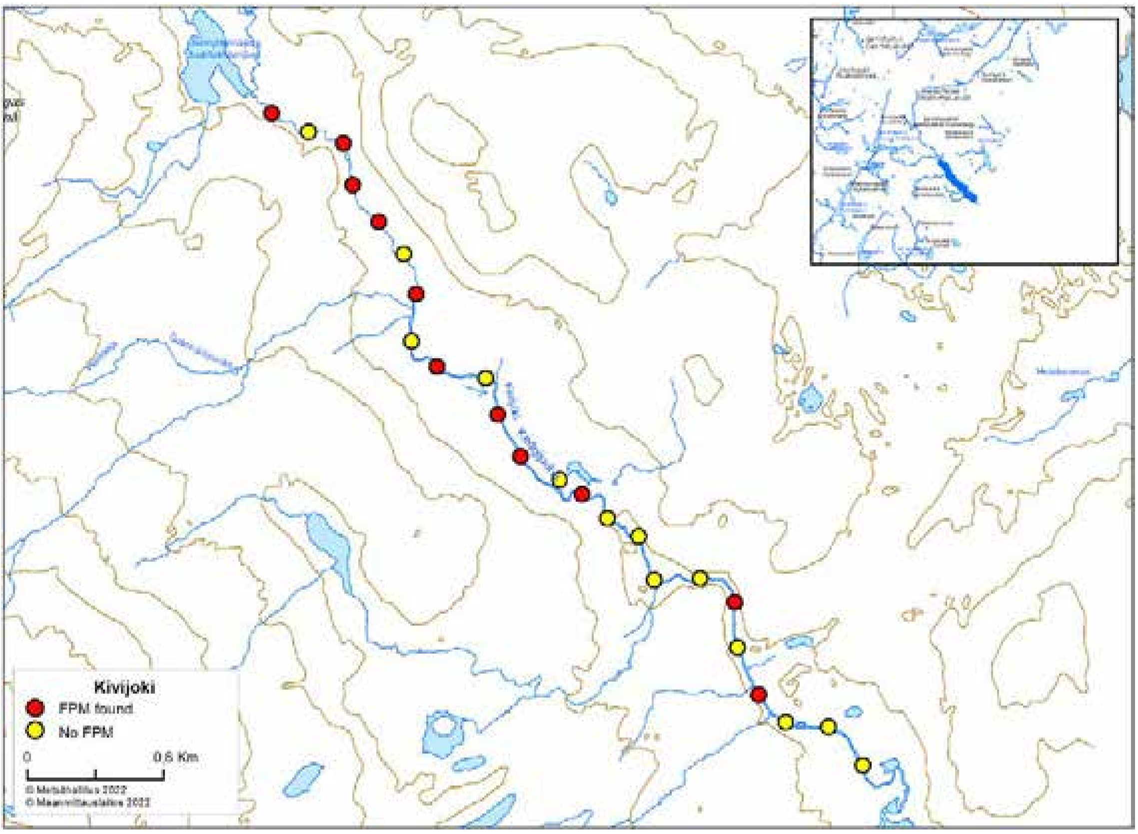

Figure 114. Random transects in river Kivijoki. Small map: River Kivijoki marked with a thicker blue line.

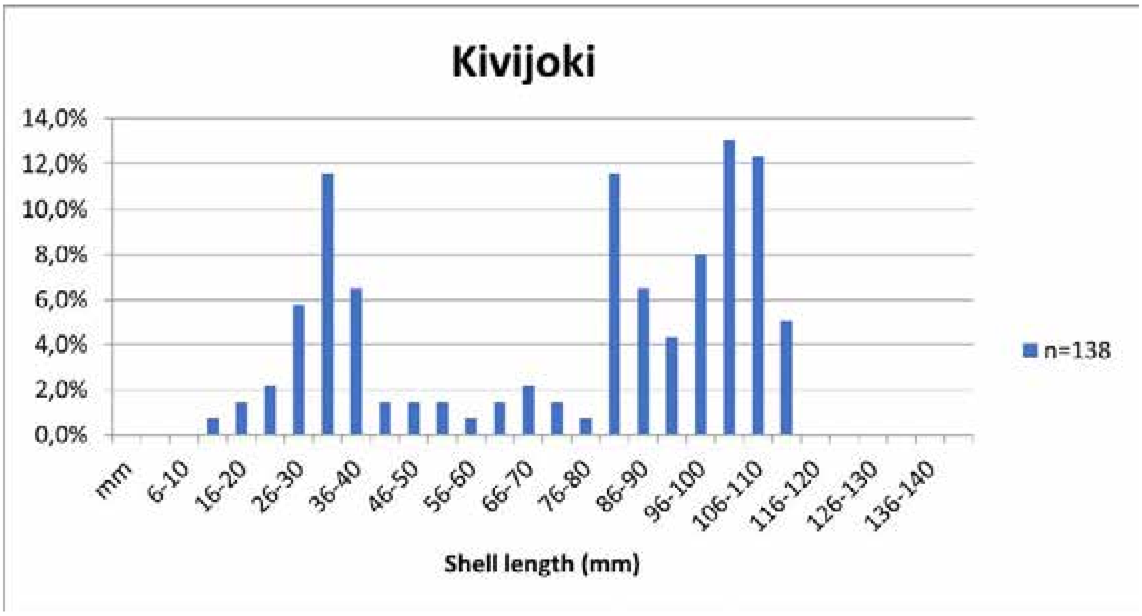

Figure 115. Size distribution of the mussels in river Kivijoki. Mussels less than 55 mm are 20 years or younger. The size distribution shows that the recruitment rate of new mussel generations has been good during the last two decades.

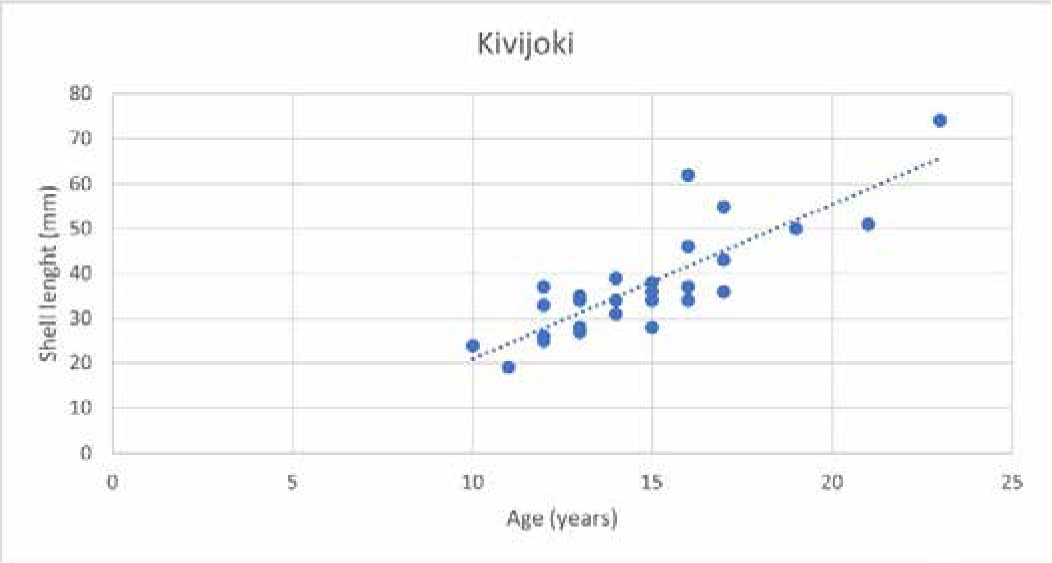

Figure 116. Growth rate of the young mussels in river Kivijoki.

River Rytioja

Rytioja (Fig. 117) belongs to Kivijoki sub-catchment. It starts from the lake Mukka-Rytijärvi (7.9 ha; 204.6 m above sea level) and runs 3.7 km to lake Joenyhtymäjärvi (173 m above sea level) and further to river Kivijoki, dropping 31.9 m on its way. The size of the catchment area is 7.8 km². Besides lake Mukka-Rytijärvi, also Nokanpalelluttamajärvi lake (3.69 ha), above Mukka-Rytijärvi, belongs to this catchment.

The local indigenous people, the Skolt Sámis, used to exert pearl fishing knowing potential mussel rivers well. In Interreg Kolarctic project 2000–2005, historical data about pearl mussel rivers of the area was gathered and local people interviewed (Veersalu 2006). One representative of the Fofanoff family, living around the Madsašjaur lake (now in Russian territory), talked about FPM population occurrence in the river Tshauddlemjok (the name of Kivijoki in Skolt Sámi language), which has its headwaters in Rytioja, Finland. This information was confirmed during the same project by observations of Kai Kangas (Metsähallitus) in 2004 (reported by Oulasvirta 2006).

In this project, river Rytioja was investigated in August 2021. At first, random transect method was used, placing 18 transect to the river (Fig. 118). Transects were studied between 5. and 7.8.2021. FPM was found only from one transect, which was the third transect below the lake Mukka-Rytijärvi. In order to get a more reliable picture of the population, a new survey, using total count method, was conducted in the uppermost part of the river in 9.08.2021 (Fig. 119).

According to the total count the size of the FPM population in river Rytioja was 350 mussels (Appendix 1). The distribution range is 560 metres. Shell length measurements of the mussels were not done. However, based on visual *in situ* observations, most of mussels were old (Fig. 120). Only a couple of ca. 30 mm mussels and two empty shells of the same size were found.

In Rytioja, large-scale forestry is the main threat to its FPM population. Almost the entire catchment of the river has been clearcut, and a forest road crosses the river. Increased sedimentation was observed in the FPM area and also increased amount of rooted submerged vegetation more downstream (Fig. 121).

Figure 117. River Rytioja, FPM area in the upper course. Photo: Heikki Erkinaro.

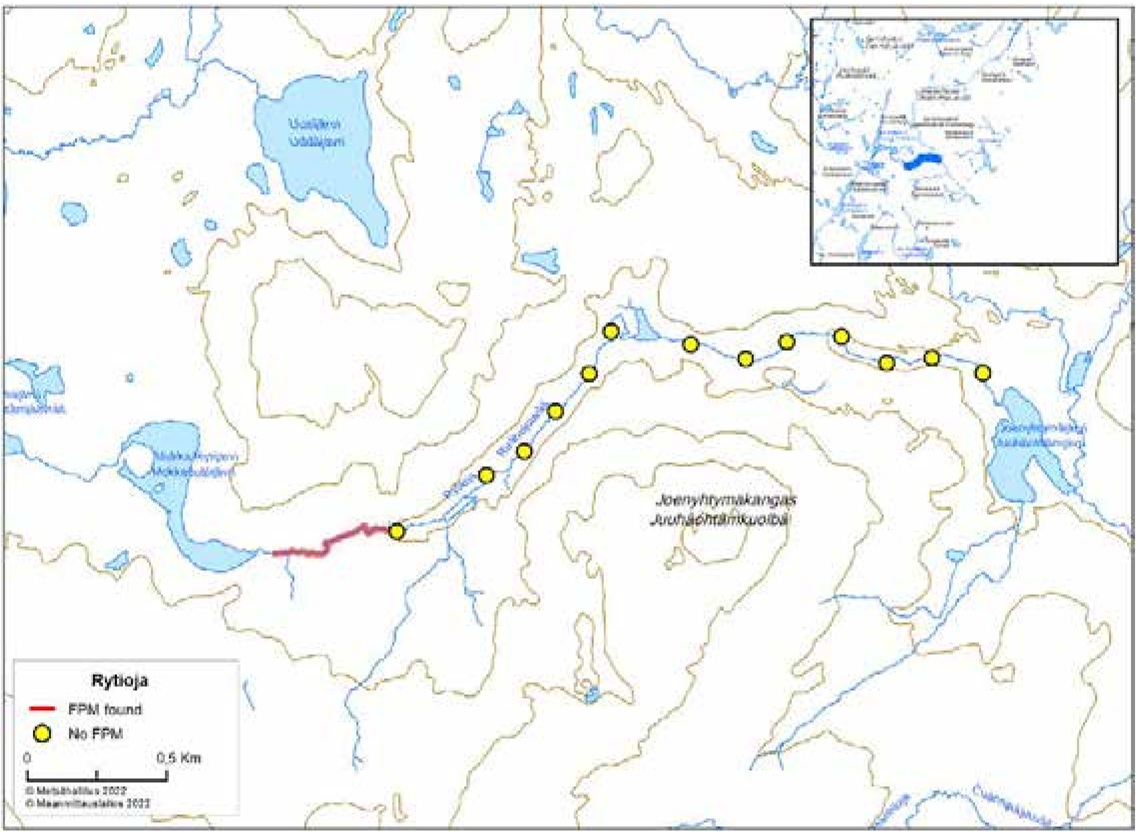

Figure 118. Investigated sites in river Rytioja. Yellow dots: random transects. Constant line: total count. Small map: River Rytioja marked with a thicker blue line.

Figure 119. Rytioja total count in August 2021. Surveying small streams can be challenging. Sometimes the stream and the diver are fully covered by the vegetation. Photos: Heikki Erkinaro.

Figure 120. River Rytioja situates geologically in granulite belt area, which protects rivers against acid peaks. Granulite rock can be seen on background as a white rock with red garnet spots. Photo: Aune Veersalu.

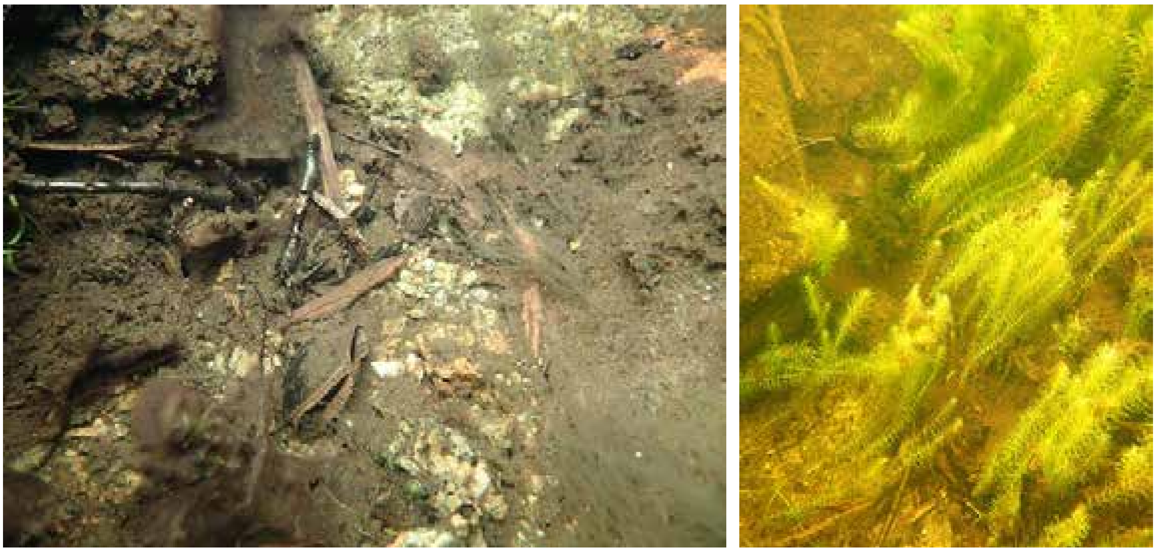

Figure 121. Increased sedimentation of FPM habitats towards downstream areas was observed in the total count of Rytioja in 2021. Photos: Aune Veersalu.

River Ristinmorostonjärvenoja

Ristinmorostonjärvenoja (Fig. 122) belongs to the headwaters of river Hanhioja, which is a tributary of river Kivijoki. It starts from lake Ristinmorostonjärvi (area 3.9 ha, ca. 286 m above sea level) and flows 1.18 km down to lake Hanhijärvi (16.33 ha), dropping ca. 51 metres on its way. The steepest section is in the middle course of the stream. Catchment area is about 2 km².

River Hanhioja is known to inhabit a viable FPM population (Oulasvirta et al. 2006, Oulasvirta 2006, Oulasvirta et al. 2015a). FPM was found from Ristinmorostonjärvenoja in 2005. FPM population of the Ristinmorostonjärvenoja is considered as a sub-population of the Hanhioja river population.

The distribution range of the Ristinmorostonjärvenoja FPM population was mapped by S. Kankaanpää and A. Veersalu (Metsähallitus) in September 2020. The mussel count was performed by total count method using an aquascope in connection of the SALMUS project activities in 24.9.2021 (Fig. 123).

The mussel counting resulted in totally 147 FPM individuals (Appendix 1). The distribution range was 950 metres. Most of the mussels were either in the upper course or in the lower course where the river profile is not as steep as in the middle course. Although the mussels were not abundant, the juveniles were commonly met (Fig. 124). Shell length was measured from 12 mussels out of which 58% were less than 50 mm (Fig. 125). If the viability of the Ristinmorostonjärvi sub-population is measured only by the proportion of juvenile mussels, the population would be classified as *viable*. However, since the number of mussels is so small, this is questionable. As part of the *viable* Hanhioja FPM population, this sub-population can with no doubt be defined also as *viable*.

Figure 122. Lake Ristinmorostonjärvi (background of the left picture) and the river Ristinmorostonjärvenoja starting from it. The shallow upper part of the stream was so narrow that it was hard to fit aquascope into it in places. Mostly young mussels were found from this section of the stream. Photos: Aune Veersalu.

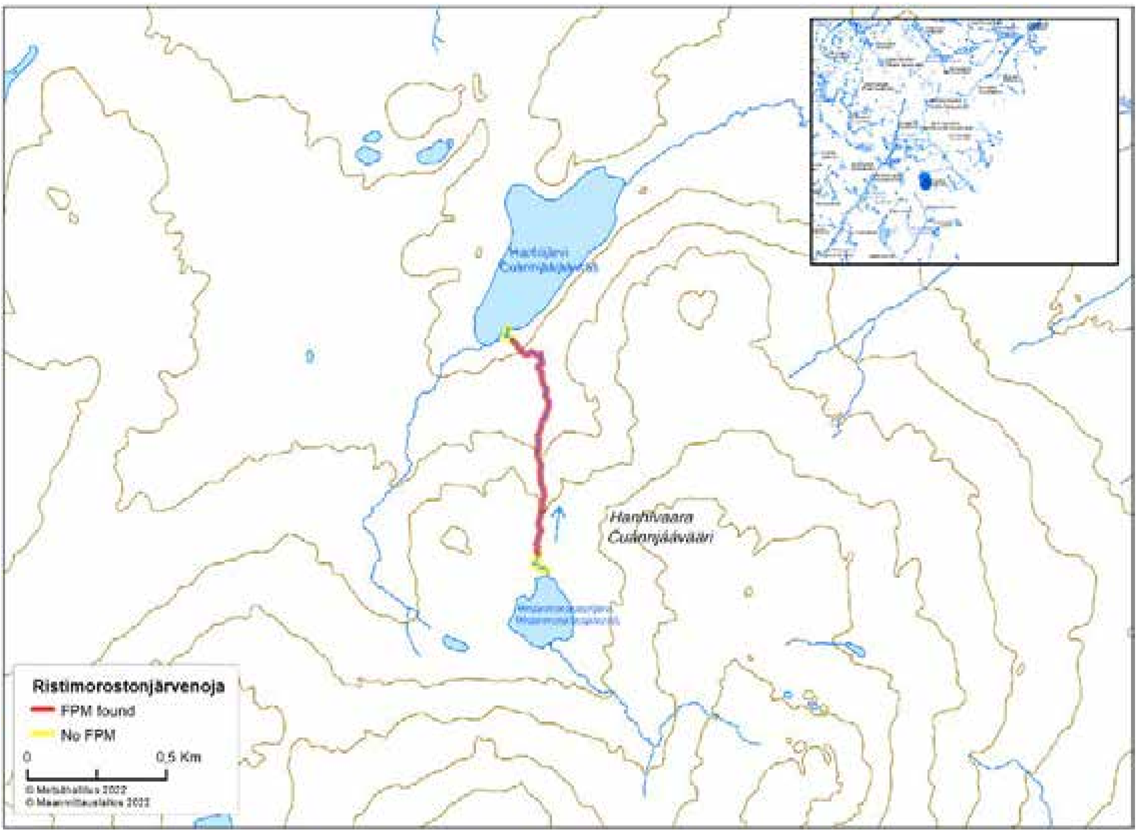

Figure 123. Investigated area (total count) in river Ristinmorostonjärvenoja. Small map: River Ristinmorostonjärvenoja marked with a thicker blue line.

Figure 124. Mussels in Ristimorostonjärvenoja dug deep into the substrate in September. FPM individuals differed quite a lot in size. Photos: Aune Veersalu.

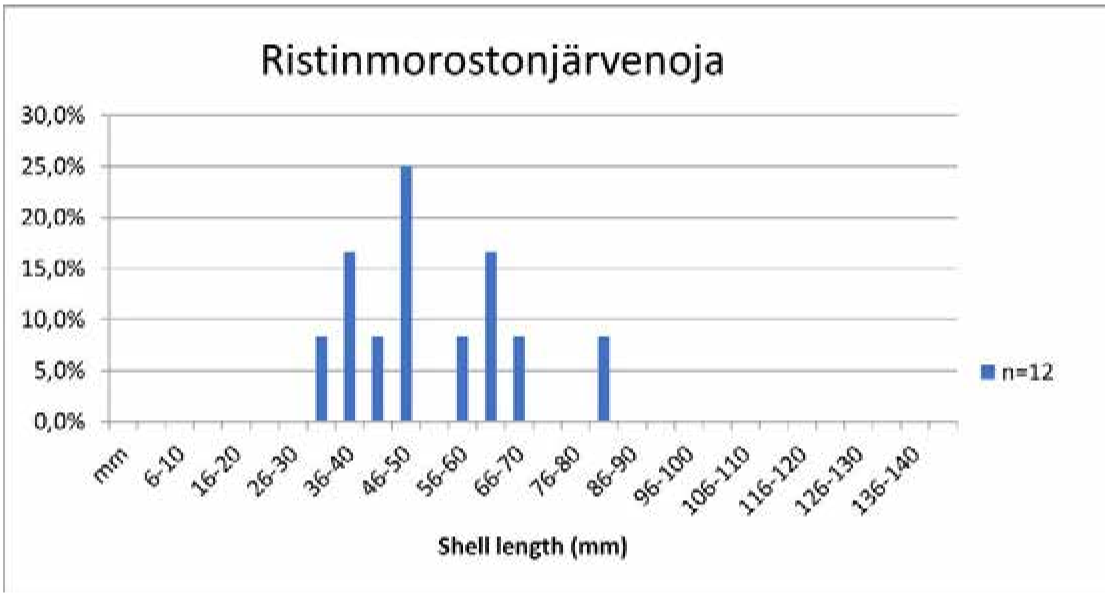

Figure 125. Size distribution of the mussels in the River Ristinmorostonjärvenoja.

River Ahvenlammenoja

Ahvenlammenoja (Fig. 126) is a tributary of river Kulasjoki. It collects water from several lakes in its headwaters which flow to lake Ahvenlampi (area 11.15 ha). Actual Ahvenlammenoja starts there and has its outlet in the river Kulasjoki after running 2.5 km and falling about 50 metres in its course. In total, the catchment area is a bit more than 18 km^2. Around 25% of the catchment area belongs to the Urho Kekkonen National Park (FI1301701). Most of catchment, including the FPM area, is affected by forestry and numerous forest roads. The river has variable habitats – deep silt and organic bottom bog sections, very shallow rapid sections, rocky areas with almost no water visible, but also 50–120 cm deep boulder and gravel areas optimal for FPM.

The FPM population in Ahvenlammenoja was confirmed by P. Oulasvirta (Alleco) in 2013 and the distribution range of the mussels was mapped by A. Veersalu (Metsähallitus) in 2021. The upper limit of the population was detected to be about 270 metres down from Lake Ahvenlampi and the lower limit around 60 metres upstream from River Kulasjoki.

In this study, a total count of mussels was conducted with an aquascope in September 2021 between river Kulasjoki and lake Ahvenlampi (Fig. 127). Altogether 806 mussels were counted (Appendix 1). The distribution range was 1,200 metres. Major part of the population was concentrated on a ca. 200 metres long river stretch in the middle course. Only very few mussels were detected in other areas. The river is challenging, as some sections of it flow through bolder/big stone areas, where the mussels are difficult to perceive (Fig. 126). Due to this reason, the real number of mussels is probably a bit bigger than the counting result. Still, most of the mussels were probably counted, since quite many empty shells were found just downstream from such dry rocky areas. Empty shells may indicate winter freezing and not so many living mussels in these sections of the river.

The shell length was measured from 51 mussels (Fig. 128). Almost all individuals in the sample taken for measurement were bigger than 50 mm in length but based on visual evaluation some more smaller mussels (ca. 30–35 mm in length) were also present on the riverbed.

Figure 126. River Ahvenlamminoja in September 2021. Photos: Aune Veersalu.

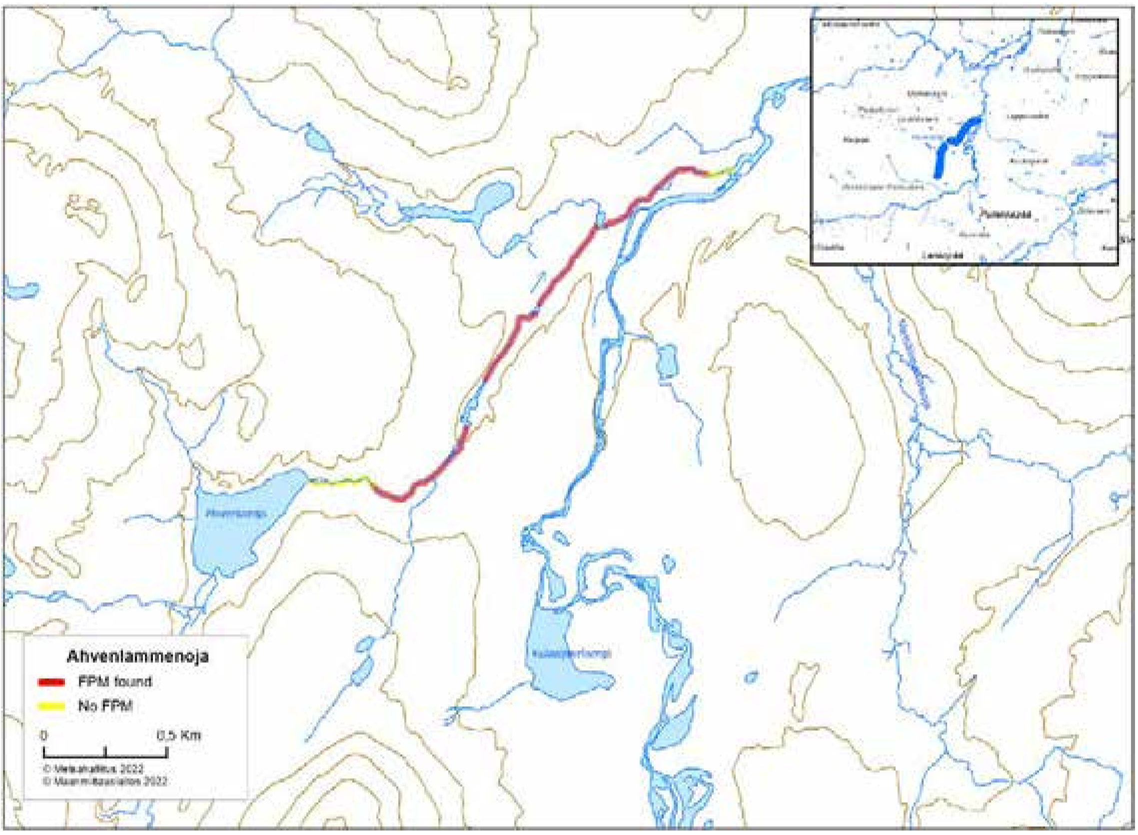

Figure 127. Investigated area (total count) in river Ahvenlammenoja. Small map: thicker blue line marks river Ahvenlammenoja.

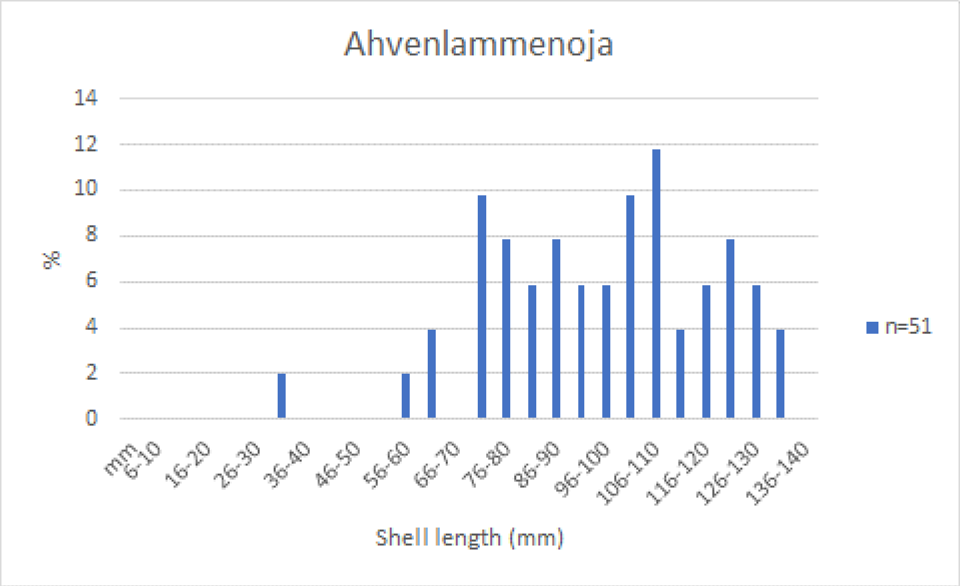

Figure 128. Size distribution of the mussels in the river Ahvenlammenoja.

River Nohkimaoja–Vuoksijoki

Rivers Nohkimaoja–Vuoksijoki are tributaries of river Lutto. Both rivers belong to the same, ca. 13 km long, river chain, in which the upper course carries name Nohkimaoja and the lower course below the confluence with the Vuoksioja tributary has the joint name Vuoksijoki. Further downstream another tributary, Torkonoja, joins Vuoksijoki (Fig. 129). Nohkimaoja originates from lakes Iso-Suorsajärvi (254 m above sea level), Nohkimajärvi (223 m above sea level) and Tervavesijärvi (263 m above sea level). The whole catchment covers 82.77 km^2 out of which 3.33% are lakes (Ekholm 1993).

FPM is known to live in Vuoksijoki subcatchment in many tributaries such as Torkonjoki, Vuoksioja and its headwater Urakkajärvenoja. Nohkimaoja FPM population was investigated first time in 1979 by Ilmari Valovirta (Natural History Museum) and his field team Kirsi Arino and Hilkka Autio (Arino & Autio 1979, unpublished field notes). The investigations of 1979 showed that river Nohkimaoja hosted a viable FPM population with all year classes present.

In this study altogether 31 random transects were established into the Nohkimaoja-Vuoksijoki. 15 transects were in the Vuoksijoki part and 16 transects in Nohkimaoja (Fig. 130). The transects were investigated in Nohkimaoja 19.9.2019 and 24.9.2019 and in Vuoksijoki 17.6.2020 and 27.6.2020.

FPM was found from 16 transects. There was a clear difference between Nohkimaoja and Vuoksijoki. In the Vuoksijoki, only four out of 15 transects had FPM. The estimated number of mussels for the whole Nohkimaoja was 13,420 individuals while the estimated number of mussels in Vuoksijoki was only 386 individuals (Appendix 1). The mean density of the mussels was in Nohkimaoja 0.545 individuals/m^2 and in Vuoksijoki 0.017 individuals/m^2. The overall distribution range of the mussels is around 11 km.

The size distribution of the mussels is shown in Fig. 131. The smallest found mussel from Nohkimaoja was 21 mm in shell length. In Vuoksijoki the smallest found mussel was 48 mm. The proportion of mussels less than 50 mm was 13.5% (Appendix 1). According to that percentage the population was classified as *non-viable*. Notable, however, is that

Figure 129. Establishing a random transect at the river Vuoksijoki in June 2020. Photo: Panu Oulasvirta.

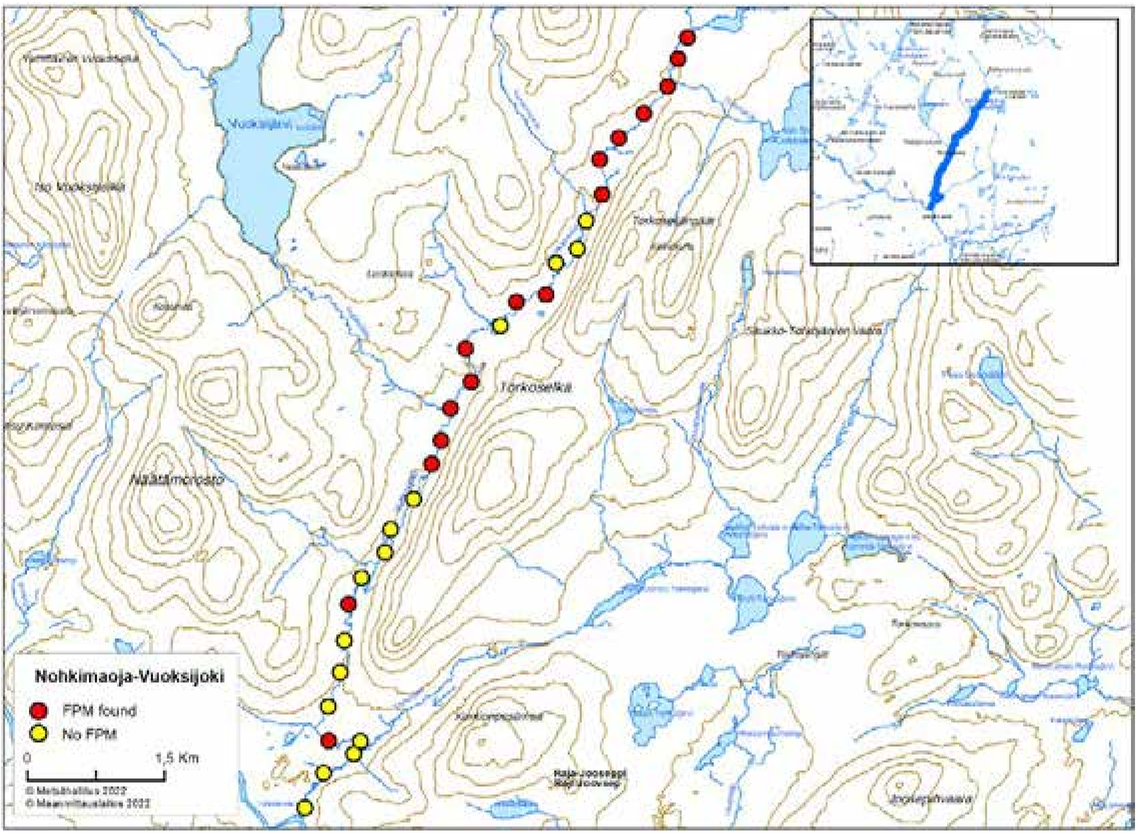

Figure 130. Random transects in rivers Nohkimaoja and Vuoksijoki. Small map: River Nohkimaoja–Vuoksijoki marked with a thicker blue line.

if the estimate is based on the real age of the mussels the viability class changes to *maybe viable*. This is because the proportion ≤ 10yr mussels would be 4.5% and the proportion of ≤ 20yr old mussels 13.5% (Table 3). According to the estimated growth rate the shell length of the 10yr old mussel is in average 29 mm and 20yr old mussels 52 mm (Fig. 132). The age was inspected from 25 juvenile mussels with ages from 6 to 25 years.

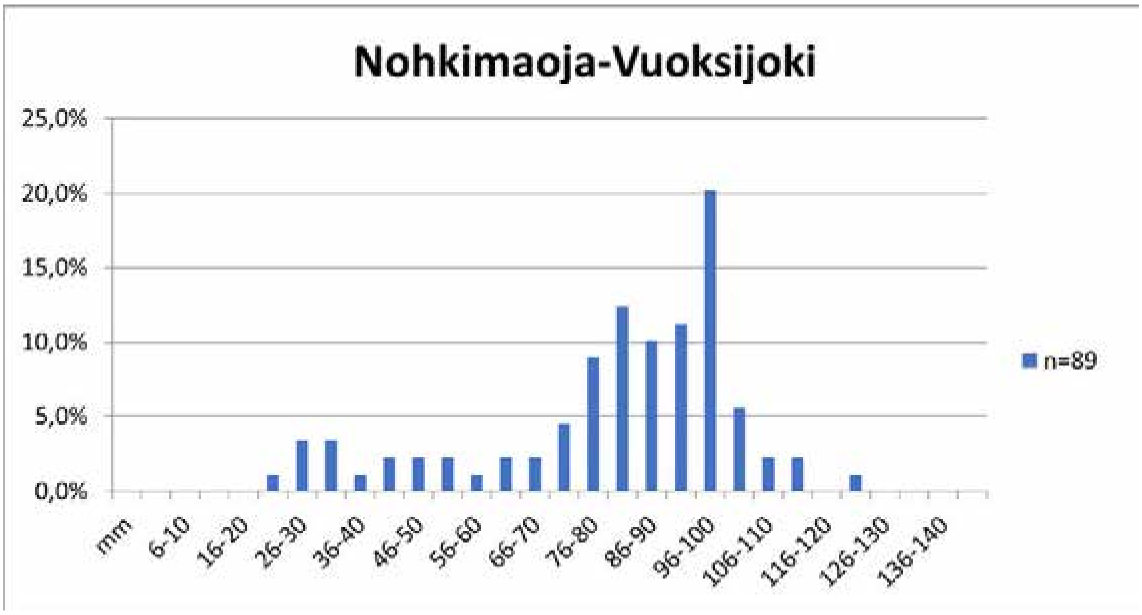

Figure 131. Size distribution of the mussels in Nohkimaoja–Vuoksijoki.

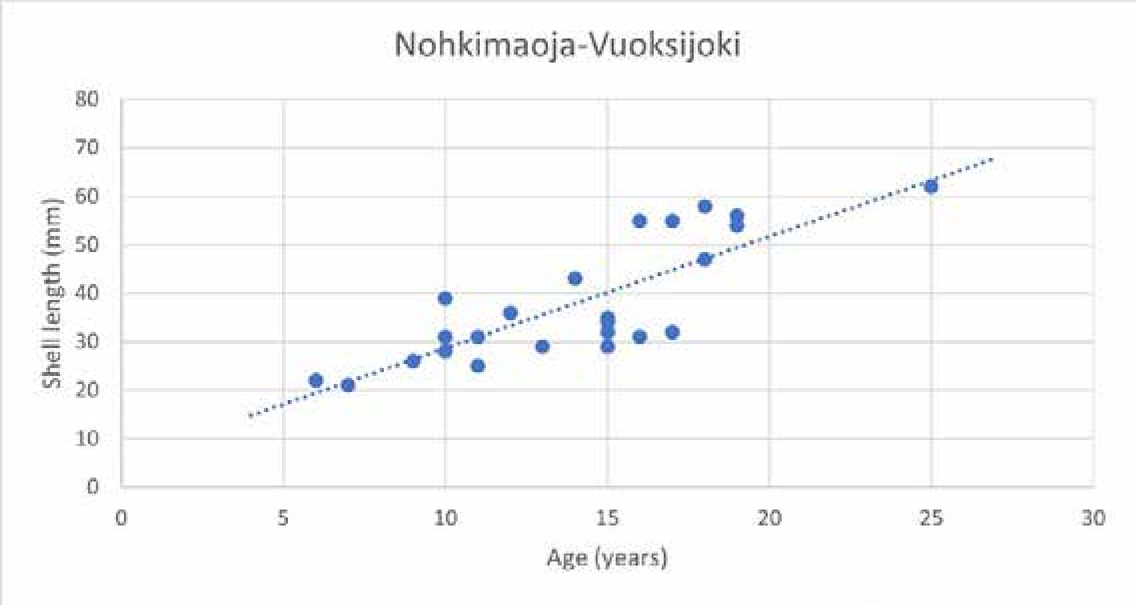

Figure 132. Growth rate of the juvenile mussels in Nohkimaoja–Vuoksijoki.

River Urakkajärvenoja–Vuoksioja

Urakkajärvenoja–Vuoksioja is a small tributary of river Vuoksijoki. The upper part of the rivers, above lake Vuoksijärvi (219 m above sea level) is called Urakkajärvenoja (Fig. 133) and the part below the lake Vuoksioja. The catchment is 20.58 km^2 out of which 8.7% are lakes. Besides Lake Vuoksijärvi there is a lake called Urakkajärvi (265 m above sea level) in the headwaters, where the whole river system starts. FPM was found from the Urakkajärvenoja in 2004 during the Interreg Kolarctic project (Oulasvirta et al. 2006, Oulasvirta 2006).

In this study 12 random transects were established into the Vuoksioja (Fig. 134). In Urakkajärvenoja, the mussel counts were also conducted in 20 meter transects, but unlike other rivers, now the transects were located one after other so that the next transects started where the previous one ended. In other words, the method was corresponded to total count method with only the exception that the number of mussels was recorded in every 20 metre sections. By this way the total number of transects in Urakkajärvenoja became 76. The distribution range of the mussels in Urakkajärvenoja is 1 520 metres and in Vuoksioja 3,200 metres. The transects in Urakkajärvenoja were investigated in 8.–9.8.2019 and 1.9.2019 and the transects in Vuoksioja 4.9.2019 and 17.9.2019.

In Vuoksioja, FPM was detected in all transects except for the lowermost one (Fig. 134). In Urakkajärvenoja, FPM was found from 63 out of 76 transects. The counted total number of mussels in Urakkajärvenoja was 7,700 individuals. In Vuoksioja the total number of mussels, 10,733 is an estimate based on the mussel numbers from random transects. Thus, the Urakkajärvenoja–Vuoksioja FPM population would be 18,333 individuals in total (Appendix 1). The mean density of mussels in Vuoksioja was 1.39 individuals/m^2 and in Urakkajärvenoja 4.96 individuals/m^2. Maximum densities in Urakkajärvenoja were very high, exceeding 200 mussels/m^2 in some areas.

Figure 133. River Urakkajärvenoja is mostly a narrow brook running in a marshland area. Photo: Panu Oulasvirta.

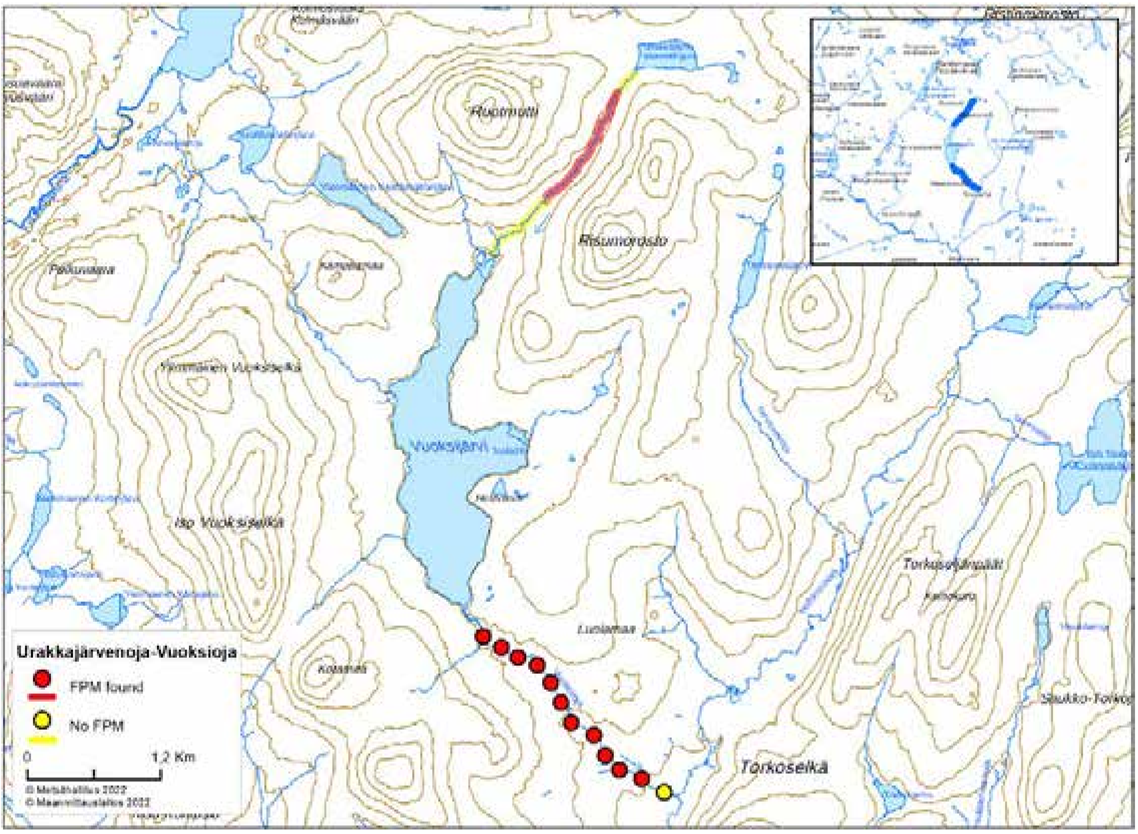

Figure 134. Investigated area in river Urakkajärvenoja (total count) and Vuoksioja (random transects). Small map: Rivers Urakkajärvenoja and Vuoksioja marked with a thicker blue line.

The status of the population was good in both rivers. The smallest mussels found were only 10 mm in Vuoksioja and 13 mm in Urakkajärvenoja. The size distribution of the mussels is shown in Fig. 135. The proportion of < 20 mm mussels was 1% and < 50 mm mussels 20%, which means that the population can be classified as *viable* (Appendix 1). The age of juvenile mussels was studied from 24 individuals. The mussels were in average 29 mm long at the age of 10yrs and 48 mm at the age of 20yrs. (Fig. 136). When using these figures, the proportion of ≤ 10yr mussels would be 7% and the proportion of ≤ 20yr mussels the same as based on the length criteria, i.e., 20% (Table 3).

Figure 135. Size distribution of the mussels in Urakkajärvenoja–Vuoksioja

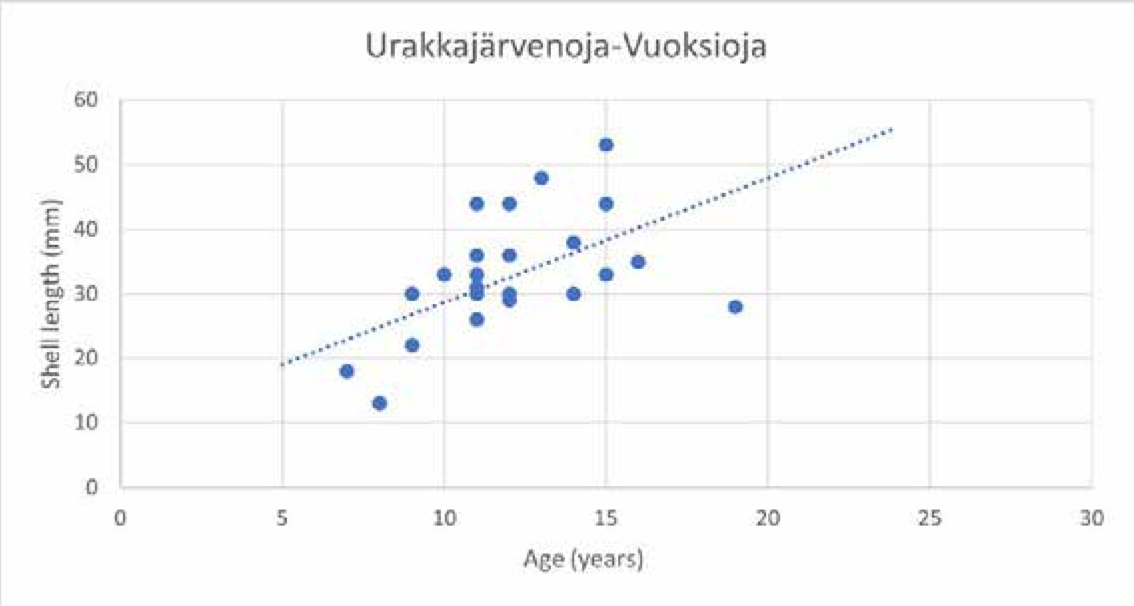

Figure 136. Growth rate of the juvenile mussels in Urakkajärvenoja–Vuoksioja.

Kulasjoki

Kulasjoki (Fig. 137) headwaters have their origin at more than 400 m a.s.l. in the terrain of Kiilopää, Kuutamokuru and Rautupää, joining below Luuvaara to form the river Kulasjoki (305 m a.s.l.).

The total river length is 28.4 km, and the river flows following the border of Sodankylä and Inari municipalities joining finally the river Luttojoki. The catchment area is 158.7 km², only 0.47% of this consists of lakes. Upper part, about two-thirds of the catchment, belongs to the Urho Kekkonen National Park (FI1301701). The upper part of the river is mostly shallow and steep, dropping down 137 m on its way from Luulampi ponds down to the mouth of Ahvenlammenoja, where the actual occurrence area of the FPM population starts at 168 m a.s.l. (Fig. 138). The FPM population area is situated in the lower course of the river – a 11.7 km long river stretch from the mouth of Ahvenlammenoja (the biggest lake in the catchment) down to the confluence of rivers Lutto and Kulasjoki. During this course Kulasjoki is up to 3 m deep and has a gradient of only 15 m. In all, the FPM area of the river is not included in the protected part of the river catchment, and it is largely affected by forestry and forest roads, erosion, and sedimentation (moving sand) being the main influencing factors in the river environment (Fig. 139).

Earlier FPM shell findings in Kulasjoki have been mentioned by Valovirta (1997), and during the Interreg Kolarctic project six living FPM specimens were found in 2004 (Oulasvirta 2006). In 2020, due to the renewal of the Kulasjoki road bridge, Alleco Oy surveyed a short river stretch (starting 50 m above the bridge and ending one kilometer below the bridge) finding three living specimens (Oulasvirta 2020). This part of the river was not surveyed in 2022, but results of that survey were included in the present study. The headwaters of the Kulasjoki around Luuvaara were surveyed earlier in 2020 by Metsähallitus.

Figure 137. Surveying clear waters of Kulasjoki in June 2022. Photo: Heikki Erkinaro.

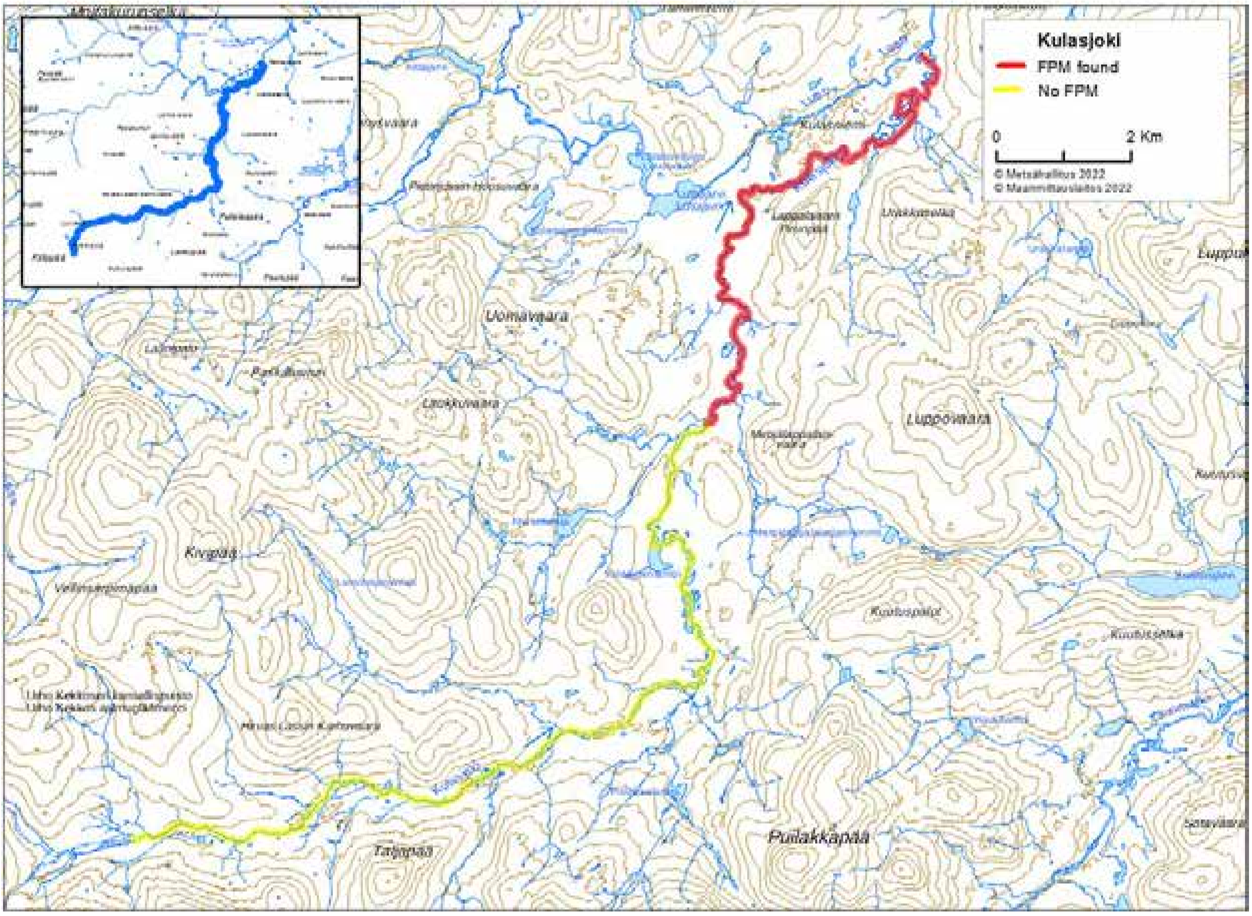

Figure 138. Investigated area (total count) in the river Kulasjoki. All FPM individuals were found downstream from the confluence of Ahvenlammenoja and Kulasjoki (red line). Small map: River Kulasjoki marked with a thicker blue line.

In June 2022, the occurrence limits of the Kulasjoki FPM population were determined, and the population size assessed using a total count method, in a survey performed by a rubber boat and snorkeling (Figs 137–139). The water of Kulasjoki is very clear (Figs 137 and 139), and even the deep parts could be explored by snorkeling. The survey covered the total river length from Luuvaara to the confluence with the Lutto river. No FPM individuals were detected in the upper course of the river.

As described above, the occurrence area of the FPM population started from the mouth of Ahvenlammenoja (Fig. 140). The population density was highest just below the Ahvenlammenoja mouth – 67% of the total river population (50 specimens) was found in a 500 m long river stretch downstream from the mouth of Ahvenlammenoja. A sparse FPM population extends downstream to the confluence of Kulasjoki and Lutto river.

Totally 72 specimens were counted in this study, so the approximated total size of the Kulasjoki FPM population, including the earlier study by Oulasvirta (2020), was 75 specimens. The mussels were not measured, but mussels under 70 mm in length were not detected at all, hence the population status should be considered as *dying*. Still, as no FPM were detected upstream from the Ahvenlammenoja mouth, it is possible that the FPM population in Ahvenlammenoja is part of the river Kulasjoki population. In that case, younger mussels found there (see chapter of Ahvenlammenoja above) could act as a source population for the Kulasjoki FMP population. This connection increases even more importance for the protection of the Ahvenlammenoja FPM population.

Figure 139. Trying to find better place in the sedimented substrate of Kulasjoki – the trail of an FPM individual. The moving sand forms wave patterns onto the river bottom. b. Sandy riverbanks in the lower course of Kulasjoki river. Photos: Aune Veersalu and Sakari Kankaanpää.

Figure 140a. A diver spotting the upper limit of the Kulasjoki FPM population. Surveying 28 km of Kulasjoki was done by snorkeling in 2022, using a rubber boat for logistics. **b.** The habitat near the upper limit of the Kulasjoki FPM population is more stony and less sedimented. Photos: Sakari Kankaanpää and Aune Veersalu.

Akanjärvenoja

River Akanjärvenoja (Fig. 141) is a sub-tributary of the river Kuutusoja and a tributary of the river Suomujoki. Its headwaters have origins in Riukuselkä, one of them (Linjamaanoja) flows steeply about 3 km from Linjamaanlampi (about 3 ha, 248 m a.s.l.) to Harrijärvi (10.95 ha; 178 m a.s.l.). The river continues 1.2 km from Harrijärvi to Pajujärvi (32.2 ha; 166 m a.s.l.) and 650 m from Pajujärvi to Akanjärvi (15.031 ha; 163 m a.s.l.). From Akanjärvi it continues 750 m, dropping some more 10 m, and joins Kuutusoja about 1.2 km upstream from the confluence of Kuutusoja with Suomujoki. The catchment area of Akanjärvenoja is 16.4 km², 3.7% of it are lakes. The river is not protected, except for the lowermost 100 m of its course when it flows as the border river of the Urho Kekkonen National Park (FI1301701). The upper limit of the FPM area is situated in the stretch between Harrijärvi and Pajujärvi, and the lower limit at the Kuutuanoja river mouth. Interestingly, FPM is totally lacking in the middle parts of the rivercourse, between Pajujärvi and Akanjärvenoja, so the FPM population is divided in two parts with a empty gap between.

The information about the existence of FPM population in Akanjärvenoja had earlier been documented with a shell sample and observations of living FPM individuals noticed for the Finnish Museum for Natural History (LUOMUS) by Valovirta (1997). According to a pearlfisher Matti Huru, interviewed in 2001, the mussels in Akanjärvenoja were destroyed in 1930s as the river freezed down to the bottom. Apparently not all the mussels had died,

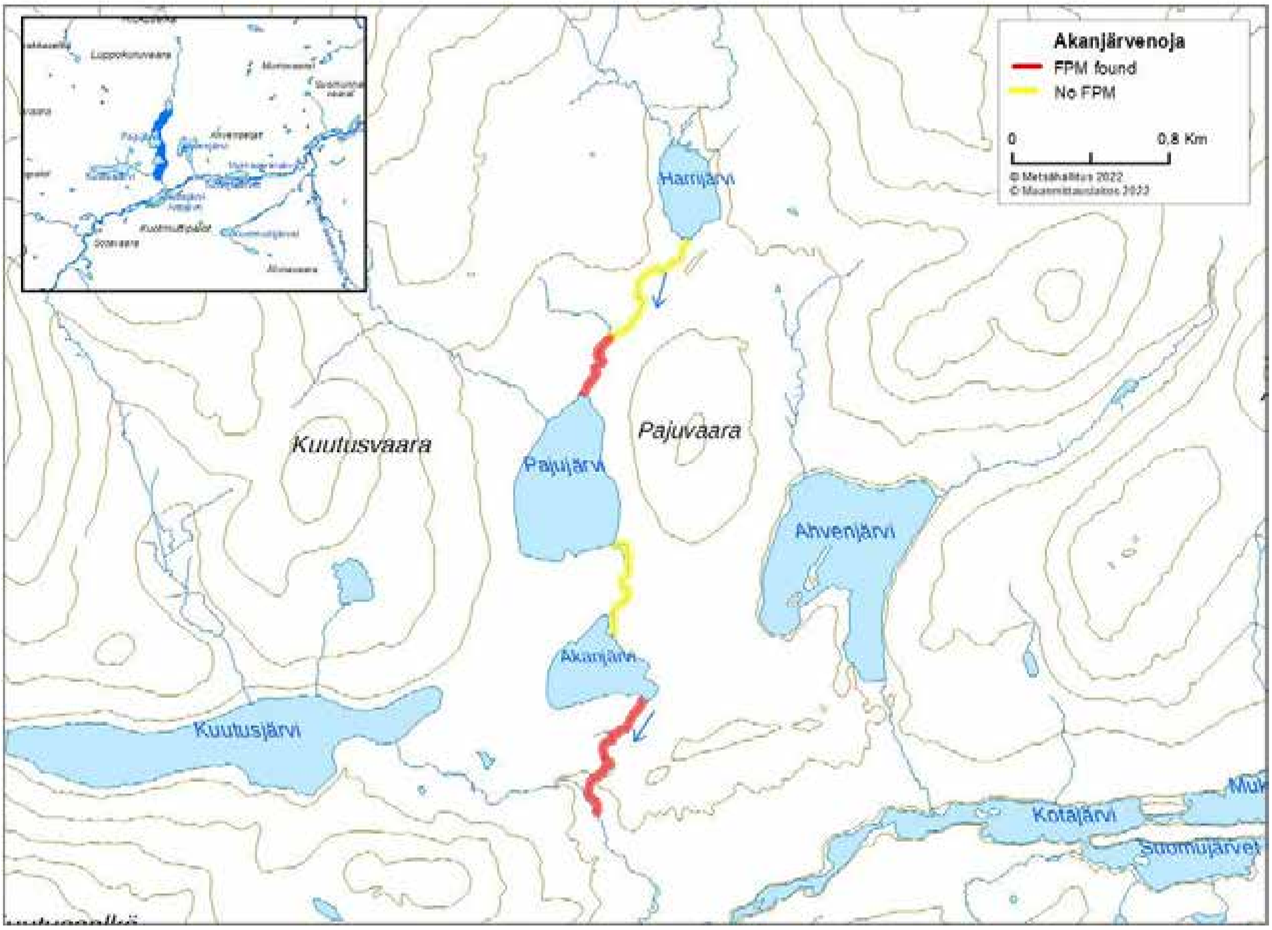

Figure 141. Investigated area (total count) in Akanjärvenoja. The occurrence of FPM individuals was divided in two separate areas (red line). Small map: Akanjärvenoja marked with a thicker blue line.

Figure 142a. Akanjärvenoja downstream from Harrijärvi is steep in the upper course, but slows down in the middle course, where the occurrence area of the FPM population starts. **b.** Stones and gravel on the bottom are typical FPM habitat in the Akanjärvenoja. Photos: Aune Veersalu.

as the FPM population was refound and its limits determined in 2020 by Metsähallitus.

In the SALMUS project, the population size was determined by using a total count method with snorkeling in August 2022. Totally 271 FPMs were counted in Akanjärvenoja, 168 individuals between Harrijärvi and Pajujärvi and 103 individuals between Akanjärvi and Kuutusoja, respectively. The mussels were not measured, except for the mussels that were visually assessed to be under 50 mm in length. Three mussels were measured between Harrijärvi and Pajujärvi – being 25 mm, 43 mm and 47 mm in length (Fig. 143) and for comparison one mussel of 78 mm. Most mussels in this part of the river were about 70–80 mm in length based on visual assessment.

Between Akanjärvi and Kuutusjoki the youngest mussel found was 39 mm in length, in addition individuals of 47.2 mm and 49.7 mm were measured. Largest mussels found were 119 mm and 138 mm in length. This part of the population consists mostly of larger mussels, except for the last rapid area before joining the Kuutusjoki. The younger measured mussels mentioned above were found also in this river section where individuals of ca. 70 mm in length prevailed based on visual assesment. Still, as the proportion of mussels under 50 mm is only 2.25% of the total population, the FPM population of the Akanjärvenoja should be considered as *non-viable*.

Figure 143. The youngest FPM, found in Akanjärvenoja, had a length of 25 mm, the FPM next to it is 47 mm in length. Photo: Aune Veersalu.

Nameless creek at Suomuhaara

A tiny, less than 0.5 m wide nameless creek is a small tributary of river Suomujoki with a single 3 ha headwater lake (180 m a.s.l.) under Suomunniemivaara (Figs 144 and 145).

The catchment area is about 2.9 km^2, of which lakes make about 1,7%. The creek has a gradient of 40 m on its 2 km long course, joining another nameless creek about 1 km upstream from the final confluence with the river Suomujoki. The creek runs last 500 m of its course inside the Urho Kekkonen National Park (FI1301701), but protected areas cover only 1,7% of its catchment area. It is situated near Niemioja (see the Niemioja chapter earlier) and is affected by the same forest clearcuts. Large clearcut areas and a forest road crossing have enormous influence on such a small creek. Even though the creek is small, it is surprisingly deep – more than 1 m in many sites – and widens like a bottle under its banks. The bottom substrate in the FPM area is mostly composed of stones, gravel, and sand, but the sediment load is remarkable (Fig. 146).

FPM population in this creek was found only in 2022 by Metsähallitus. The occurrence area is strongly concentrated on a river section of only 120 m in length (Fig. 145). In this study, the population size was estimated using a total count method by snorkeling in August 2022.

Totally 237 living individuals (Appendix 1) were counted in the creek. The mussels were not measured, but young mussels under 70 mm in length were not found at all. The number of empty shells found was also remarkably high – 127 shells, which makes 53% of the total number of FPM found alive. So, the population could be classified as *dying*. Still, possible options to save the FPM population in such a small creek with a well-defined catchment and clear water should be kept in mind.

Figure 144a. A nameless FPM creek under Suomunniemivaara. **b.** Sometimes the creek disappears under the sods of the riverbank vegetation, and it is mostly too narrow and deep to fit aquascope in, so a slim diver and torch were used for survey. Photos: Aune Veersalu.

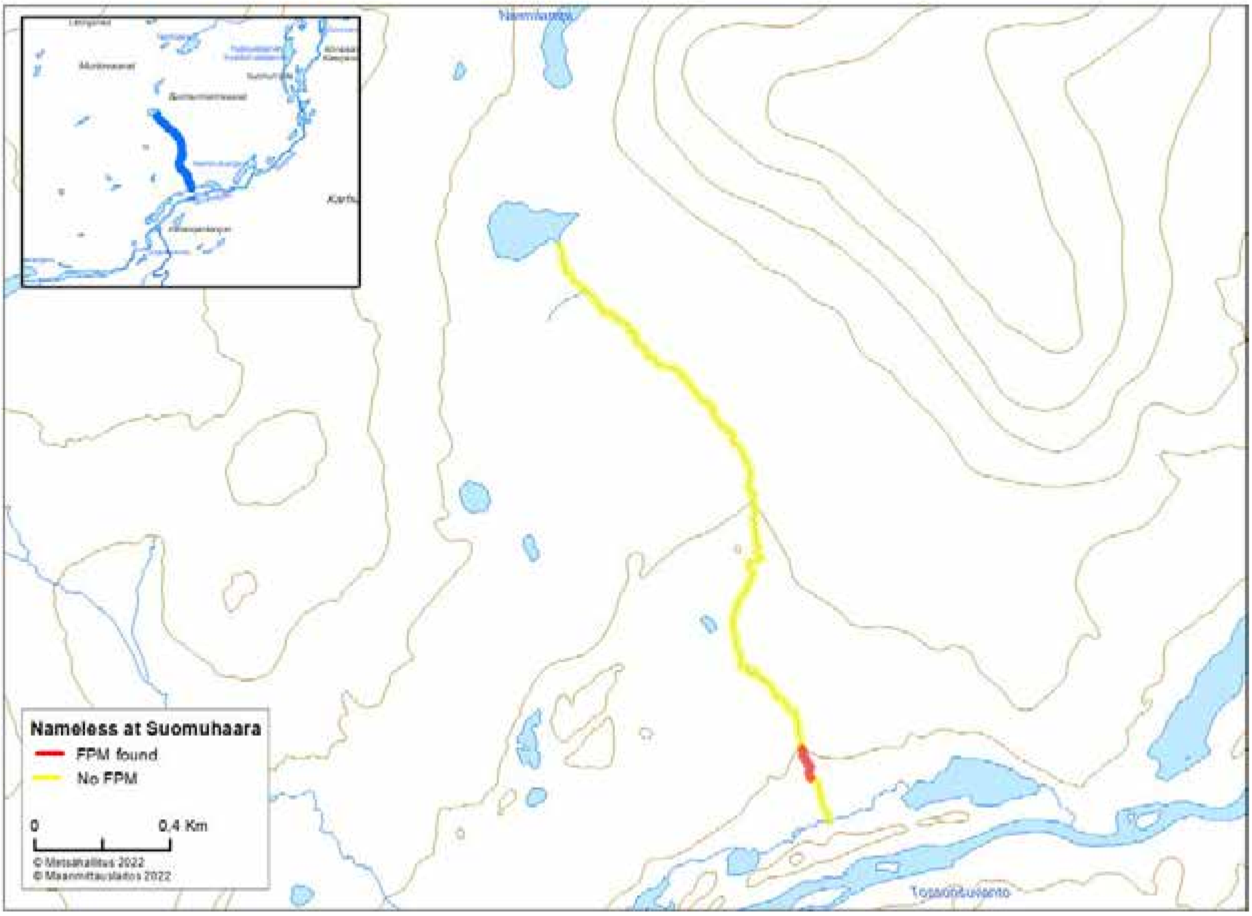

Figure 145. Investigated area (total count) in the nameless creek at Suomuhaara. All FPM individuals were found in a quite restricted stretch of only 120 m in length. Small map: The target creek marked with a thicker blue line.

Figure 146. The bottom substrate is covered by moving sand in many places. Submerged plants are rooting even in strong current, indicating nutrient load. Several empty FPM shells can be seen on the bottom. Photo: Aune Veersalu.

3.4.2.2 Kemijoki catchment

The Kemijoki River basin, with its 49,467 km^2 is the second largest river catchment area in Finland and covers a major part of Lapland. The length of the Kemijoki main river is ca. 550 km. The main tributaries are rivers Ounasjoki, Kitinen and Luiro. Some of the headwaters have their origin in Norway or Russia (Fig. 147). When these areas are included, the whole catchment area covers in total 51,127 km^2. The freshwater pearl mussel is currently known from 50 rivers in Kemijoki catchment. Several new populations have been found in recent years. For example, in SALMUS project alone between 2019–2020 seven previously unknown FPM rivers have been located (Moilanen & Luhta, this report). Only seven years ago the number of known FPM rivers in Kemijoki catchment was 31 (Oulasvirta et al. 2015a).

Although the Kemijoki River basin hosts major part of the Finnish FPM populations, the state of the populations is in many places unfavourable. Above all, the main channel of River Kemijoki and its big tributaries Kitinen and Luiro have been harnessed for hydropower production with numerous hydropower dams and reservoirs. The hydropower dams have prevented Atlantic salmon from ascending to the Kemijoki River, and as a consequence of this, major part of the FPM populations nowadays live in headwater tributaries where the host fish for FPM is brown trout. In this context, the individual FPM discoveries made in 2017 and 2019 in the main channel of Kemijoki are encouraging and give hope that Kemijoki main channel could still host somewhere a viable FPM population (Syväranta & Oulasvirta 2017, Syväranta et al. 2017, Oulasvirta 2019). Besides hydropower dams, another big threat to the FPM

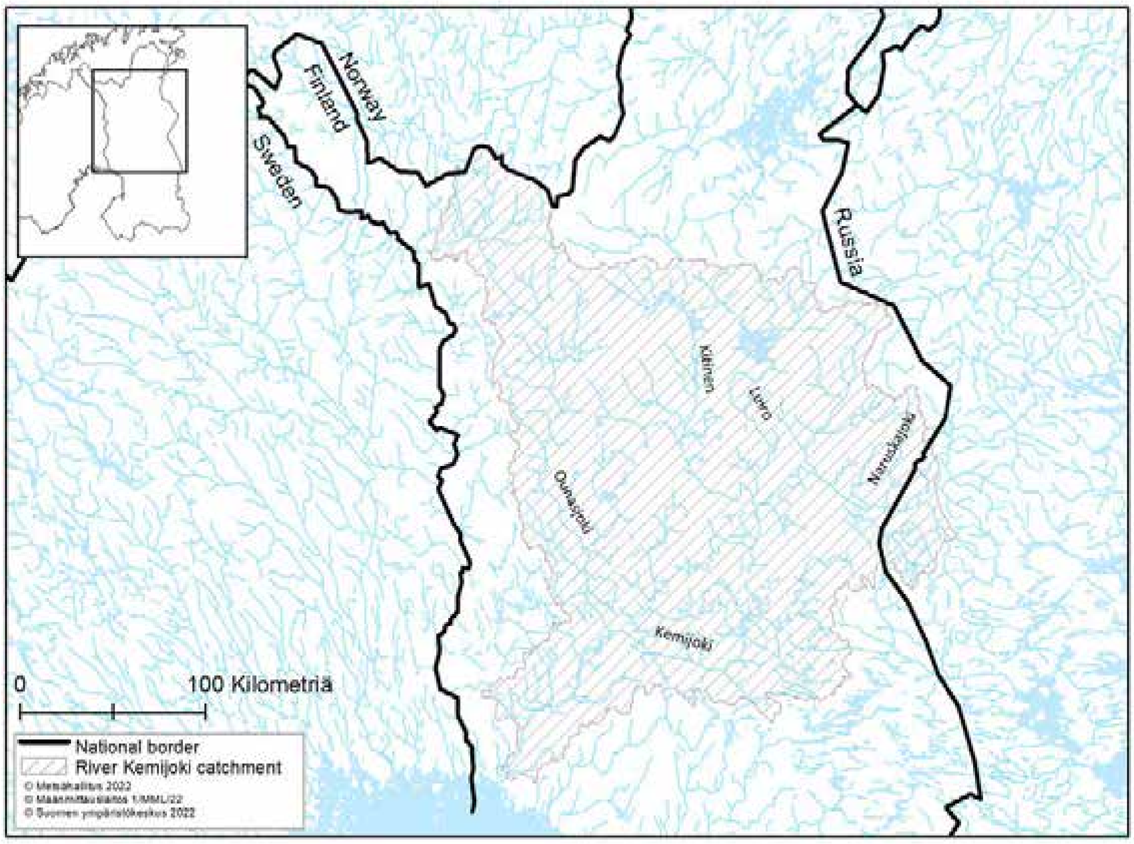

Figure 147. River Kemijoki catchment area.

in Kemijoki catchment is the forestry and the land use connected to it. Forest clearcuts and intensive drainage operations have been devastating to many populations.

In Kemijoki catchment, the population status of FPM was studied in seven rivers during the Interreg North Raakku! -project in 2011–2014 (Oulasvirta et al. 2015a). In 2021, Alleco company carried out population status assessments in three more rivers (Oulasvirta et al. 2021). The target rivers in the SALMUS project were Sätsijoki, Ahvenoja and Tammakkolammenoja–Hangasjoki in the municipality of Salla and Salmijoki, Vääräjoki and Köykenejoki in the municipality of Posio. None of these rivers belong to any nature protection area.

3.4.2.2.1 River Ahvenoja

Ahvenoja (Fig. 148) is a small brook that starts from two, each around 4 ha large, Ahvenlammit lakes close to Russian border. Below these lakes the two channels merge to one, which flows mostly slowly twisting to Lake Saukkojärvi, descending around eight metres on its way. Ahvenoja has a small catchment of 4.12 km². Part of the river is in the Finnish border zone. The area is affected by large clearcuttings, that extend close to the river at its fast-flowing section, which also the main FPM population of the river is inhabits. The river is 50–200 cm wide, in deeper parts organic bottom and moving sand was observed (Fig. 149). Ahvenoja is a headwater of river Saukko-oja, that flows from Lake Saukkojärvi to River Naruskajoki. Saukko-oja is hosting FPM population with some reproduction, studied in 2013 (Oulasvirta et al. 2015a). We did inspections in few spots also

Figure 148. Ahvenoja FPM area was surveyed during SALMUS project in September 2021. Photo: Heikki Erkinaro.

Figure 149. Transect 12. Some living mussels, empty shells, organic bottom, and fine moving sand was observed in deeper sections of the river with slow current. Only empty shells were found in lower course of the river. In some lower river sections willow bushes made surveying quite hard. Photos: Aune Veersalu and Heikki Erkinaro.

in Saukko-oja during the field season in 2021. Those revealed several FPM juveniles under 20 mm.

The FPM population (and its limits roughly) in Ahvenoja was refound during the SALMUS project in 2020 (Moilanen & Luhta, this report), but information about FPM shells and living individuals in this stream, called then by the name Ahvenharjunoja, is mentioned already in 1997 (Valovirta & Huttunen 1997).

In this study, 20 random transect were established to the River Ahvenoja (Fig. 150). Those were investigated by snorkel diving in 10.–12.09.2020. Living FPMs were found from nine transects. Five transects contained dead shells and six were totally empty. The total number of mussels in Ahvenoja was estimated to be 3,054 individuals (Appendix 1). The mean density of mussels was 1.88 individuals/m^2. The best FPM areas were quite densely populated (Fig. 151). The distribution range of the mussels is 1,320 metres.

The smallest mussel found was 13 mm in shell length. The proportion of < 50 mm mussels was rather high, 18%. The size distribution of the randomly sampled mussels is shown in Fig. 152. According to the Swedish criteria, the viability class of the population would be *maybe-viable* (Appendix 1). The age determination of juvenile mussels was not performed.

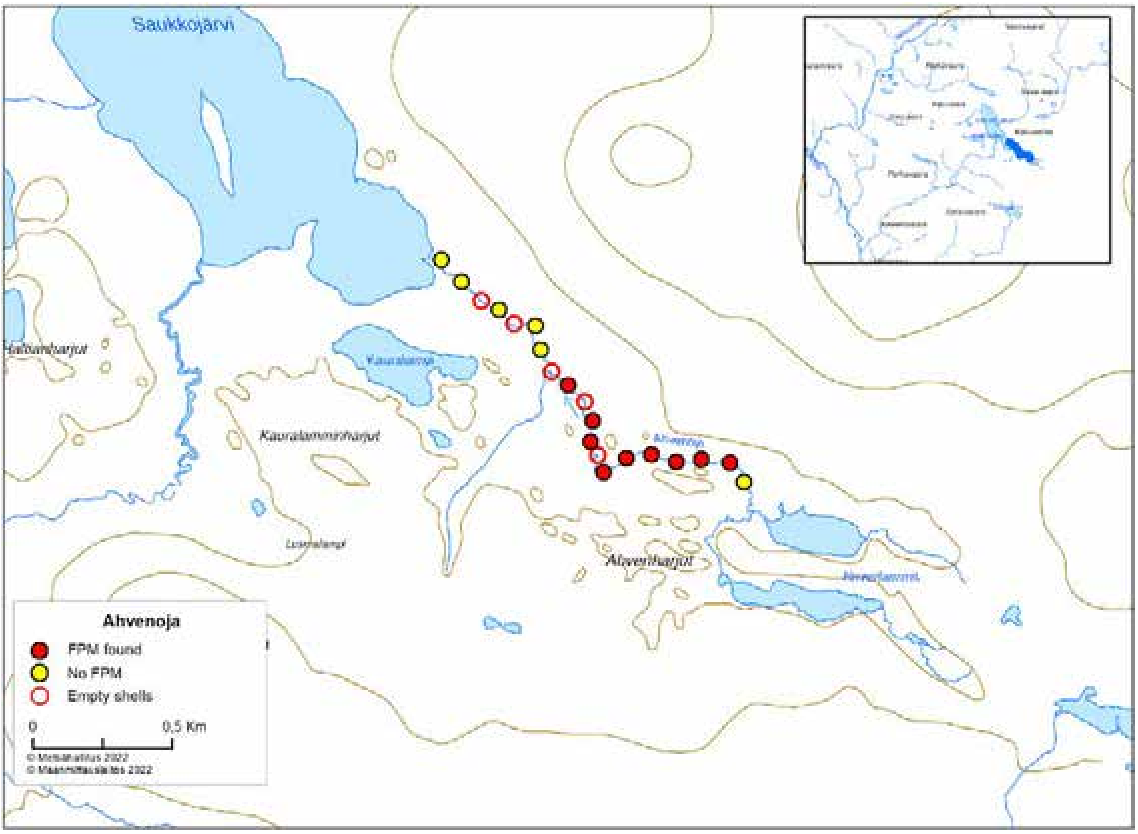

Figure 150. Random transects in river Ahvenoja. Small map: River Ahvenoja marked with a thicker blue line.

Figure 151. In this spot, more than half of the mussels were totally buried and were found only, when we started to pick up visible mussels for measurement. Photos: Aune Veersalu and Heikki Erkinaro.

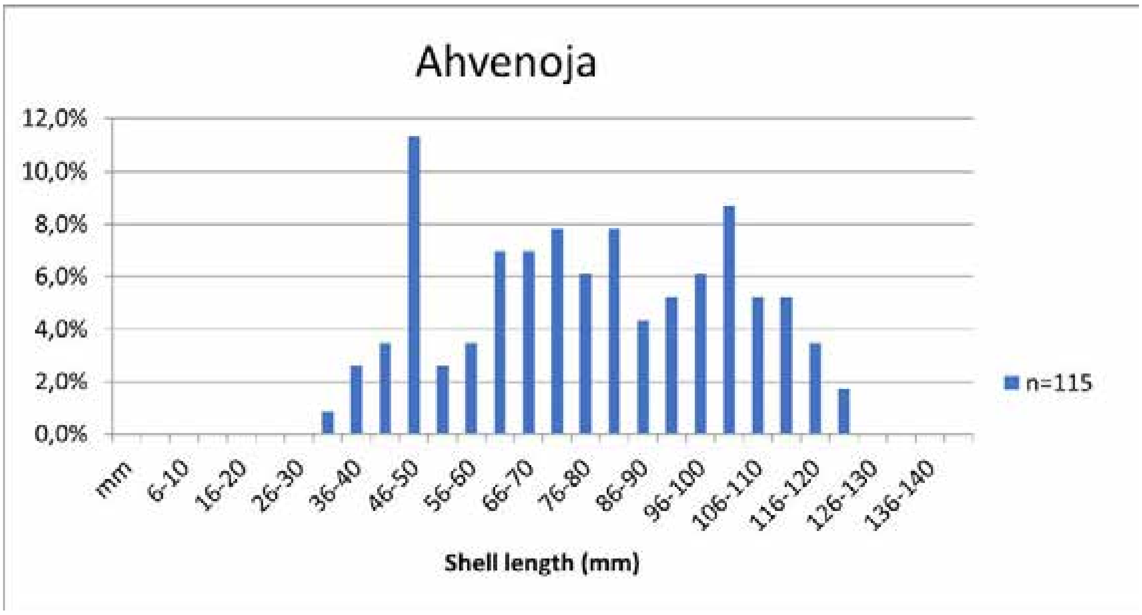

Figure 152. Size distribution of the mussels in river Ahvenoja.

River Sätsijoki

River Sätsijoki (Fig. 153) originates from lake Sätsijärvi (298 m above sea level), that is partly situated in Russia. River Sätsijoki itself also makes in one part a bend in the Russian territory and many of its tributaries originate from Russia. The size of the catchment is 89.8 km^2. The outlet of Sätsijoki river is in river Naruskajoki ca. 13 km downstream from the lake Sätsijärvi.

FPM was found from River Sätsijoki during the SALMUS project in 2020 (Moilanen & Luhta, this report). In this study 16 random transects were established into the river. In addition, a 150 metres long river stretch was investigated in the middle course (Fig. 154). We also tried to find FPM from the lower course near Naruska river. Both areas were without mussels. Sätsijoki was investigated in 10.–13.9.2020.

The results of the mussel counts revealed that the Sätsijoki FPM population is divided into two separate groups (Fig. 154). One group was situated just below the Lake Sätsijärvi and another group 6 km downstream below the lake Puolivälinlampi. Distribution range of the mussels is in both sub-populations around 950 metres. In between these two sub-populations there is an empty five kilometres long river stretch.

Sätsijoki proved to be a viable population with a lot of juvenile mussels (Fig. 155). The estimated number of the FPM in the river was 9,944 individuals (Appendix 1). The real number of mussels is, however, much higher, since the bottom in Sätsijoki was mostly rocky, where the mussels were invisible between and under the big boulders. The mean density of observed mussels in Sätsijoki was 0.057 individuals/m^2. Juvenile mussels were seen abundantly. The proportion of < 20 mm mussels was 1.2% and the proportion of < 50 mm mussels 27.7%. Population was classified as *viable*.

In Sätsijoki we could also collect a sample of juvenile mussels for age determinations. According to 14 measured mussels the shell length of the ≤ 10yrs mussels are in average 25 mm and the shell length of the ≤ 20yrs mussels 50 mm (Fig. 156).

Figure 153. River Sätsijoki in 10.9.2020. Counting of the mussels was challenging in Sätsijoki due to the big boulders in the river channel. Photo: Panu Oulasvirta.

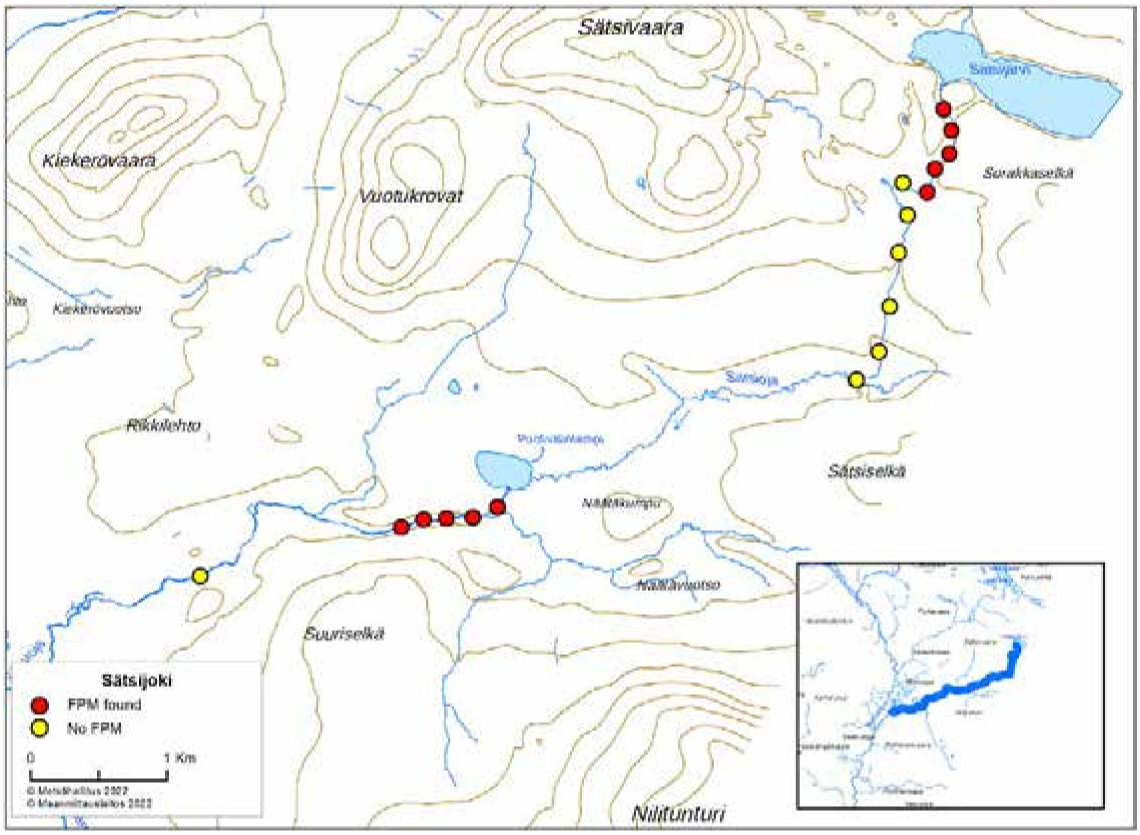

Figure 154. Random transects in river Sätsijoki. The lowermost transect on the left was a 150 metres long river stretch. The other 16 dots are 20 metres long random transects. Small map: River Sätsijoki marked with a thicker blue line.

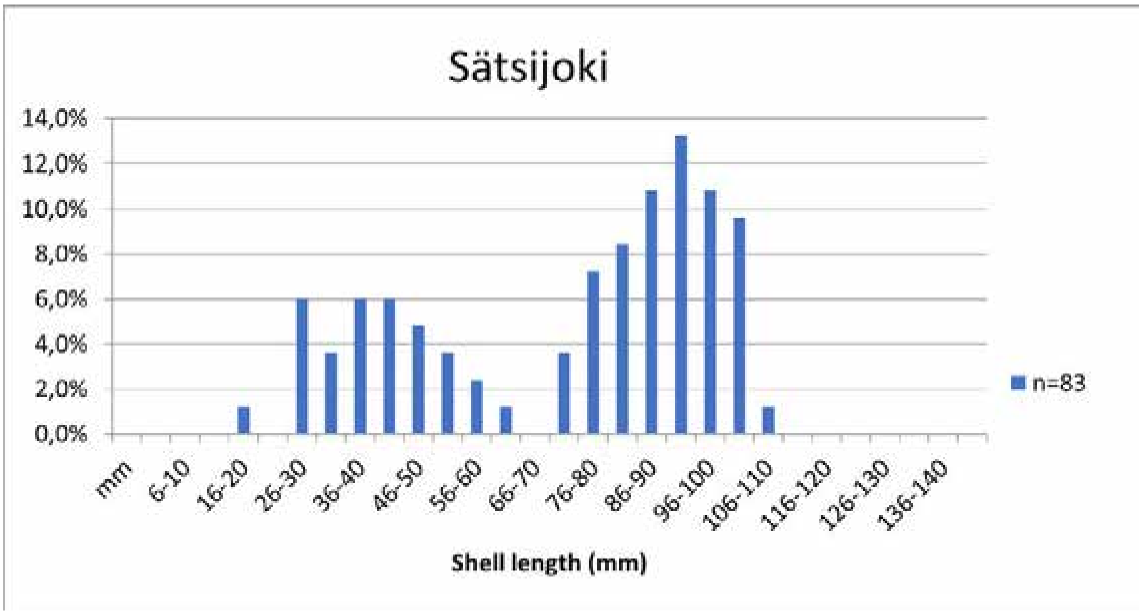

Figure 155. Size distribution of the mussels in river Sätsijoki. Mussels less than 50 mm are 20 years or younger.

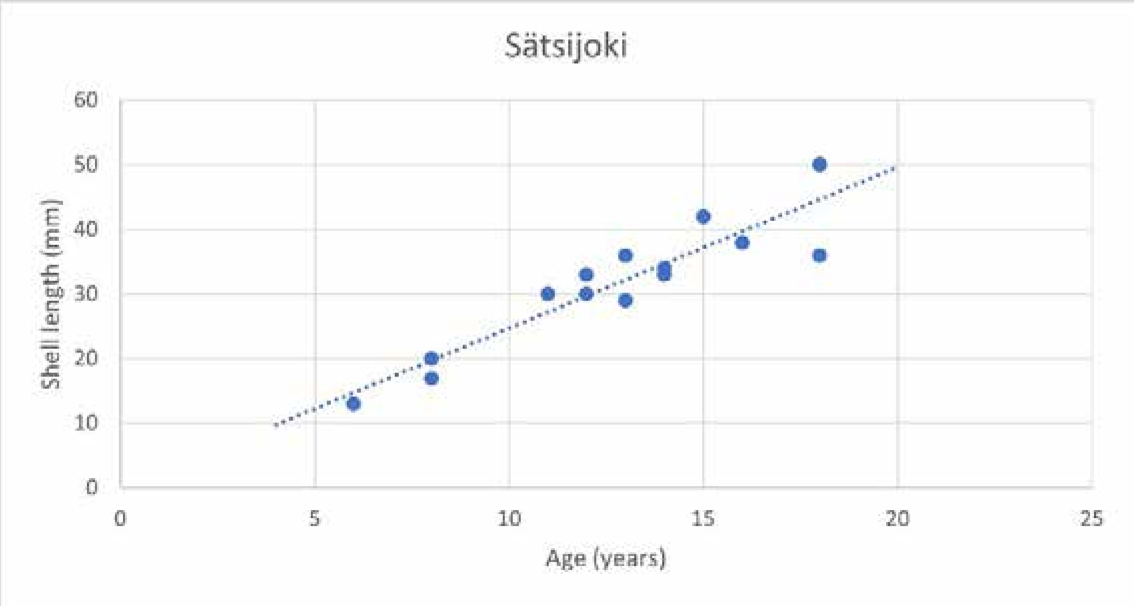

Figure 156. Growth rate of the juvenile mussels in river Sätsijoki.

River Hangasjoki–Tammakkolammenoja

River Tammakkolammenoja is a tributary of River Hangasjoki, but here they are treated together as a one river, because the FPM in these rivers represent the same population. River Tammakkolampi headwaters start from three small lakes in Tuohenlusikkajänkä marshland. The biggest of the lakes is Tuohenlusikat (1.24 ha). From there the river runs to Tammakkolampi lake (7.7 ha). After that the river carries name Tammakkolammenoja, which is ca. 1.7 km long, 100–150 cm wide (Fig. 157) and mostly shallow (20–70cm, Fig. 158) brook. More downstream Tammakkolammenoja joins a wider (200–500 cm) and deeper (50–170 cm) River Hangasjoki, which in turn originates from Lake Hangasjärvi (32.5 ha). After flowing more than 5.5 km Hangasjoki is joined to river Ruuhijoki, which flows further down to river Käsmänjoki. On its way from Tammakkolampi (273 m above sea level) to Ruuhijoki the river descends 33 metres. The Hangasjoki catchment area is 25.24 km^2 in total. The sub-catchment of Tammakkolammenoja makes about 4.5 km^2 of it. The biggest threat to FPM in the area is posed by the forest roads and the actual location in the vicinity of Salla holiday village.

The Tammakkolammenoja–Hangasjoki FPM population was found, its upper limit detected, and lower limit roughly detected during the SALMUS project in 2020 (Moilanen & Luhta, this report). In this study, 18 random transects were established into the rivers (Fig. 159). 13 of the transects were in Tammakkolammenoja and five in the Hangasjoki river. The transects were investigated in 7.–8.9.2020 by snorkel diving or aquascope.

Living FPM was found from eight transects, out of which five were in Tammakkolammenoja and three in Hangasjoki. One of the transects contained only dead shells and nine sites were totally empty (Fig. 159). The size of the population was estimated to be 450 mussels (Appendix 1). The distribution range of the mussels is 1,800 metres.

The density of mussels was high in certain river bottom patches where also juveniles were detected (Figs 160–161). The mean den-

Figure 157. A random transect at river Tammakkolammenoja. The brook has lush vegetation on its banks. Photo: Aune Veersalu.

Figure 158. Tammakkolammenoja is mostly shallow. S. Kankaanpää (Metsähallitus) is counting mussels hiding under the riverbanks. Photo: Aune Veersalu.

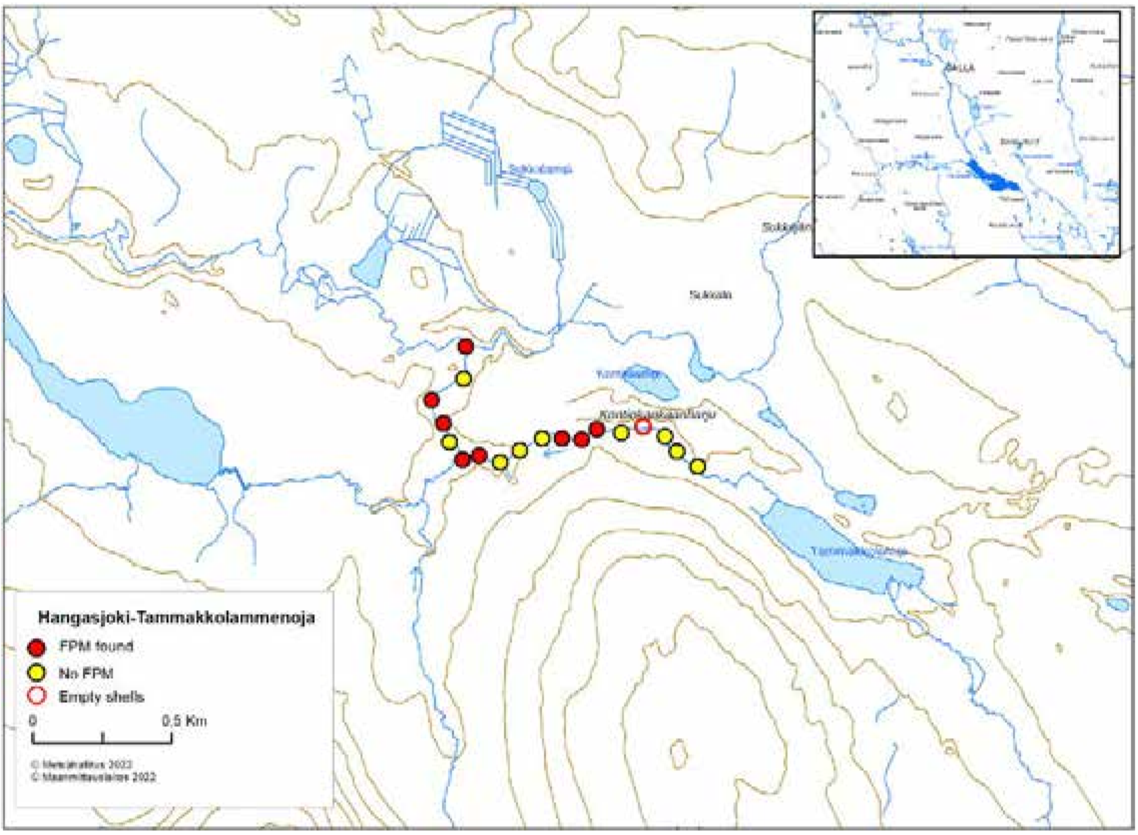

Figure 159. Random transects in rivers Hangasjoki and Tammakkolammenoja. Small map: Rivers Tammakkolammenoja and Hangasjoki marked with a thicker blue line.

sity of mussels was 0.32 individuals/m^2. The smallest mussel found was 27 mm in shell length and the proportion of < 50 mm mussels 5%. The size distribution of the measured mussels is shown in Figure 162. The viability of the population was classified as *non-viable* (Appendix 1).

Figure 160. The densest spot of Hangasjoki – Tammakkolammenoja FPM population was found from Tammakkolammenoja. Photo: Sakari Kankaanpää.

Figure 161. FPM of around 3 cm length in river Tammakkolammenoja. Photo: Sakari Kankaanpää.

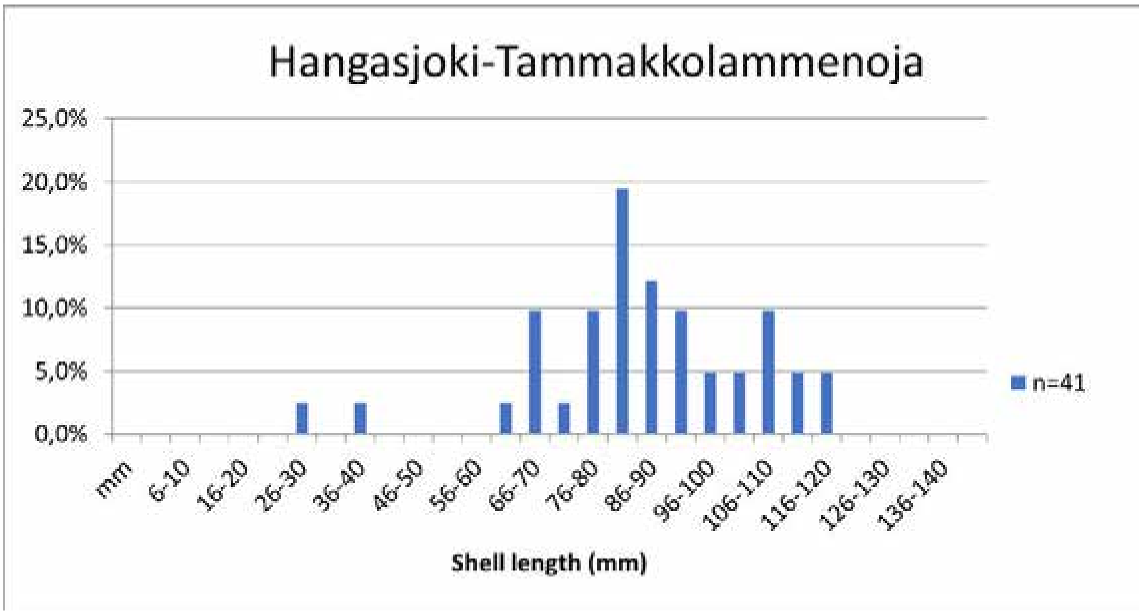

Figure 162. Size distribution of the mussels in Hangasjoki–Tammakkolammenoja.

River Köykenejoki

River Köykenejoki (Fig. 163) originates from two small lakes called Köykenelammit (312 and 313 m above sea level). The outlet of the river is ca. 10 km downstream in lake Lauttajärvi (258 m above sea level). The catchment area of the Köykenejoki with all the tributaries is 22.41 km^2 out of which 1.5% are lakes. FPM was found from river Köykenejoki within the SALMUS project in 2020 (Moilanen & Luhta, this report). Preliminary mapping of the population showed that the mussels are present only in the lower course of the river.

In this study 18 random transects were established into the known mussel area (Fig. 164). Transects were investigated in 11.9.2021. FPM was detected from 13 transects. The five lowermost transects were empty or contained only dead shells. The number of FPM in the whole river was estimated to be 7,650 individuals. The mean density of mussels was 1.16 individuals/m^2. The distribution range of the mussels is 1,400 metres.

The length of the smallest found mussel was 38 mm, but in general the juvenile mussels were very few. The FPM population in River Köykenejoki was classified as *non-viable*. The size distribution of the mussels in Köykenejoki is shown in Figure 165.

Figure 163. River Köykenejoki 11.9.2021. Photo: Panu Oulasvirta.

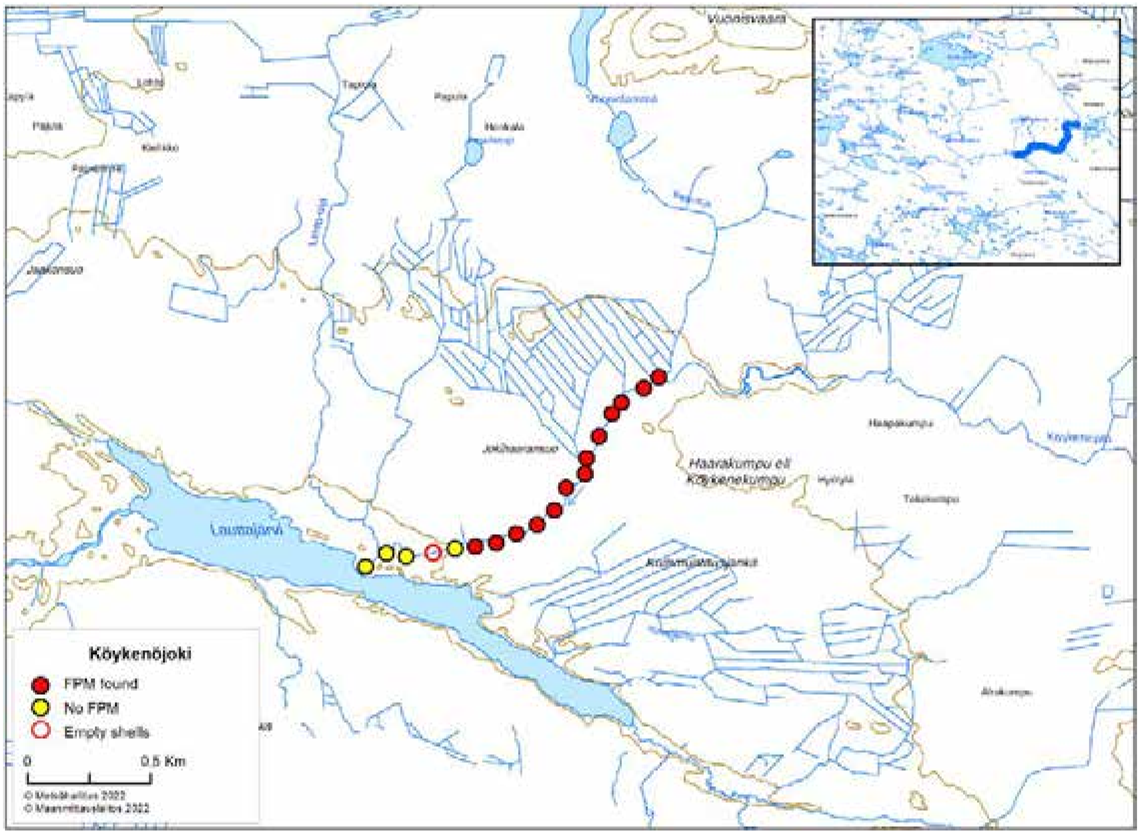

Figure 164. Random transects in river Köykenejoki. Small map: River Köykenejoki marked with a thicker blue line.

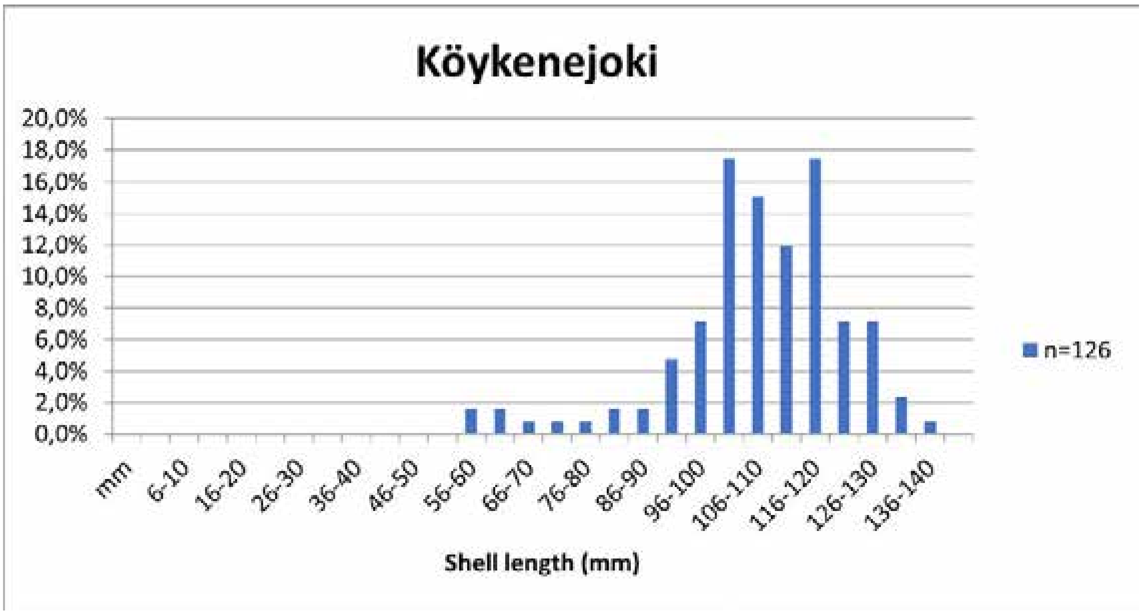

Figure 165. Size distribution of the mussels in Köykenejoki.

River Salmijoki

Besides river Köykenejoki, also river Salmijoki has its outlet in lake Lauttajärvi (258 m above sea level). Salmijoki has its origin in Lake Salmijärvi (279 m above sea level). The length of the river is ca. 2 km. Due to the small size of the river the catchment area data was not available. FPM was found from Salmijoki during the SALMUS project in 2020 (Moilanen & Luhta, in this report).

In this study the FPM in Salmijoki was investigated with the total count method in 14.–15.9.2021. During the study the river was flooding (Fig. 166), and due to that the survey was done exceptionally by swimming downstream. Distribution range of the mussels was limited into the lower 750 metres course of the river. However, one empty shell (Fig. 167) was found more upstream from steep rapids, which indicates that the distribution of the mussels has, at least earlier, extended more upstream than is detected nowadays. In total, only 45 mussels were counted from the whole river (Appendix 1). No sample for shell length measurements was collected, but visually approximated all the mussels were full size adults (> 70 mm).

Figure 166. Salmijoki was flooding during the investigation in 15.9.2021. Photo: Panu Oulasvirta.

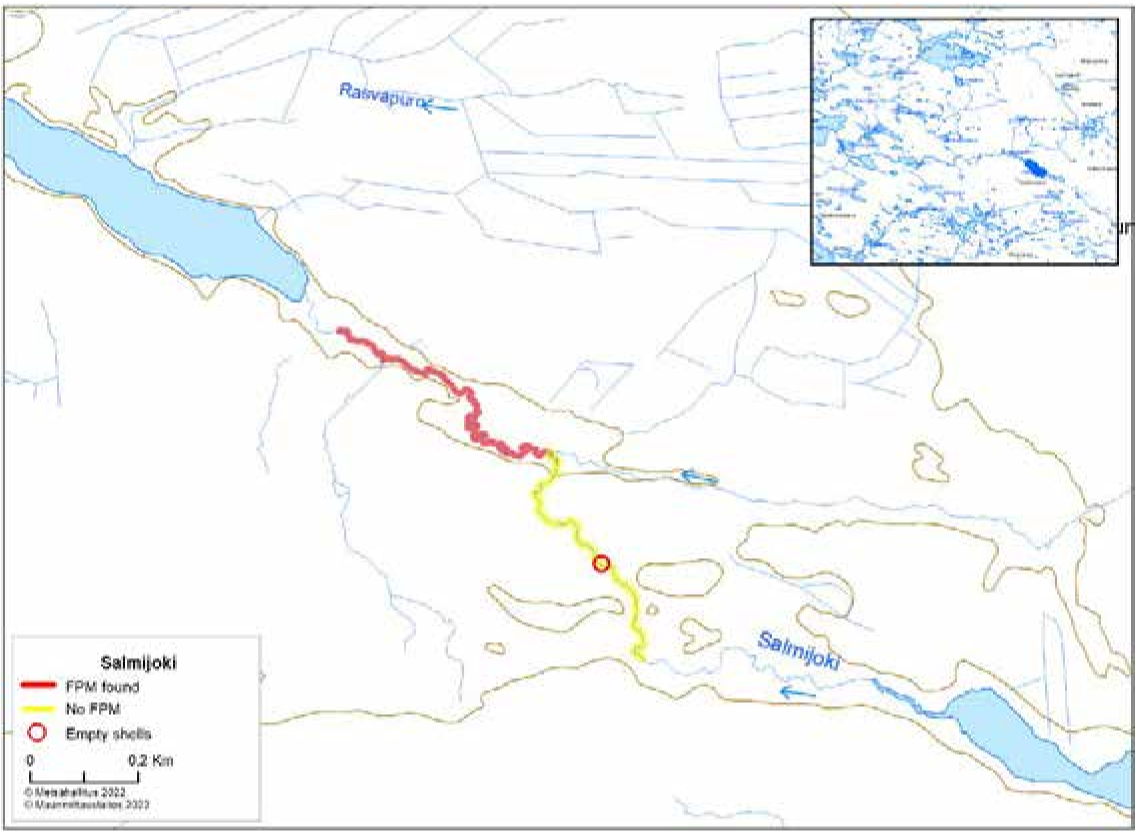

Figure 167. The distribution range of the mussels in river Salmijoki. One empty shell was found apart upstream from the living mussels. Small map: River Salmijoki marked with a thicker blue line.

River Vääräjoki

River Vääräjoki (Fig. 168) is ca. 10 km long tributary of river Mourujoki. Its origin is in lake Hankainsiula (267 m above sea level). The catchment area of the Vääräjoki is 44.43 km^2 out of which ca. 2.6% are lakes. FPM was found from River Vääräjoki during the SALMUS project in 2020 (Moilanen & Luhta, in this report).

In this study, 18 random transects were established into the known mussel area in Vääräjoki (Fig. 169). Transects were investigated in 12.–13.9.2021. Five transects did not have FPM and two transect contained only empty shells. Based on the mussel counts in the remaining 11 transects that contained living mussels, the estimated number of FPM in the whole river was 1,298 individuals (Appendix 1). The mean density of mussels was 0.07 individuals/m^2 and the distribution range of the mussels ca. 4,000 metres.

All mussels were full size adults (smallest measured mussel was 101 mm in shell length). Therefore, the FPM population in River Vääräjoki was classified as *dying*. Since no juvenile mussels were detected, we measured only 22 mussels from Vääräjoki. The size distribution of those mussels is shown in Figure 170.

Figure 168. River Vääräjoki. Photo: Heikki Erkinaro.

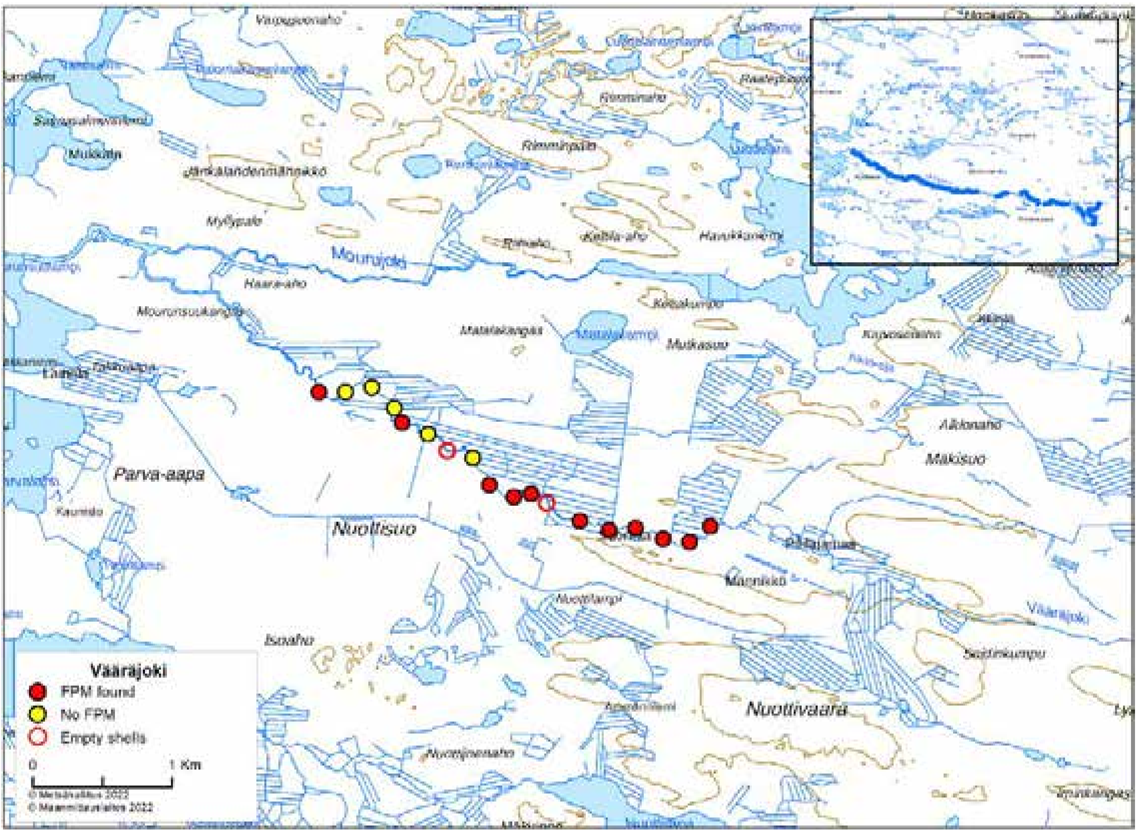

Figure 169. Random transects in river Vääräjoki. Small map: River Vääräjoki marked with a thicker blue line.

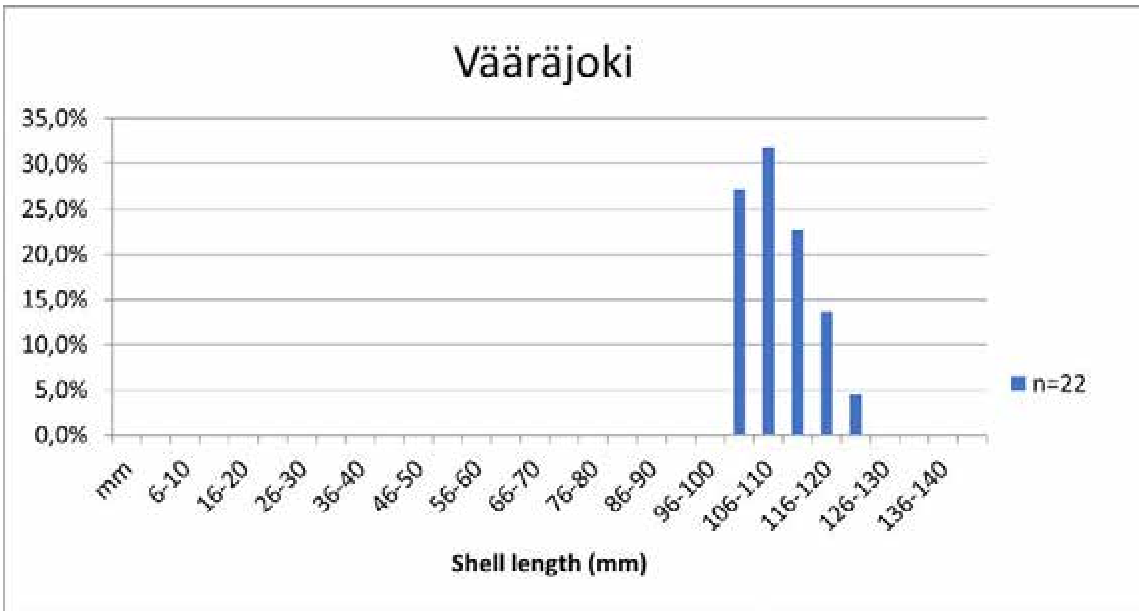

Figure 170. Size distribution of the mussels in Vääräjoki.

3.4.2.3 Koutajoki catchment

The Koutajoki river catchment has only its upper parts in Finland. Major part of the catchment is in Russia, where River Koutajoki runs into the White Sea. The catchment area in the Finnish side covers 4,915 km^2 (Ekholm 1993). The main channel in Finland is River Oulankajoki, which further has two main tributaries, the Kitkajoki and Kuusinkijoki rivers (Fig. 171). River Oulankajoki runs partly inside the Oulanka National Park (FI1101645).

The previously known FPM populations in the Koutajoki catchment in Finland are rivers Juumajoki and its tributary Salmipuro, Porontimajoki, Merenoja, Kiutaoja and the Oulankajoki mainstem. Records from river Oulankajoki are old though, from the 1990s (Valovirta & Huttunen 1997). In addition, unconfirmed data of the FPM exists from river Kitkanjoki (Valovirta & Huttunen 1997). During the SALMUS project one more FPM population was found from Koutajoki catchment, River Myllyoja (Moilanen & Luhta, in this report).

In Russia, the known FPM rivers in the Koutajoki drainage area are Tavajoki, Nuris, Mutkajoki and Tuhka, which belong to the lake Paanajärvi sub-catchment (Ieshko & Efremov 2021; Karelian Research Centre, unpublished data).

Before this study, the population status of FPM had been studied from four rivers – Juumajoki, Salmipuro, Merenoja and Kiutaoja (Oulasvirta et al. 2015b, Oulasvirta & Syväranta 2016). Target rivers in the SALMUS project were Myllyoja in the municipality of Salla and Porontimajoki in the municipality of Kuusamo.

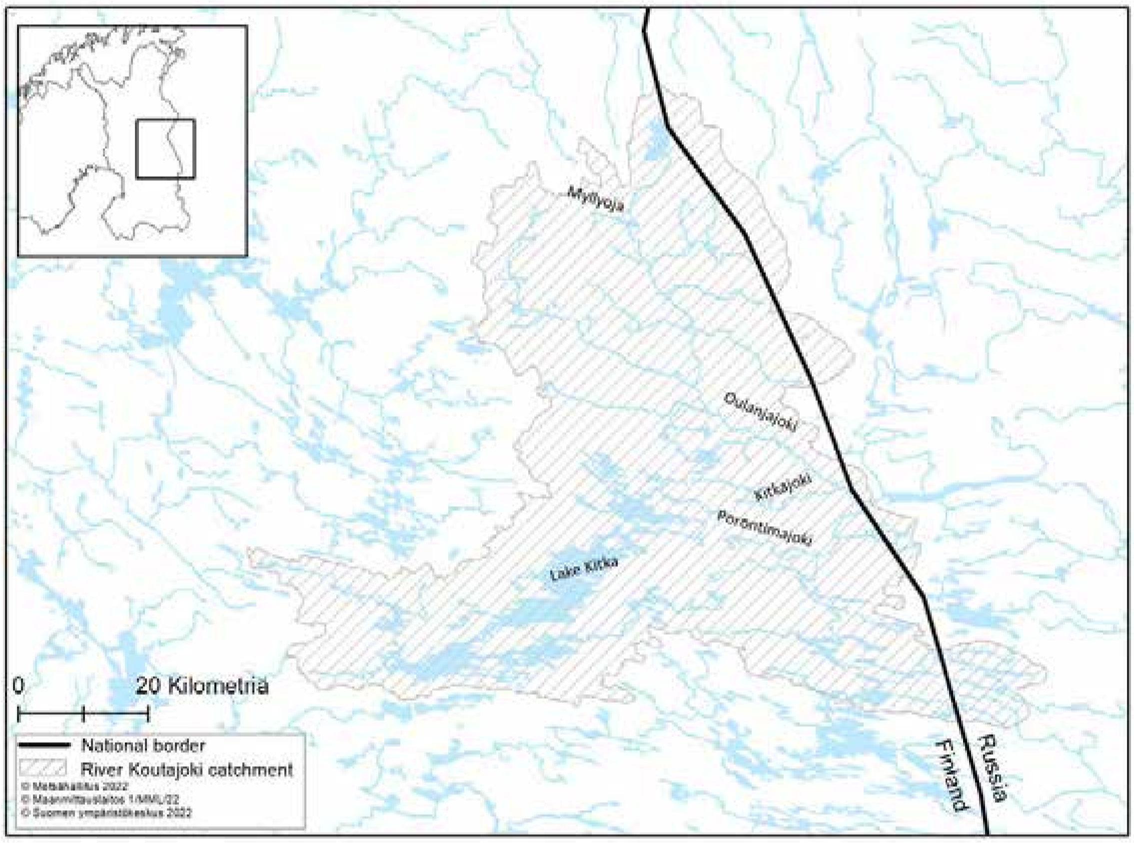

Figure 171. Koutajoki catchment area and the main tributaries in Finnish side: Oulankajoki and Kitkanjoki. Project target rivers Myllyoja and Porontimajoki also marked into the map. Koutajoki has its outlet in the White Sea, Russia.

River Porontimajoki

River Porontimajoki (Fig. 172) runs from the Lake Porontimajärvi (313 m above sea level) into the Lake Verkasjärvi (253 m above sea level). Length of the river is ca. 5 km, and the catchment area is 20.35 km^2 out of which ca. 16% are lakes. FPM is known from Porontimajoki only in the uppermost part. The lower course of the river was mapped in 2015, but no FPM was found there (Oulasvirta et al. 2015b). More surveys were conducted in 2016, when a river stretch in the middle course was investigated (Oulasvirta & Syväranta 2016). That too was without FPM.

In this study four random transects were established into the known 600 metres long FPM area in the upper course of the river (Fig. 173). The transects were investigated in 13.6.2020. All transect contained FPM. The estimated size of the FPM population in Porontimajoki was 1,213 individuals (Appendix 1). Most probably the real number is bigger than that, because in Porontimajoki the mussels were hiding in the rocky habitat so that many mussels were invisible under the stones. The mean density of observed mussels was 0.26 individuals/m^2. The smallest mussel found was 40 mm in shell length and the proportion of mussels less than 50 mm was 2% (Fig. 174). The viability class of the Porontimajoki FPM population is *non-viable*.

Figure 172. River Porontimajoki. Photo: Mahsa Hajisafarali.

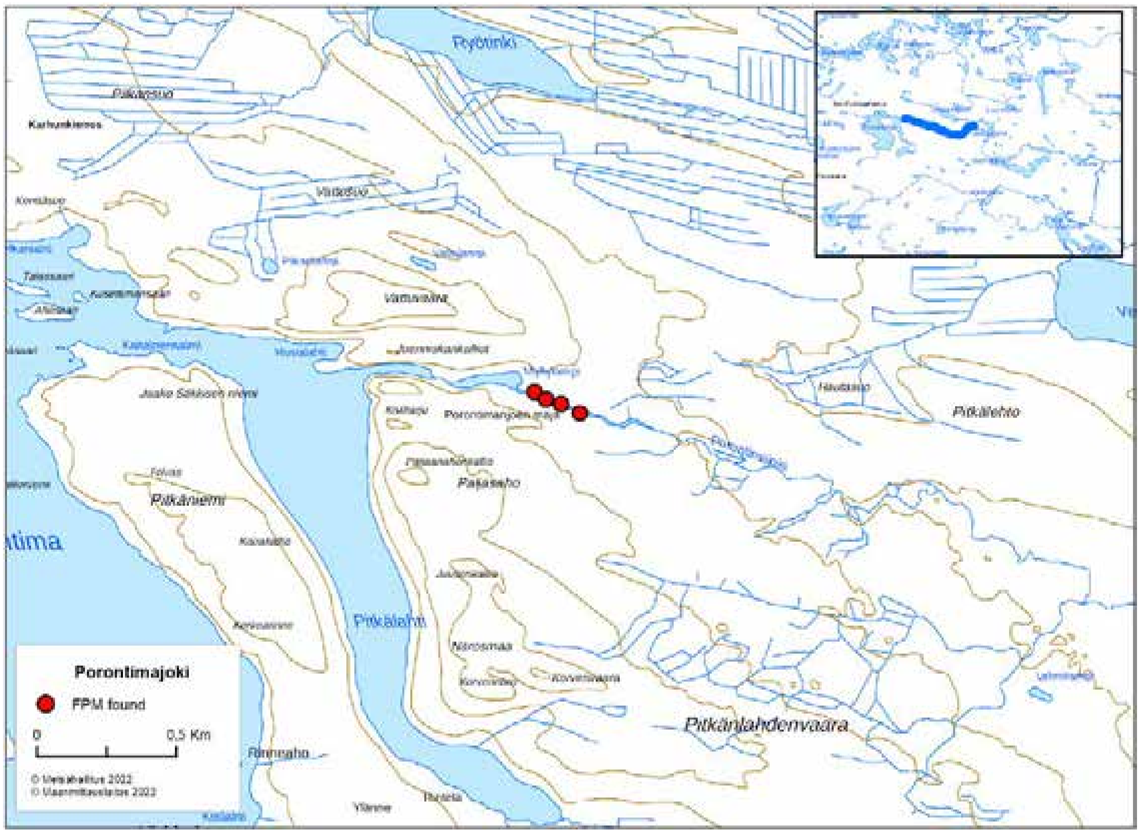

Figure 173. Random transects in river Porontimajoki. Small map: River Porontimajoki marked with a thicker blue line.

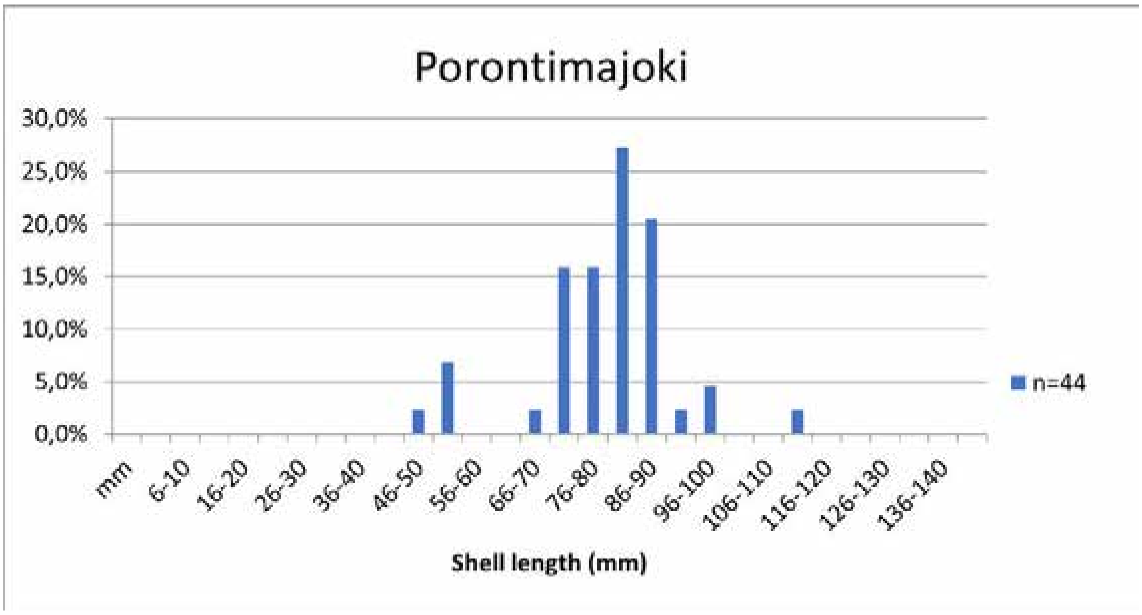

Figure 174. Size distribution of the mussels in Porontimajoki.

River Myllyoja

River Myllyoja (Fig. 175) runs from lake Potkujärvi (257 m above sea level) into lake Kallunkijärvi (238 m above sea level). The length of the river is ca. 2.3 km. The main tributary for Mylloja is river Hevosoja, that merges with Myllyoja just above lake Kallunkijärvi. The area of the Myllyoja–Hevosoja catchment is ca. 44.73 km^2 out of which 3.78% are lakes (Ekholm 1993). FPM was found from Myllyoja during the SALMUS project in 2020 (Moilanen & Luhta, in this report). River Hevosoja was also inspected for FPM, but the species was not found there.

In this study, 20 random transects were established into the expected mussel area in Myllyoja (Fig. 176). The transects were investigated in 6.–8.9.2020. The results showed that the FPM distribution range in the river was more limited than expected, since the three lowest and two uppermost transects were empty. Moreover, the population was in two parts – there were four transects in the middle course that also were empty (Fig. 176). The distribution range between the lowermost and uppermost mussels was 1,500 metres.

The estimated number of the FPM in Myllyoja was 1,130 individuals (Appendix 1) and the mean density 0.12 individuals/m^2. Juvenile mussels were very few, the proportion of mussels less than 50 mm in shell length was 2% and no mussels less than 20 mm were found (Fig. 177). Absence of youngest year class was slightly surprising, since the anthropogenic influence in Myllyoja is not particularly strong. The reason for the bad status of FPM in the river may be the lack of host fish. In the electrofishing studies made by Metsähallitus in 2020 and 2021, no brown trout was caught from Myllyoja river (Moilanen & Luhta, this report). Due to the low recruitment rate of the juvenile mussels, the FPM population in River Myllyoja was classified as *non-viable* (Appendix 1).

Figure 175. River Myllyoja. Photo: Panu Oulasvirta.

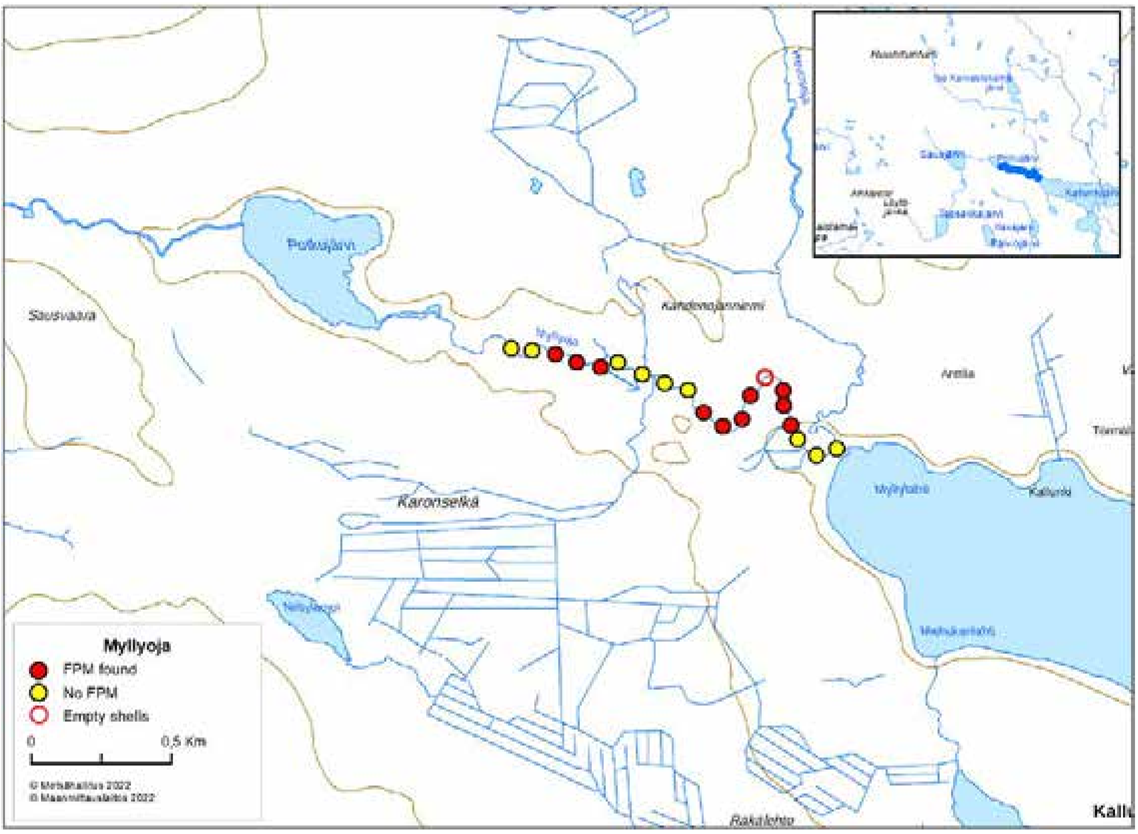

Figure 176. Random transects in river Myllyoja. Small map: River Myllyoja marked with a thicker blue line.

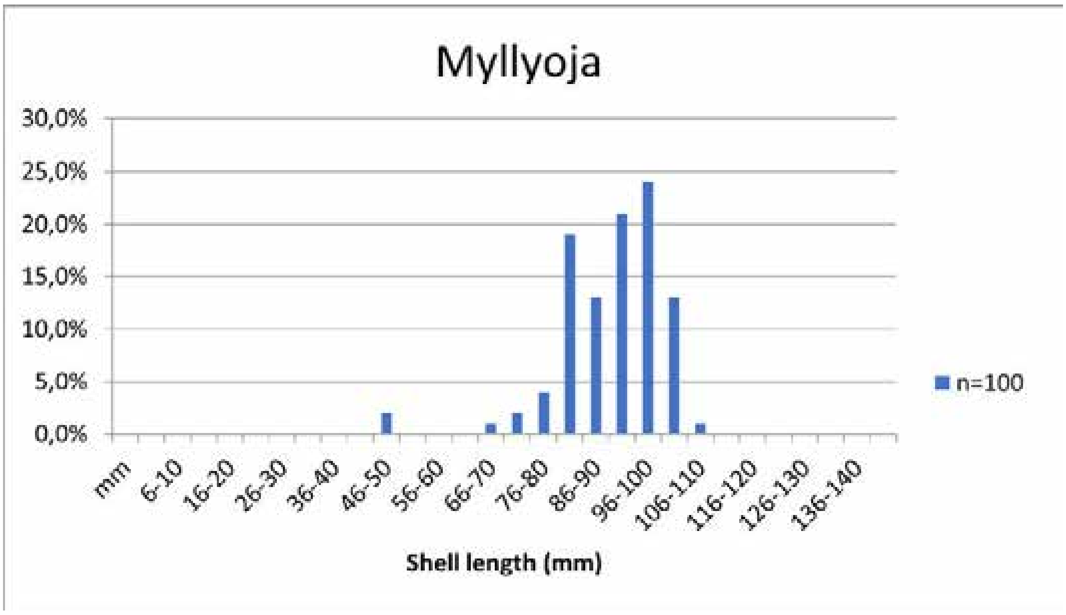

Figure 177. Size distribution of the mussels in Myllyoja.

3.4.2.4 Karelian Kem catchment

The Karelian Kem (in Finnish: Vienan Kemi) catchment (Fig. 178) has only its upper parts in Finland. Major part of the catchment is in Russia, where River Kem meets the White Sea in the City of Kem. The catchment area on the Finnish side is 1,297 km^2 (Ekholm 1993). Before this project the known FPM populations in the Finnish side of the cathment were in Rivers Meskusjoki and Juomajoki. These rivers actually belong to the same river system, and between them is only a river stretch that carries name Välijoki. The distribution range of the River Juomajoki FPM population was investigated in 2016 (Oulasvirta & Syväranta 2016). In the SALMUS project, Moilanen & Luhta (this report) detected FPM also from River Välijoki.

In Russia, the known FPM rivers in the Kem catchment are River Kem itself and its tributaries Kabajoki, Pirta, Vozhma, Ukhta, Kamennayajoki, Livo and Vuokinjoki. The last three rivers have their headwaters in Finland. Unconfirmed historical data of the FPM are also known from Rivers Sudno, Kurzhma, Vojnica and Pista whose headwaters also are in Finland. (Karelian Research Centre, unpublished data).

In the SALMUS project, population status of FPM was investigated in the Meskusjoki–Välijoki–Juomajoki river system.

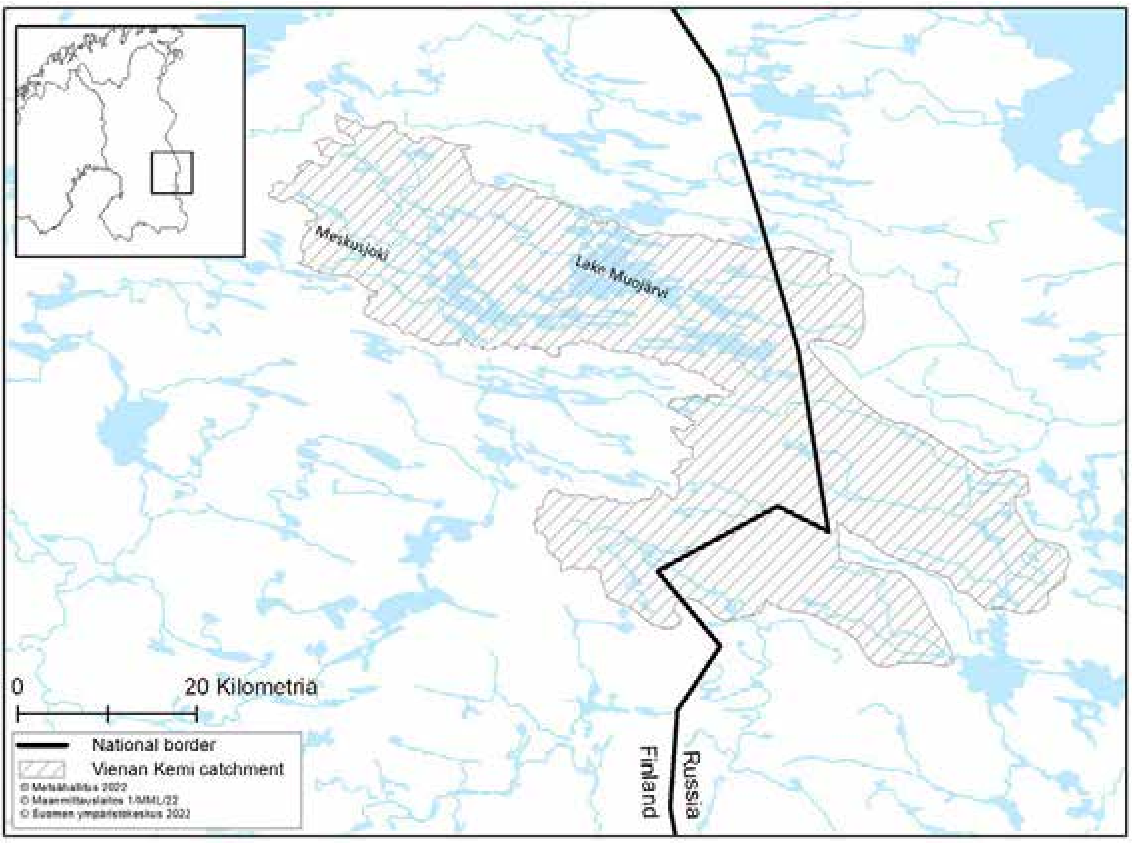

Figure 178. Upper parts of the Karelian Kem (in Finnish: Vienan Kemi) catchment area, that are in Finland.

River Meskusjoki–Välijoki–Juomajoki

Rivers Meskusjoki, Välijoki and Juomajoki form a series of three consecutive rivers separated by two lakes. The uppermost river, Juomajoki (Fig. 179) originates from the lake Autiojärvi (320 m above sea level). Juomajoki ends to the Lake Yli-Meskusjärvi (295 m above sea level), which is source of River Välijoki (Fig. 180). Next lake downstream is Ala-Meskusjärvi (271 m above sea level) from which the lowermost river Meskusjoki originates. Finally, the Meskusjoki river (Fig. 181) flows down to lake Nilonjärvi (253 m above sea level). The lengths of the different rivers in the system are Juomajoki ca. 3.2 km, Välijoki 3.8 km and Meskusjoki ca. 7 km. The drainage area of the whole river system covers altogether 30.14 km^2 out of which 4.5% are lakes (Ekholm 1993). The catchment area is heavily ditched in its lower parts around Meskusjoki river (Fig. 182).

In this study altogether 15 random transects were established into the river system (Fig. 182). Five of the transects were located into Juomajoki, seven transects into Välijoki and three transects into Meskusjoki. The transects were investigated in 9.–14.6.2020.

FPM was found from 11 transects. The estimated total number of mussels in all three rivers were 13,050 individuals (Appendix 1). The biggest sub-population 7,700 mussels were estimated from river Juomajoki. The Välijoki sub-population contained 5,000 mussels, and only 350 mussels were estimated to occur in river Meskusjoki. Mean densities of the mussels were 1.52 individuals/m^2 in Juomajoki, 0.378/m^2 in Välijoki and 0.04/m^2 in Meskusjoki. The distribution range between the lowermost and uppermost mussels in all three rivers is around 8,000 metres.

Only one mussel less than 50 mm in shell length was found from Välijoki. In Juomajoki and Meskusjoki all the observed mussels were bigger than that. The size distribution of the 107 mussels collected from rivers Juomajoki and Välijoki is shown in Figure 183. The FPM population in the river system was clas-

Figure 179. River Juomajoki 9.6.2020. Photo: Panu Oulasvirta.

Figure 180. River Välijoki 11.6.2020. Photo: Panu Oulasvirta.

Figure 181. River Meskusjoki 14.6.2020. Photo: Panu Oulasvirta.

sified as *non-viable*. If the sub-populalations are considered separately, would the viability class in Juomajoki be *dying* and in the Meskusjoki *dying-soon*. The Juomajoki FPM population was also in 2016 studies classified as *dying* (Oulasvirta & Syväranta 2016).

In the electrofishing studies carried out by the Metsähallitus field team no brown trout was caught from Juomajoki, Välijoki or Meskusjoki (Moilanen & Luhta, this report). This could explain the low rate of FPM recruitment in these rivers. In Meskusjoki, also the state of the river is so bad, that the recruitment of FPM would probably be impossible anyway.

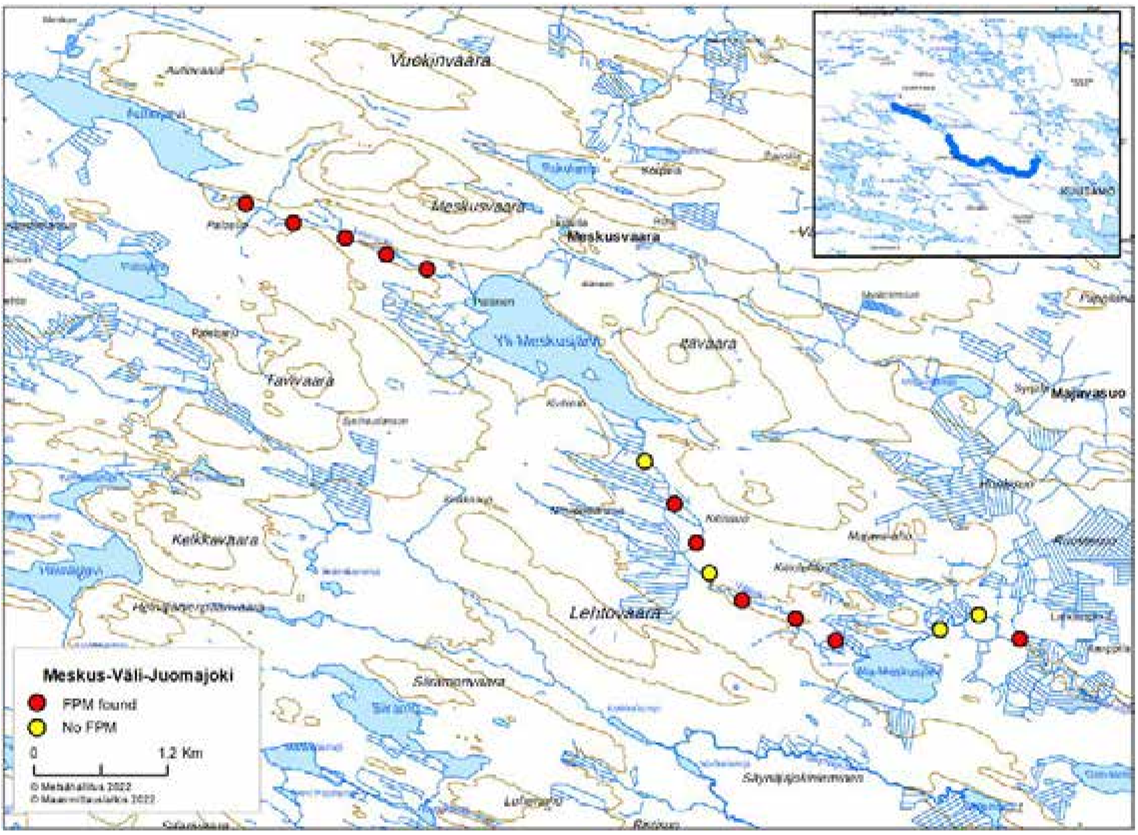

Figure 182. Random transects in rivers Meskusjoki, Välijoki and Juomajoki. Small map: Rivers Meskusjoki, Välijoki and Juomajoki marked with a thicker blue line.

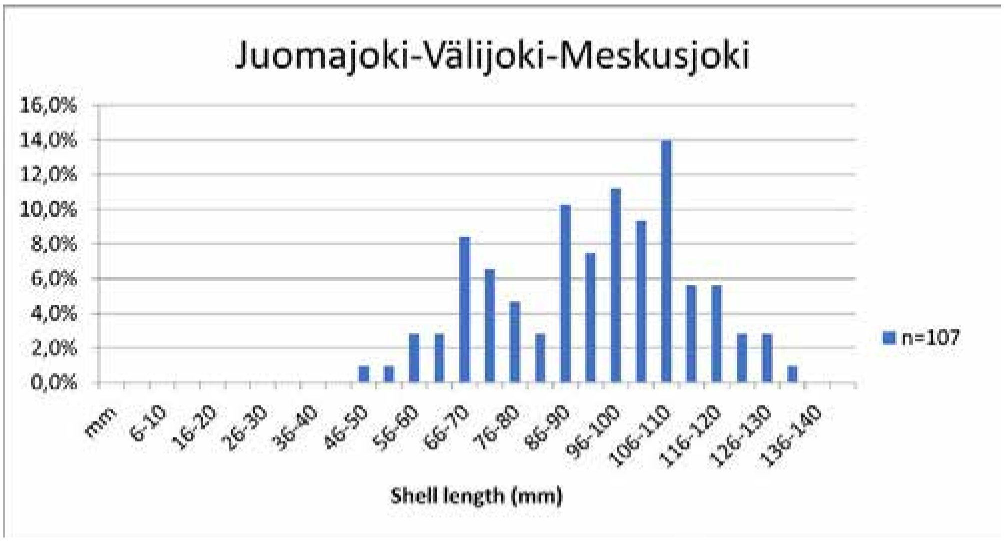

Figure 183. Size distribution of the mussels in Juomajoki-Välijoki. Mussels from Meskusjoki were not measured.

3.4.2.5 Oulujoki catchment

The drainage area of the Oulujoki river basin (Fig. 184) in central Finland covers altogether 22,509 km^2. Some of the headwaters are in the Russian territory and when those are included, the total catchment area is 22,841 km^2 (Ekholm 1993). The FPM is currently known from 10 rivers in the Oulujoki catchment. These are Lietejoki, Heinijoki–Tuomijoki, Oravijoki, Mutajoki, Nuottijoki–Alasenjoki, Humalajoki, Löytöjoki, Varisjoki–Leväjoki, Lahnajoki and Korpijoki. The FPM population in the three last mentioned rivers was found during the SALMUS project (Moilanen & Luhta, this report). They are all tributaries of the river Emäjoki, which is historically known as a pearl fishing river. Nowadays River Emäjoki is harnessed for hydropower production and modified thoroughly. FPM colonies are not known from there anymore, but on the other hand mappings there has not been done. It is remarkable that during our studies in the project one mussel was found from the outlet of river Varisjoki, but clearly in the current of river Emäjoki.

The population status of FPM has been studied before in Mutajoki, Nuottijoki–Alasenjoki and Humalajoki (Oulasvirta and Saarman 2021). In addition, preliminary studies of the status of the population have been carried out in Lietejoki, Heinijoki–Tuomijoki, Oravijoki and Löytöjoki (Oulasvirta et al. 2015c). The target rivers in the SALMUS project were Varisjoki–Leväjoki, Lahnajoki and Korpijoki, i.e., the same FPM populations that were found in this project. However, flooding of the River Lahnajoki after heavy rains prevented the investigations there in September 2021.

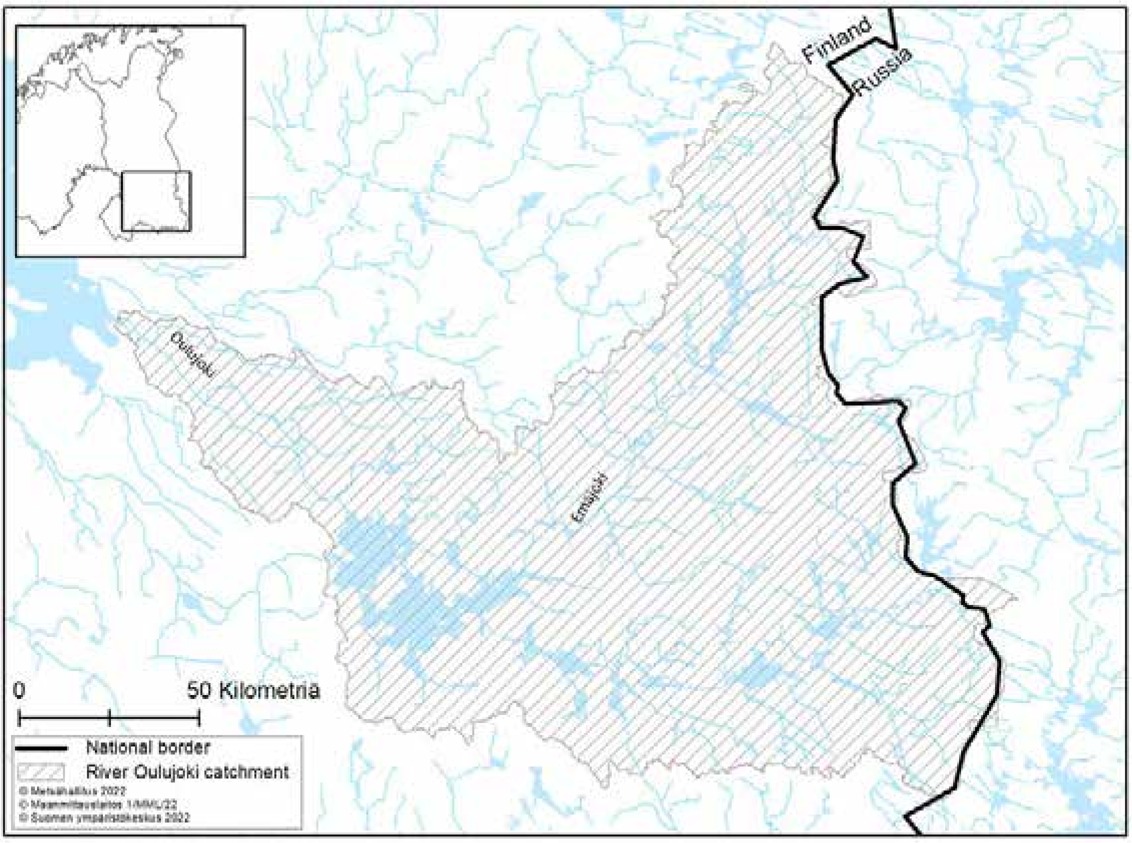

Figure 184. Oulujoki catchment area.

River Varisjoki–Leväjoki

River Varisjoki (Fig. 185) is a tributary of river Emäjoki. It originates from lake Varisjärvi (205 m above sea level) and flows down ca. 5.5 km before entering river Emäjoki. The river above lake Varisjärvi is called Leväjoki. The Varisjoki-Leväjoki drainage area covers ca. 46.9 km^2 out of which 4.5% are lakes (Ekholm 1993). The catchment area of Varisjoki–Leväjoki is intensively ditched (Fig. 186).

FPM was found from Varisjoki and Leväjoki during the SALMUS project in 2020 (Moilanen & Luhta, this report). In this study, the FPM in Varisjoki was studied with 25 random transects (Fig. 186) between 18.–22.8.2021. The distribution range of the mussels covered the whole river from lake Varisjärvi to river Emäjoki. In the middle course of the river, however, were quite many transects, where mussels were not found. The estimated number of the FPM in Varisjoki was 6,926 individuals (Appendix 1) and the mean density 0.204 mussels/m^2.

River Leväjoki was investigated between 18.–20.8.2021. The distribution range of the mussels there was limited into a ca. 80 metres long river stretch in the middle course of the river (Fig. 187). All in all, 237 mussels were counted from that area.

Size distribution of the randomly collected mussels is shown in Fig. 188. Juvenile mussels were very sparse. The smallest mussel found from river Varisjoki was 31 mm in shell length. In Leväjoki, the smallest mussel detected was 63 mm. The viability class of the Varisjoki–Leväjoki FPM population is *non-viable* (Appendix 1).

Figure 185. River Varisjoki 19.8.2021. Photo: Panu Oulasvirta.

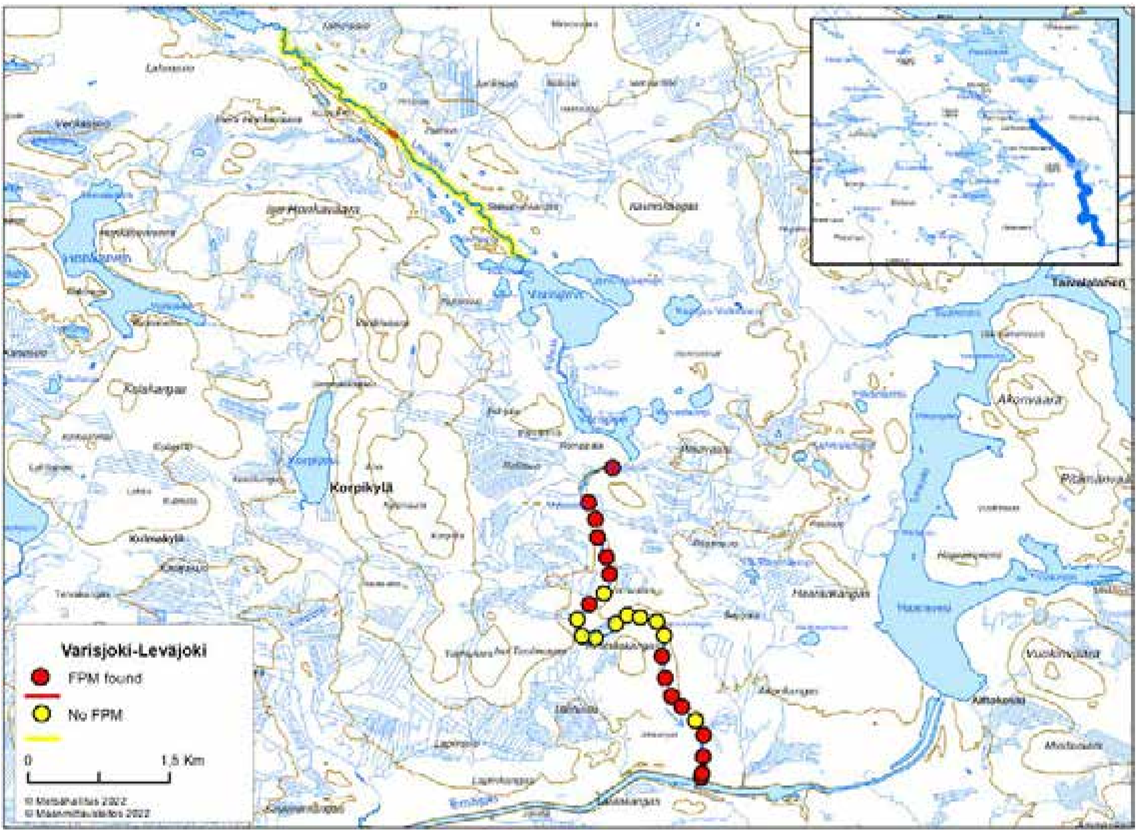

Figure 186. Investigated area in river Leväjoki (total count) and Varisjoki (random transects). Small map: Rivers Varisjoki and Leväjoki marked with a thicker blue line.

Figure 187. River Leväjoki mussel area 20.8.2021. Photo: Panu Oulasvirta.

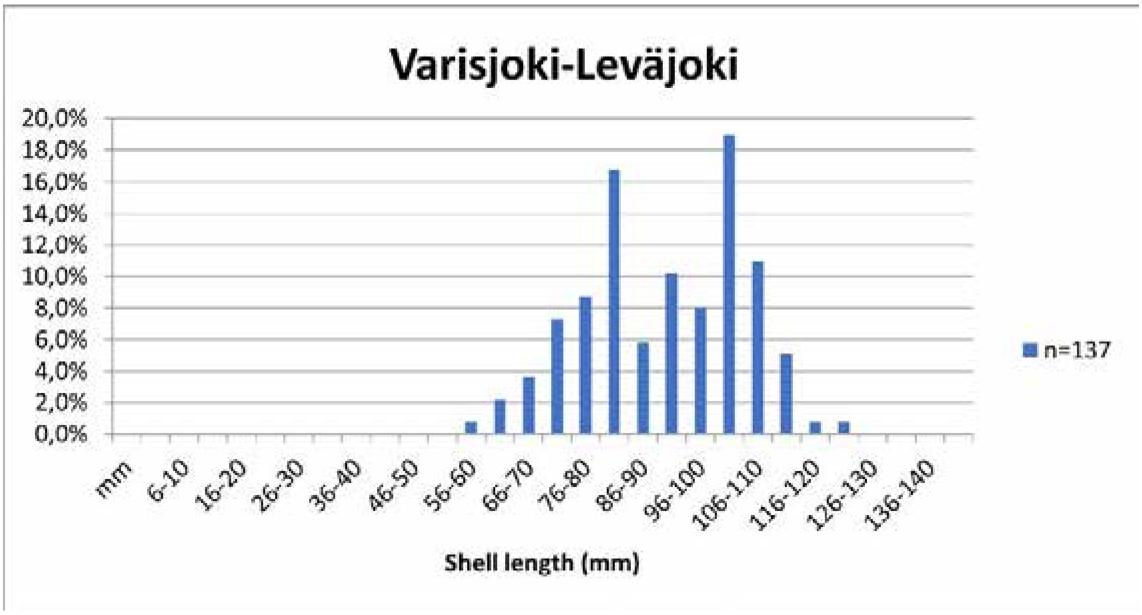

Figure 188. Size distribution of the mussels in Varisjoki-Leväjoki.

River Korpijoki

River Korpijoki (Fig. 189) is a tributary of river Emäjoki. It originates from lake Korpijärvi (194 m above sea level) and runs down ca. 5 km before entering to River Emäjoki. The size of the drainage area 22.85 km^2 out of which 4.6% are lakes (Ekholm 1993). Typically to this area, the catchment area is heavily ditched (Fig. 190).

FPM was found from Korpijoki during the SALMUS project in 2020 (Moilanen & Luhta, this report). In this study the FPM was studied in Korpijoki with the total count method between 21.–22.8.2021. FPM was found from Korpijoki only from an 850 metres long river stretch in the upper course. In total, only 118 mussels were counted from that area. Since all the mussels were adults, sample for the shell length measurements was not collected. The smallest individual mussel was 63 mm in shell length. Due to the small number of mussels and absence of juveniles, the population was estimated to belong to the status class *dying-soon* (Appendix 1).

Figure 189. River Korpijoki. Photo: Pirkko-Liisa Luhta.

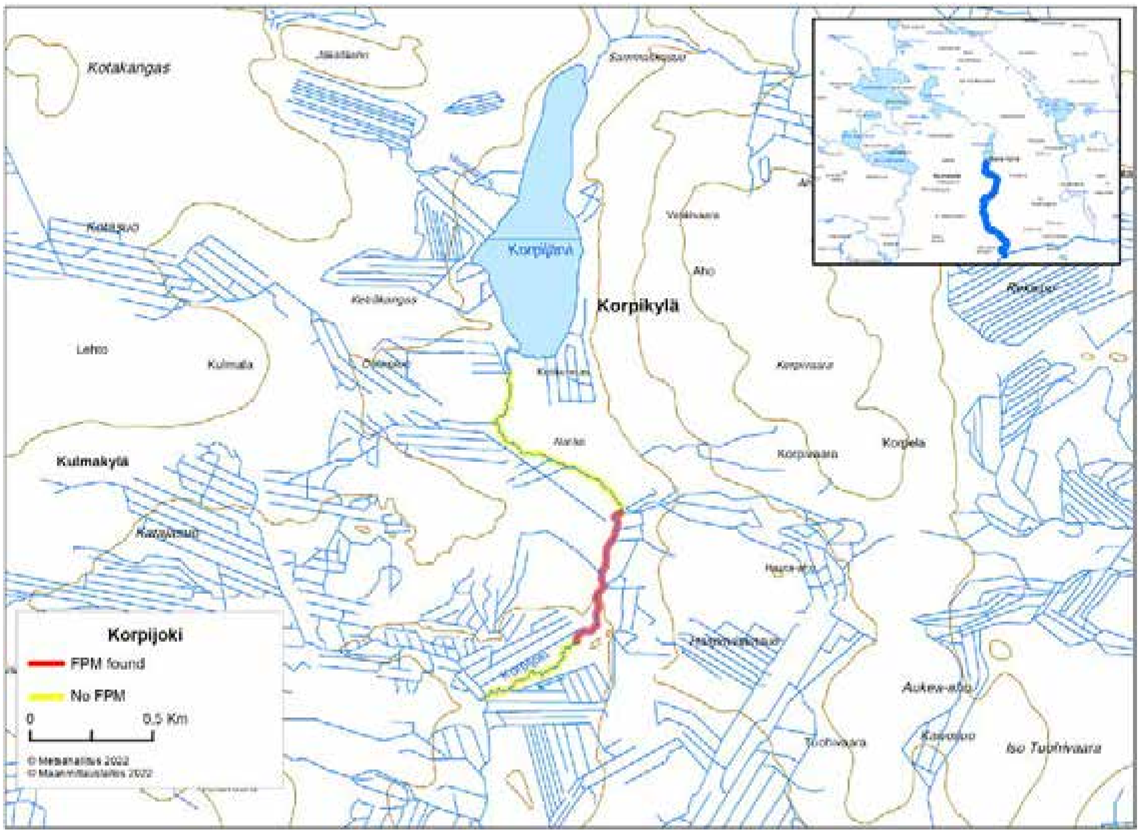

Figure 190. Investigated area (total count) in river Korpijoki. Small map: River Korpijoki marked with a thicker blue line.

3.4.2.6 Teno catchment

River Teno (in Norwegian Tana) is a border river between Norway and Finland (Fig. 191). The main tributaries of the Teno are River Inarijoki on the border between Norway and Finland, River Karasjok in Norway, and River Utsjoki in Finland (Fig. 191). The drainage area of River Tenojoki is 14,891 km^2, out of which 5,123 km^2 is in Finland and 9,768 km^2 in Norway (Ekholm 1993). The outlet of the Tenojoki is in Norway at the bottom of the Tanafjorden. Teno is an important salmon river with an annual catch of 60,000–250,000 kg salmon (Erkinaro et al. 2012).

FPM is known only from a couple of streams in the Teno catchment. The known FPM rivers in Finland are Utsjoki, Lovtajohka, Galddasjohka, Námmájohka and Vuohččojohka. The FPM in the last three mentioned rivers were detected only recently. In Norway, at least Karasjok is known to host FPM (Paul Aspholm, personal communication). Historically FPM is known also from Inarijoki river, but in 1998 only dead shells were found in the surveys there (Mela 2006). One should note, however, that river Teno and its tributaries are mostly remote uninvestigated wilderness areas, which makes it likely that there are still populations to be discovered.

The status of the FPM population has been studied earlier in Lovttajohka (Oulasvirta et al. 2015a). The target rivers in the SALMUS project were Námmájohka, Galdasjohka and Vuohččojohka in the municipality of Utsjoki. However, due to the tight schedule, only preliminary investigations could be carried out in these rivers. What makes the Teno catchment rivers challenging for the research, are the long distances to the rivers from the road.

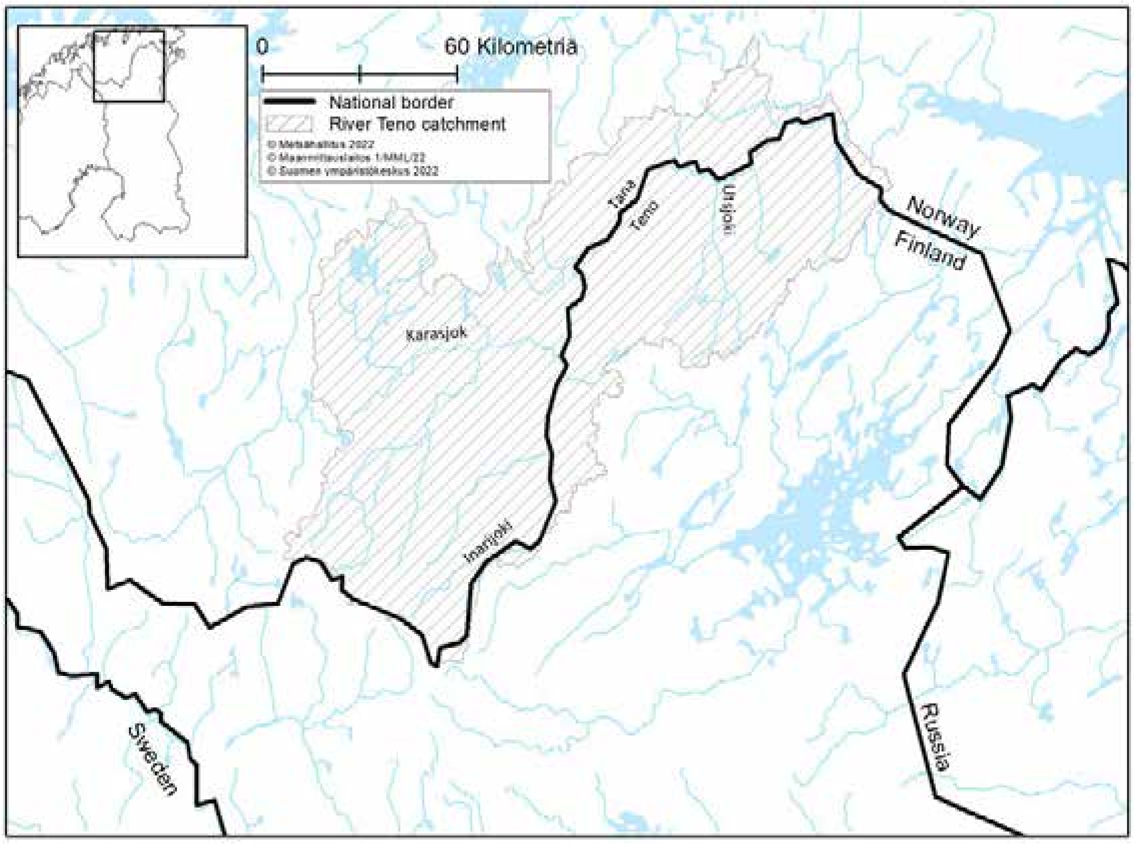

Figure 191. Teno (Tana in Norwegian) catchment area.

River Vuohččojohka

River Vuohččojohka (Figs 192–193) flows from lake Vuohččojávri (5.66 ha; 250.5 m above sea level) to Ohcejohka /Utsjoki river, descending 50.5 m on its way. The river is 10 km long. Size of the catchment area is 24 km². In addition to Vuohččojávri, lakes of 2.42 ha and 1.5 ha in size accompanied by a couple of smaller ponds are included to it. Upper part of the catchment belongs to Kalddoaivi Wilderness Natura 2000 area (FI1302002), the lower course is not protected. In its lower course the river runs through two culverts. The one going under the main road E75 is in good shape, but the other one, situating in private land, needs reparation since it may prevent juvenile salmon (probable FPM host in this river) from ascending (Fig. 194).

The FPM population of Vuohččojohka was found in 2020 by A. Veersalu and M. Hynninen (Metsähallitus). The river flows to the bigger Utsjoki river, where FPM was found in 2009 by Juho Vuolteenaho (WWF Finland). According to local people FPM have been seen also in Gukčejohka, next to Vuohččojohka, but no mussels were found there. Stories still tell that in the past there has been a connection between those two rivers. Juvenile salmon is found in both rivers, as well as calcifilous plants on their riverbanks.

In the SALMUS project, the Vuohččojohka FPM population was studied in July 2020 and in May-June 2021 by the total count method using snorkeling. Investigated area was from Vuohččojávri to the main road E75 (Fig. 195). The remaining river stretch between the main road and Utsjoki river had been surveyed separately before the project.

Only empty shells were found from the upper course of the river. Totally five FPM individuals alive (Appendix 1) were found

Figure 192. Vuohččojohka FPM area on October 5, 2021. Red tapes indicate temperature logger site, next to an FPM individual. Photo: Aune Veersalu.

Figure 193. Lake Vuohččojávri was still partly covered with ice when S. Kankaanpää and Halla were ready to start the river survey in May 2021. Due to strong current the river was investigated downstream. In its upper/middle course the river sometimes totally disappears under the turf. Under the turf it widens like a bottle and is still about 1 m deep with strong current and gravel/sand bottom. Unfortunately, only empty shells were found in this part of the river (as far as it was possible to investigate). Photos: Aune Veersalu and Sakari Kankaanpää.

from the river section downstream from some bog pools in the area known as juvenile salmon area. The river flows most of its course in boggy depression, but in some places mountain birch forests come next to the river. Bottom substrates variate from areas with 100% gravel to almost 100% coverage with stones, but also organic bottom and even clay could be seen in some places (Fig. 196).

Mussels were not measured, and data is also insufficient to judge the viability class of the FPM population in the river.

Figure 194. Culvert pipes under a private road in Vuohččojohka may prevent salmon parr ascending into the river. Photo: Aune Veersalu.

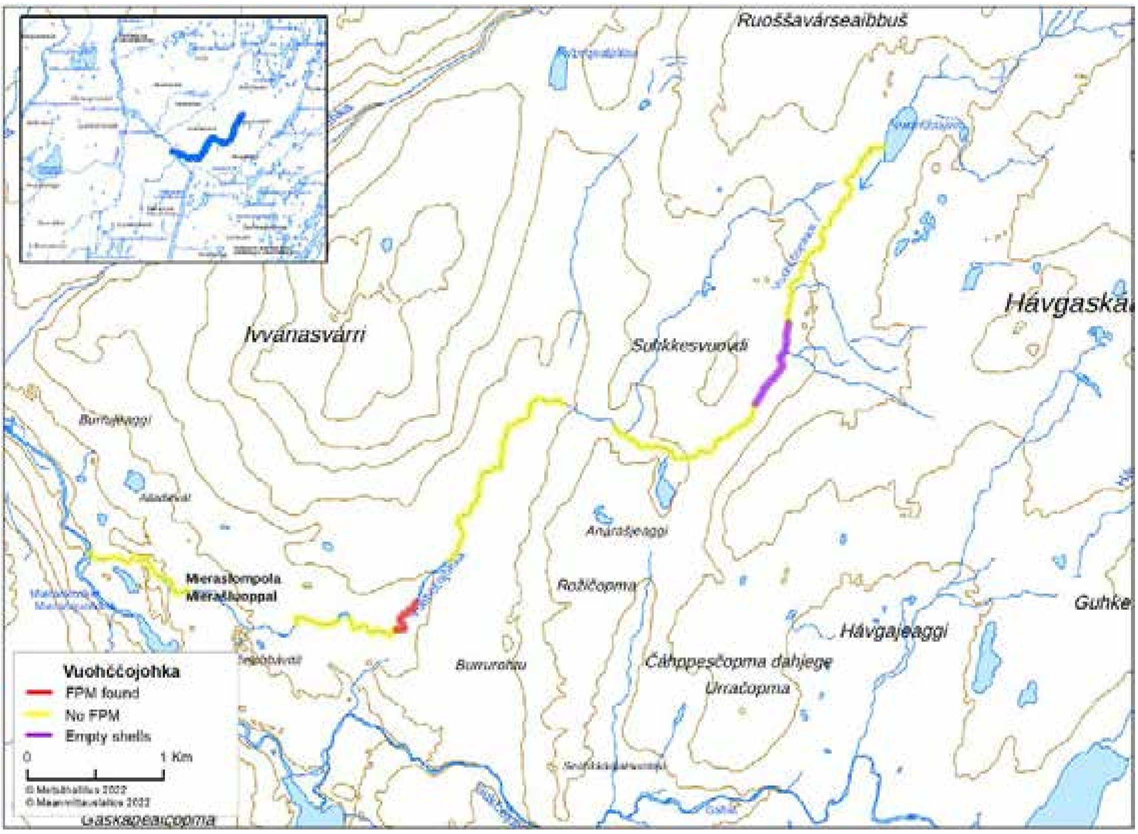

Figure 195. Investigated area (total count) in river Vuohččojohka. Small map: River Vuohččojohka marked with a thicker blue line.

Figure 196. Bottom substrates in Vuohččojohka are slightly covered by moving sand in several places. Photo: Aune Veersalu.

River Námmájohka

River Námmájohka (Fig. 197) starts from Námmáčohkka hill as a small stream and flows about 3 km before it reaches the three Námmájávri lakes. Uppermost of the lakes is 2.5 ha and 190 m above sea level, the middle one is 2.25 ha and the lowermost Námmájávri is 3.19 ha and 169.5 m above sea level (Fig. 198). After the Námmájávri lakes the brook flows around 3 km to Ohcejohka river lower course and descends about 70 m (Fig. 199). The catchment area of Námmájohka is 10.7 km², out of which lakes make 1.5%. The upper part of catchment until lower Námmájávri lake is protected as part of Paistunturi Wilderness Natura area (FI1302003). The lower course, where the mussels are found, is not protected. After reaching the Utsjoki valley the river flows 350 metres under the electricity line and close to the road E75. Then the river runs through the culvert about 100 metres before it reaches to Ohcejohka/Utsjoki river. Moving sand and several artificial objects were found from the river bottom in this section, but no mussels. Salmon parr gathering was observed next to culvert, downstream from the road. The culvert may be a barrier to the upstream migration of young salmon and hence it should be repaired.

Figure 197. River Námmájohka FPM area in June 2020. Regardless of boggy surroundings streams in the north are often deep with gravel bottom and strong current. Photo: Aune Veersalu.

Figure 198. The lower Námmájávri lake in June 2020. Cloudberries are flowering on peat banks; some snow can still be seen in some higher areas above the mountain birch zone in Paistunturi Wilderness Area. Photo: Aune Veersalu.

Figure 199. The steepest part of Námmájohka ocuurs when the brook descends from upper plains to the Utsjoki valley in two branches. The wider branch is probably not too steep for the ascent of juvenile salmon. Photos: Aune Veersalu.

The FPM population of Námmájohka was found in June 2020 by A. Veersalu and M. Hynninen (Metsähallitus). In order to find out the distribution range of the mussels and the size of the population, the river was surveyed in 2020 and in 2021 with the total count method using snorkel diving and aquascope. The area, investigated in SALMUS project, extended from Námmájávrrit lakes down to Ohcejohka/Utsjoki river (Fig. 200). Although the river was inspected thoroughly, only one living mussel (Fig. 201) and some old shells were found. However, it is possible that all mussels in the river were not detected, since in some rocky areas (Fig. 202) searching for mussels was impossible.

Mussels were not measured, and data is also insufficient for judging the viability class of the FPM population in the river.

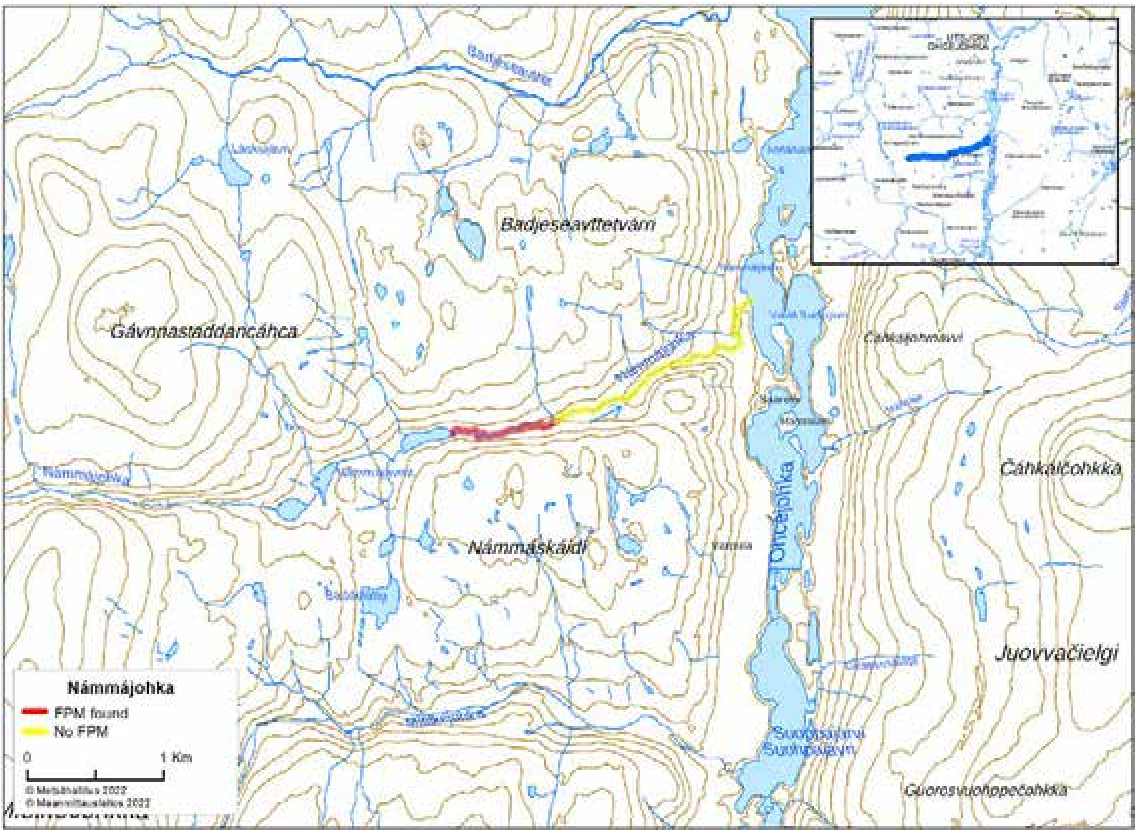

Figure 200. Investigated area (total count) in river Námmájohka. Small map: River Námmájohka marked with a thicker line.

Figure 201. The only living mussel found from Námmájohka, on June 21 and on September 22 in 2020. Photos: Aune Veersalu and Sakari Kankaanpää.

Figure 202. Some areas in the river consisted of large stones in several layers, which do not allow effective search for mussels. Photos: Aune Veersalu.

River Gálddašjohka

River Gálddašjohka (Fig. 203) starts from Gálddoaivi uplands (> 300 m above sea level) and flows to lake Buolbmatjávri/Pulmankijärvi, 12.6 m above sea level. Gálddašjohka has two main tributaries, Luovosvarjohka and Lovttajohka. Luovosvarjohka gathers its water from several small lakes, biggest of them being 9 ha. Luovosvarjohka joins to Gálddašjohka in its upper coarse. River Lovttajohka joins to Gálddašjohka around 7 km downstream from that point. Then the river flows 7 km more down to lake Buolbmatjávri/Pulmankijärvi. Gálddašjohka catchment before joining with river Lovttajohka is 59.9 km^2, out of which 1% is lakes. The total catchment area of the Gálddašjohka–Lovttajohka rivers is 120.28 km^2 (Eklund 1993). The upper part of catchment is protected as part of Gálddoaivi Wilderness Natura area (FI1302002). The lower course of the Gálddašjohka belongs to lake Pulmankijärvi Natura area (FI1302004). Thus, the direct human impact to the river is not remarkable, but in the 1990s extensive destruction of mountain birches in this area due to autumnal moth (*Epirrita autumnata*) may have increased sedimentation and nutrient flow into the river.

FPM was detected in the river Lovttajohka in 2005 during the Interreg Kolarctic Project "The existence and state of the populations of FPM in the parts of the North Calotte" (Oulasvirta et al. 2006, Oulasvirta 2006). At the same time, a single FPM was found also a little bit downstream from Lovttajohka outlet, in river Gálddašjohka. The population status of FPM in Lovttajohka was studied in the Interreg Raakku! project 7.–9.8.2012 by Janne Nyyssölä & Aune Veersalu, Metsähallitus (Oulasvirta et al. 2015a). The lower course of Gálddašjohka, between the river Lovttajohka to Buolbmatjávri lake was surveyed in

Figure 203. Gálddašjohka, viewed a bit upstream from the lower limit of the FPM population. M. Hynninen (MH) looking for suitable place for temperature logger. Photo: Aune Veersalu.

the same project, but no FPM was found from that river stretch.

In the SALMUS project, the upper course of the river, ca. 870 metres upstream from the Lovttajohka outlet, was investigated in 2021 (Fig. 204). In total, six FPM individuals were found (Appendix 1).

Mussels were not measured, and data is also insufficient to enable viability class assessment for the FPM population in the river.

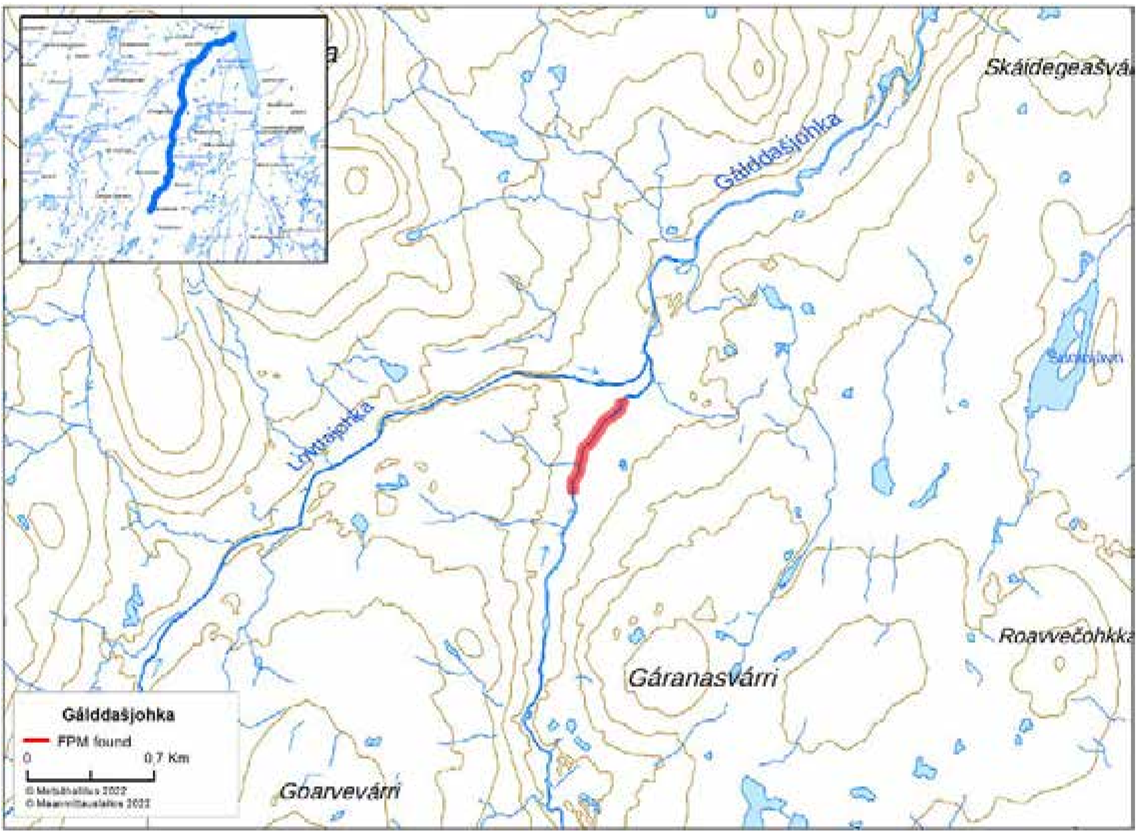

Figure 204. Investigated area (total count) in river Gálddašjohka. Small map: River Gálddašjohka marked with a thicker line.

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Appendix 1 Viability status of different FPM populations according to the proportion of the < 20 mm and < 50 mm mussels

The populations marked (?) did not fully fit the criteria presented in Table 7. No data = not enough data to evaluate the viability class. * Total population including Russian side < 2,000, **Estimate 33,000.

Country	River	Pop. size	% <20 mm	% <50 mm	Smallest	Distribution (m)	Viability
SWE	Silpakbäcken	18,325	0.70%	30.00%	16 mm	1,300	Viable
SWE	Harrijaurebäcken	7,998	0%	25.90%	16 mm	3,000	Viable
FIN	Urakkajärvenoja–Vuoksioja	18,333	1%	20%	10 mm	4,760	Viable
FIN	Sätsijoki	9,944	1.2%	27.7%	13 mm	4,070	Viable
FIN	Niemioja	9,592	2.90%	39.4%	9 mm	1,800	Viable
FIN	Kivijoki	3,442	2.17%	31.16%	12 mm	5,000	Viable
FIN	Ristimorostonjärvenoja	147	0%	58%	24 mm	950	Viable (?)
SWE	Souksaurebäcken	1,789	2.30%	12.50%	13 mm	8,500	Maybe viable
SWE	Ljusträskbäcken	791,988	0.4%	16.20%	15 mm	10,000	Maybe viable
FIN	Ahvenoja	3,054	> 0%	18%	13 mm	1,320	Maybe viable
SWE	Bölsmanån	110,356	0.003%	8.70%	11 mm	3,800	Maybe viable (?)
NOR	Grense Jakobselv	633*	1.65%	10.74%	5 mm	no data	Maybe viable
NOR	Ørnebekken	1,340	1.42%	8.28%	5 mm	no data	Maybe viable (?)
NOR	Spurvbekken	8,386 **	0.66%	8.01%	10 mm	no data	Maybe viable (?)
NOR	Botnelva	2,017	~ 1%	~ 3%	2 mm	no data	Maybe viable (?)
NOR	Krakojokki	11,498	1.15%	7.85%	5 mm	no data	Maybe viable (?)
SWE	Kääntöjoki	222	0%	13.30%	41 mm	7,000	Non-viable (?)
SWE	Korsträskbäcken	4,656	0%	0.50%	49 mm	7,100	Non-viable
SWE	Görjeån (upper)	59,849	0%	13.30%	24 mm	5,400	Non-viable
SWE	Görjeån (lower)	1,742	0%	1.00%	44 mm	5,000	Non-viable
SWE	Rutnajoki	444	0%	1.30%	47 mm	2,640	Non-viable (?)
SWE	Tvättstugubäcken	20,792	0%	0.80%	40 mm	2,240	Non-viable
FIN	Nohkimaoja–Vuoksijoki	13,806	0%	13.5%	25 mm	12,934	Non-viable
FIN	Meskus–Väli-Juomajoki	13,050	0%	0.93%	48 mm	9,220	Non-viable
FIN	Porontimajoki	1,213	0%	2%	40 mm	600	Non-viable
FIN	Kolmosjoki	36,547	0%	1%	21 mm	14,230	Non-viable
FIN	Hangasjoki–Tammakko-lammenoja	450	0%	5%	27 mm	1,800	Non-viable
FIN	Myllyoja	1,130	0%	2%	35 mm	1,500	Non-viable
FIN	Varisjoki–Leväjoki	7,163	0%	> 0%	31 mm	5,280	Non-viable
FIN	Köykenejoki	7,650	0%	> 0%	38 mm	1,400	Non-viable
FIN	Takkireuhkajärvenoja–Pesäjärvenoja	936	> 0%	3.6%	20 mm	1,860	Non-viable/partly viable (?)
NOR	Føllelva	707	0.29%	0.86%	11 mm	no data	Non-viable (?)
FIN	Lutto	41,100	0%	0%	> 70 mm	45,000	Dying
FIN	Vääräjoki	1,298	0%	0%	101 mm	4,000	Dying
SWE	Tjartsebäcken	11	0%	0%	77 mm	3,100	Dying soon
FIN	Korpijoki	118	0%	0%	63 mm	850	Dying soon
FIN	Salmijoki	45	0%	0%	> 70 mm	750	Dying soon
NOR	Sandneselva	0	n/a	n/a	n/a	n/a	Extinct (?)
FIN	Ahvenlammenoja	806	no data	> 0%	35 mm	1,200	no data
FIN	Rytioja	350	no data	> 0%	31 mm	560	no data
FIN	Saari-Ahvenjärvenpuro	28	no data	> 0%	32 mm	400	no data
FIN	Vuohččojohka	5	no data	no data	no data	no data	no data
FIN	Námmájohka	1	no data	no data	no data	no data	no data
FIN	Gálddašjohka	6	no data	no data	no data	no data	no data
NOR	Neiden	1	no data	no data	no data	no data	no data

4 Host Fish Studies

4.1 Electrofishing studies

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4.1.1 Study area

The cross-border areas of Finland, Norway and Russia (Green Belt of Fennoscandia; GBF) comprise several river basins, where migrating Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) stocks are of both national and international value. The Teno- and Näätämöjoki rivers are important salmon breeding grounds and fishing destinations in the cross-border area of Finland and Norway (Fig. 205). To the south, the Finnish headwaters of the transboundary Tuulomajoki river basin (Finland-Russia), Lutto, Anteri, Jauru and Nuortti (Fig. 206), sustain some of the last potamodromous wild brown trout populations in Finland. The headwaters on the Finnish side of the Tuulomajoki were

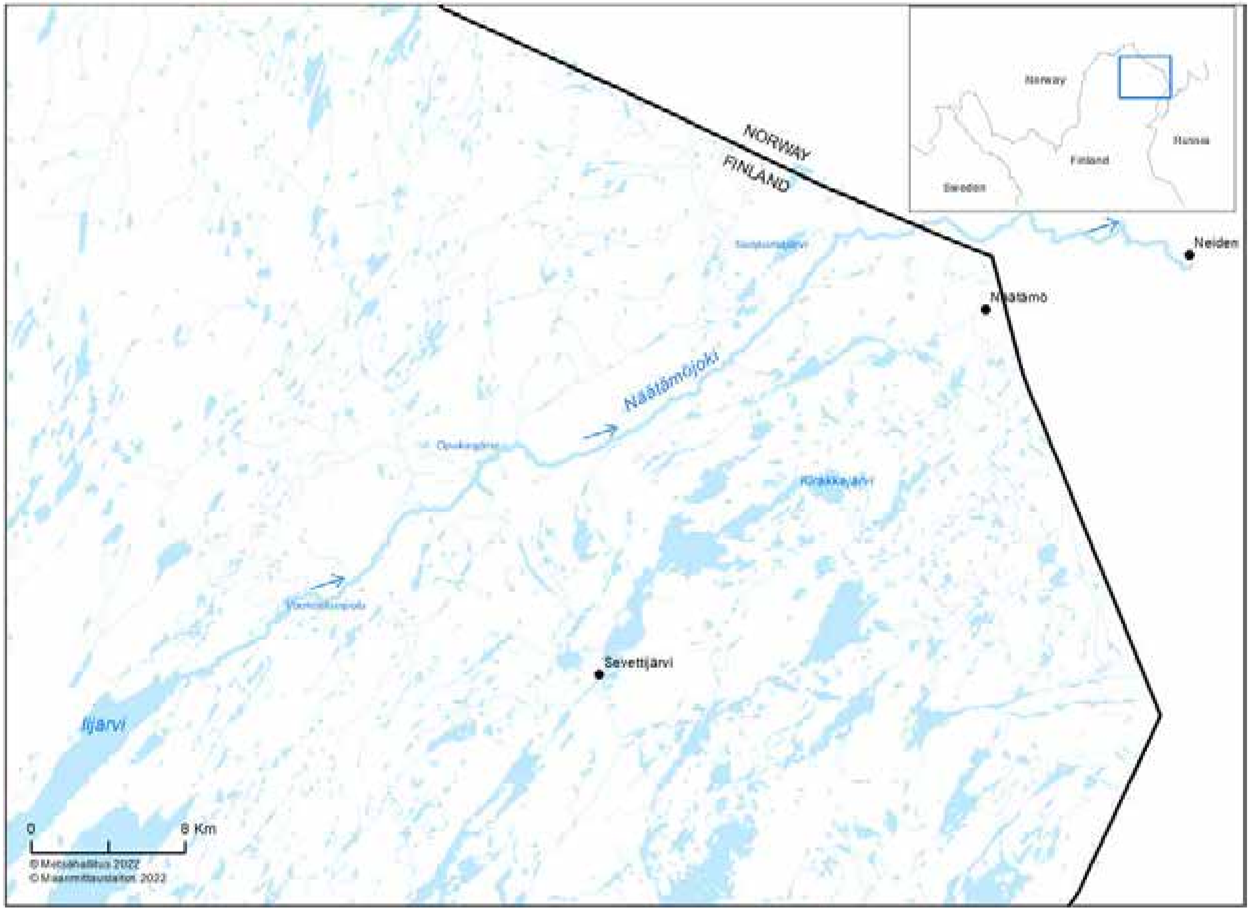

Figure 205. The Näätämöjoki river system.

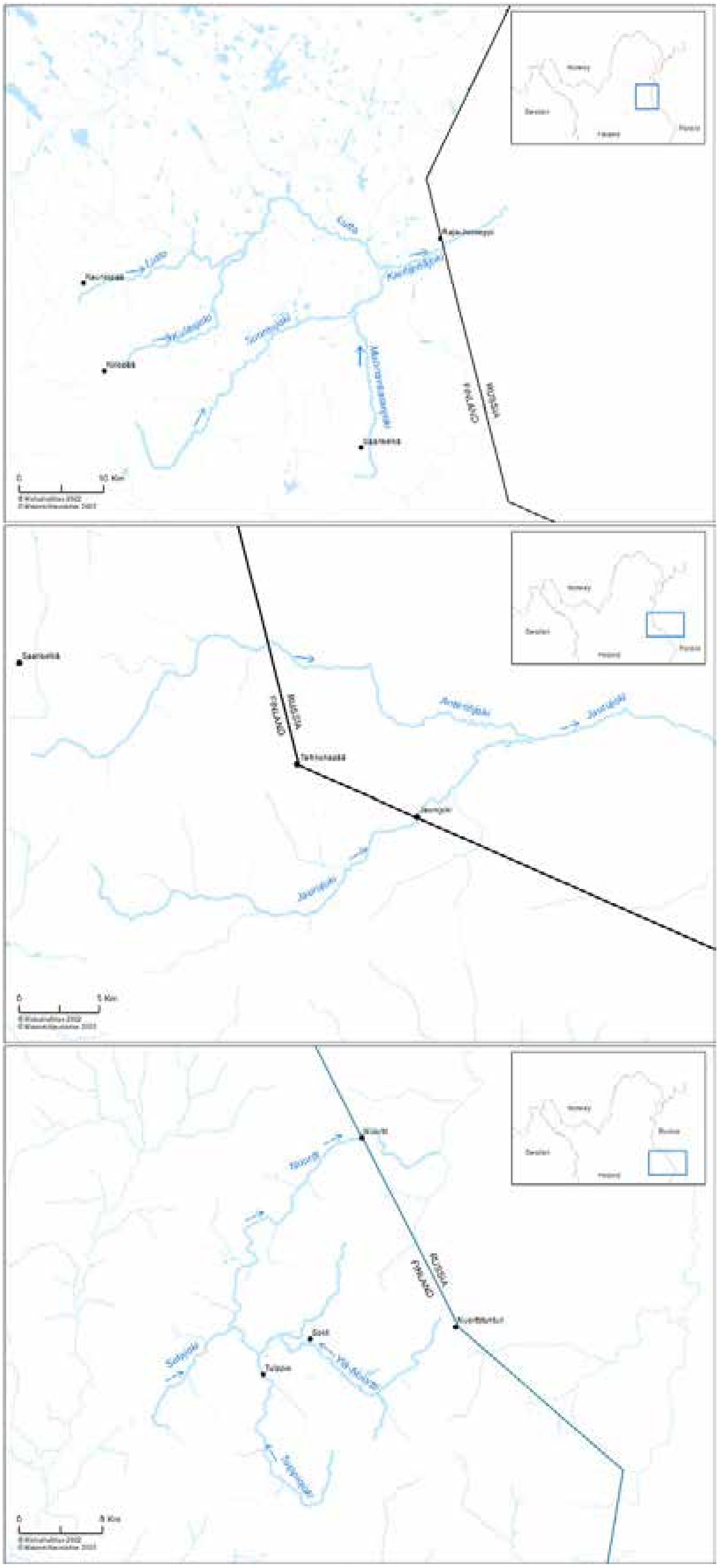

Figure 206. The most significant tributaries in the Tuuloma river system originating in Finland.

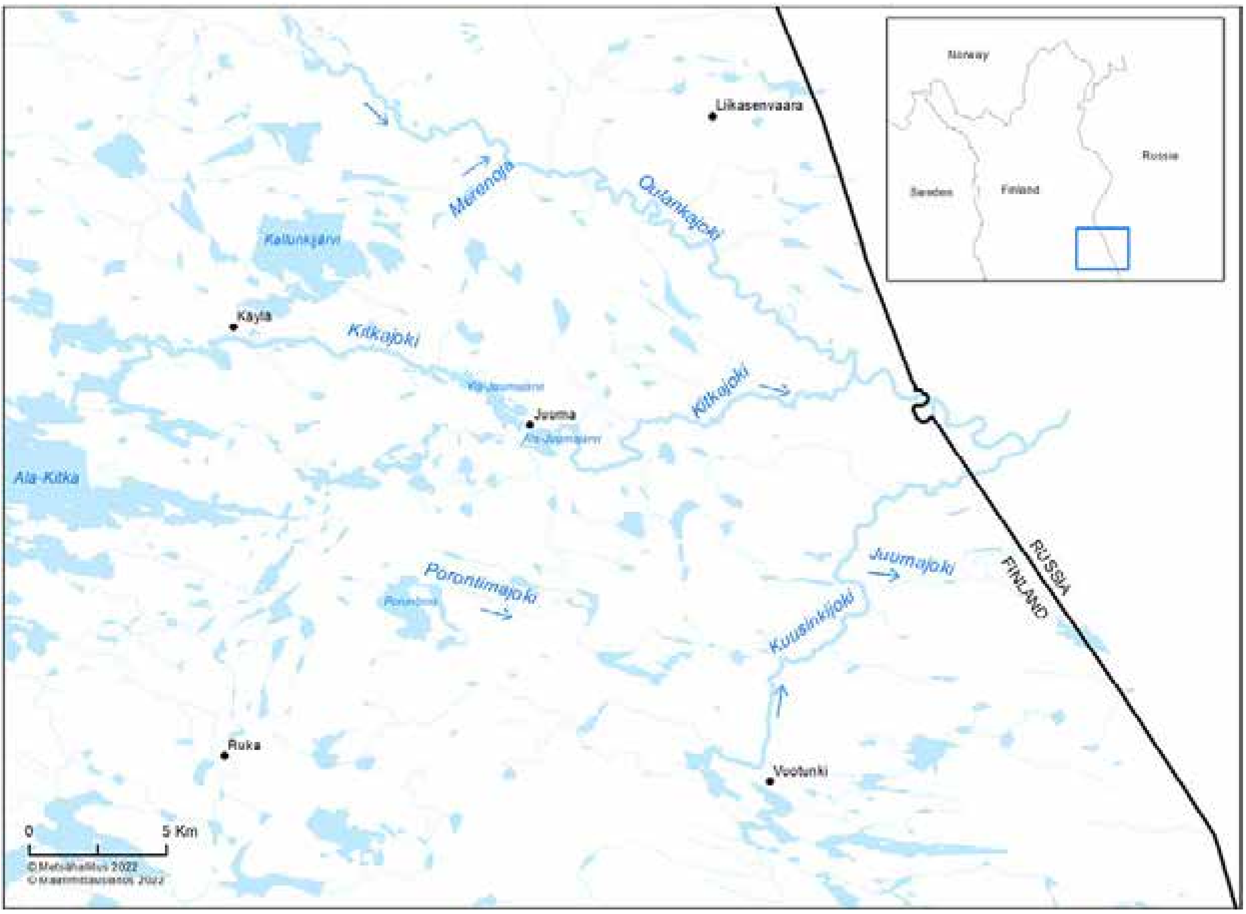

Figure 207. The Finnish part of the Koutajoki river basin with the main tributaries Oulanka, Kitka and Kuusinki.

also historically significant salmon breeding and fishing areas, but the construction of the Upper Tuuloma Power Plant in the 1960s cut off the salmon migratory connection to the Finnish parts of the watercourse. Three large headwater rivers Oulanka, Kitka and Kuusinki, in the Finnish part of another Finnish-Russian transboundary system, the Koutajoki river basin (Fig. 207), south of the Arctic Circle, are significant production areas of migratory, adfluvial brown trout in the watershed despite their complete or temporal natural migration barriers (Kiutaköngäs Falls, Jyrävä Falls) and Myllykoski hydropower plant. The central lake of the system is the Lake Pyaozero in Russia, which is the feeding area for the migrating brown trout. In addition, some field studies and electrofishing surveys in the SALMUS project were carried out in other river systems in northern Finland, namely in Kemijoki, Vienan Kemi and Oulujoki catchments.

4.1.2 Long-term monitoring of migrating salmonid fish in the GBF region

The long-term monitoring of the status on valuable salmon and brown trout populations in the study area include some watersheds where surveys have been conducted since the 1970s by the former Finnish Game and Fisheries Research Institute, and nowadays by the Natural Resources Institute Finland (Luke). These monitoring programmes include fishing and catch statistics, estimation of juvenile densities and lately also counting of adult ascending fish by sonar, video cameras or snorkeling. The most comprehensive monitoring programme is used in the Teno system including all the above-mentioned surveys (Tana Monitoring and Research Group 2021), and in the Näätämöjoki river the monitoring also includes several sources of annual data. In the Tuuloma system, electrofishing of juvenile trout and counting of adult spawners by snorkeling is included in the annual monitoring programme. Long-term monitoring of Koutajoki brown trout populations is also based on diverse assortment of surveys, including electrofishing, catch and release fishing, Carlin-tagging at Kiutaköngäs Falls, and catch statistics (A. Huusko, unpublished).

Juvenile salmonid fish densities are presented in this report as uncorrected numbers of individuals per 100 m² per one electrofishing pass. Electrofishing has been conducted using standard methods (EN 14011:2003) and following the recently approved CEN guidelines.

The juvenile Atlantic salmon production in the Näätämöjoki systems is wide-ranging, from the lowermost, tidal areas of the system in Norway, all the way to the long headwater tributaries in Finland. Juvenile densities are quite good especially in the lower parts of the system, but the densities decrease considerably towards the upper reaches, especially upstream of the Lake Opukasjärvi (Fig. 205, Tables 9 and 10). This implies that salmon spawning populations would have the potential to be larger given the high-quality rearing habitats available in the area.

In the Finnish headwaters of the Tuuloma system brown trout densities are generally rather low and large river areas show very limited trout production or no trout at all (Tables 9 and 10). Overall, the highest trout densities are generally found in the upper reaches of the tributaries. Currently the best and stable densities are found in the Muorravaarakka river, where all fishing has been prohibited for c. 15 years (Tables 9 and 10; Fig. 206). The relatively high juvenile densities in the Muorravaarakka river are in good concert with the annually counted numbers of spawners that have been higher than elsewhere in the system (Orell et al. 2015).

Long-term average brown trout densities in the Finnish headwater tributaries of the Koutajoki river basin are relatively high in the Rivers Kitka and Kuusinki, but clearly lower in the River Oulanka (Fig. 207, Tables 9 and 10). There seem to be some between-years variation in the densities in all the rivers reflecting annual variations in the number of spawners and/or survival of young fish. In general, the densities of young (age-0+) brown trout reflect the estimated abundances of spawning populations in these rivers, with River Oulanka having the lowest and River Kuusinki the largest annual spawning run sizes (A. Huusko, unpublished).

4.1.3 Salmonid fish surveys at the potential areas supporting freshwater pearl mussel (FPM)

In addition to the long-term salmonid monitoring programs in the northern transboundary river systems, salmonid fish populations were also surveyed in other areas during this project, partly in other parts of the same watersheds than the long-term monitoring programs, partly in other watersheds. The field work and data analyses were conducted by both Natural Resources Institute Finland (Luke) and Metsähallitus. The surveyed areas included selected tributaries of the Tenojoki, Kemijoki, Koutajoki, Vienan Kemi and Oulujoki watersheds (Fig. 208; Tables 9, 10 and 11). In these so-called potential freshwater pearl mussel (FPM) areas, the densities and distribution of Atlantic salmon and brown trout were investigated in late summer or autumn by electrofishing. Besides salmon and brown trout, the occurrence of other fish species was also recorded, with a special focus on alien species such as brook trout (*Salvelinus fontinalis*) in some catchments.

Among the potential FPM areas, one small tributary of the Teno system, the river Nammajohka, was electrofished to find if the road culvert near the river mouth is a barrier for migration of juvenile salmon entering this tributary from the river Utsjoki mainstem

Table 9. Fry (0+) densities of Atlantic salmon (Näätämö) and brown trout (other rivers), one pass electrofishing.

Year	Näätämö Finland	Näätämö Norway	Tuuloma Lutto	Tuuloma Kulas	Tuuloma Suomu const.	Tuuloma Suomu ext.	Tuuloma Muorra	Tuuloma auru	Tuuloma Anteri	Tuuloma Kiertämä	Tuuloma Nuortti	Koutajoki Oulanka	Koutajoki Kitka	Koutajoki Kuusinki	Koutajoki Juuma	Koutajoki Porontima	Koutajoki Merenoja
2003	23.4	8.5	4.1	4.1	5.8	-	-	-	-	-	-	18.9	11.1	17.7	-	-	-
2004	7.8	10.8	0.8	7.8	8.9	-	-	-	-	-	-	4.9	13.2	13.5	-	-	-
2005	4.5	6.6	3.6	8.3	10.4	-	-	-	0.4	-	-	8.1	10.1	17.0	-	-	-
2006	9.7	8.1	4.9	5.2	7.3	-	-	-	-	-	-	1.5	8.6	15.2	-	-	-
2007	23.5	12.2	5.3	2.4	8.3	-	-	-	-	-	8.0	2.3	16.1	7.9	-	-	-
2008	12.7	7.7	5.0	11.0	11.7	-	-	-	5.6	-	5.4	0.7	7.9	12.8	-	-	-
2009	12.7	9.1	8.6	8.9	3.0	-	17.9	2.8	-	-	8.6	1.7	7.6	4.9	-	-	-
2010	6.9	3.0	3.6	3.7	5.1	2.0	11.3	-	-	-	6.3	6.2	4.0	13.3	-	-	-
2011	12.9	4.9	5.7	1.5	5.7	-	7.8	-	-	-	5.6	0.4	5.0	5.8	-	-	-
2012	13.1	8.4	4.1	6.3	12.7	-	14.3	-	-	-	7.8	0.7*	0.3*	1.1*	-	-	-
2013	14.6	7.4	4.9	6.0	7.0	-	11.0	-	-	-	8.7	1.6	12.2	8.8	-	-	-
2014	27.8	22.9	8.2	5.5	18.0	-	28.7	-	-	-	-	4.4	8.0	8.0	-	-	-
2015	16.2	12.7	5.3	18.1	31.6	-	15.1	-	-	-	-	1.7	4.2	18.9	-	-	-
2016	23.3	10.2				-	-	-	-	-	-		8.1	16.5	-	-	-
2017	18.9	4.7	4.1	8.0	19.8	-	-	-	-	-	-	1.1	9.8	15.2	-	-	-
2018	8.0	7.8	5.5	12.2	19.4	-	29.4	-	-	-	-	9.6	9.1	15.7	-	-	-
2019	18.0	15.0	8.2	9.6	15.1	-	41.7	-	-	-	-	8.9	14.9	10.3	-	-	-
2020	5.1	7.0	9.2	8.2	15.6	8.7	24.6	-	-	-	-	0	18.0	8.7	0.0	9.9	0.0
2021	10.2	17.6	-	-	-	-	-	-	-	0.0	-	0.6	10.2	5.0	-	-	-
N	10–19	6–15	8	4	3	13–14	16	10	9–12	12	15	1–4	5	7	2	2	1
Avg.	**14.2**	**9.7**	**5.3**	**7.5**	**12.1**	**5.3**	**22.6**	**2.8**	**3.0**	**0**	**7.2**	**3.0**	**9.9**	**12.1**	**0**	**9.9**	**0**

Table 10. Parr (≥1+) densities of Atlantic salmon (Näätämö) and brown trout (other rivers), one pass electrofishing.

Year	Näätämö Finland	Näätämö Norway	Tuuloma Lutto	Tuuloma Kulas	Tuuloma Suomu const.	Tuuloma Suomu ext.	Tuuloma Muorra	Tuuloma Jauru	Tuuloma Anteri	Tuuloma Kiertämä	Tuuloma Nuortti	Koutajoki Oulanka	Koutajoki Kitka	Koutajoki Kuusinki	Koutajoki Juuma	Koutajoki Porontima	Koutajoki Merenoja
2003	25.3	25.9	3.9	2.9	1.4	-	-	-	-	-	-	1.0	2.4	2.7	-	-	-
2004	14.8	24.0	4.4	3.2	0.3	-	-	-	-	-	-	3.1	3.1	3.5	-	-	-
2005	8.8	32.6	4.4	1.0	2.6	-	-	-	3.7	-	-	2.9	5.0	5.7	-	-	-
2006	13.1	32.7	2.2	1.4	1.7	-	-	-	-	-	-	1.5	3.0	4.0	-	-	-
2007	15.2	29.6	2.5	0.9	0.9	-	-	-	-	-	3.9	0.5	3.6	6.1	-	-	-
2008	17.7	41.5	3.4	0.4	3.0	-	-	-	3.8	-	3.7	1.2	2.8	3.6	-	-	-
2009	15.6	43.5	3.2	1.5	1.0	-	5.8	1.7	-	-	8.2	0.7	2.9	4.3	-	-	-
2010	11.1	42.8	2.6	1.8	1.0	5.3	2.5	-	-	-	5.8	2.6	4.1	2.8	-	-	-
2011	16.6	36.1	2.3	1.0	1.4	-	0.8	-	-	-	4.3	0.5	1.5	3.0	-	-	-
2012	15.3	36.5	3.2	1.4	0.3	-	2.2	-	-	-	7.1	0.5*	1.5*	0.6*	-	-	-
2013	23.3	50.4	3.3	1.0	1.7	-	3.8	-	-	-	8.8	0.3	7.7	8.5	-	-	-
2014	11.3	31.8	3.8	2.7	2.0	-	3.1	-	-	-	-	0.6	5.0	4.6	-	-	-
2015	8.8	19.8	3.0	0.3	1.9	-	2.7	-	-	-	-	0.9	6.8	3.2	-	-	-
2016	13.9	17.2	-	-	-	-	-	-	-	-	-		3.3	3.7	-	-	-
2017	14.2	29.9	4.0	1.8	1.5	-	-	-	-	-	-	0.8	3.2	3.2	-	-	-
2018	8.7	17.4	3.8	1.4	1.5	-	3.3	-	-	-	-	0.0	2.3	3.5	-	-	-
2019	18.4	40.7	5.3	2.1	1.7	-	6.1	-	-	-	-	3.1	6.2	2.4	-	-	-
2020	10.3	39.8	3.0	0.4	2.1	3.7	3.9	-	-	-	-	0.6	7.8	5.9	1.1	6.2	6.5
2021	9.9	46.3	-	-	-	-	-	-	-	1.3	-	0.6	6.2	1.6	-	-	-
N	10–19	6–15	8	4	3	13–14	16	10	9–12	12	15	1–4	5	7	2	2	1
Avg.	**14.3**	**33.6**	**3.4**	**1.4**	**1.5**	**4.5**	**3.4**	**1.7**	**3.8**	**1.3**	**6**	**1.2**	**4.3**	**4**	**1.1**	**6.2**	**6.5**

*Flood in rivers Oulanka, Kitka and Kuusinki in 2012 during the period of electrofishing reduced the catchability of fish.
These estimates were not included in the calculation of long-term averages. Empty cells = no electrofishing.

(a large tributary of the Teno river). Based on earlier surveys, the Nammajoki supports some freshwater pearl mussel individuals. It appeared that the culvert is at least a partial migration barrier. Salmon parr densities were more than tenfold higher below the culvert than above it (36 vs. 2 salmon parr/100m^2, one pass electrofishing)

There are several previously surveyed areas in the Koutajoki river basin where FPM is known to occur, and electrofishing surveys were targeted especially in areas where FPM population status had been studied and confirmed earlier. In the River Porontima, flowing into River Kuusinki, brown trout densities were clearly higher than in the nearby River Juumajoki (6.2 vs. 1.1 parr; ≥ 1+ age) which is

Table 11. Brown trout densities in FPM rivers (Kemijoki, Koutajoki, Vienan Kemi and Oulujoki river basins) in 2020–2021 (electrofishing conducted by Metsähallitus).

River basin	River/site	Year	Area	0+	Brown trout/100 m^2 ≥ 1+	Brown trout/100 m^2 total	Coord. YKJ	Coord. YKJ
Kemijoki	Ahvenoja 1	2020	120	-	4.2	4.2	3606279	7466340
Kemijoki	Ahvenoja 1	2021	210	-	1.4	1.4		
Kemijoki	Sätsijoki 1	2020	196	-	5.1	5.1	3600324	7459690
Kemijoki	Sätsijoki 2	2020	175	3.4	16	19.4	3605043	7461643
Kemijoki	Sätsijoki 2	2021	140	5.7	21.4	27.1		
Kemijoki	Tammakkolammenoja 1	2020	108	1.9	18.5	20.4	3579020	7406754
Kemijoki	Tammakkolammenoja 1	2021	197	0.5	6.6	7.1		
Kemijoki	Hangasjoki 1	2020	145	2.1	4.1	6.2	3578904	7407161
Kemijoki	Hangasjoki 2	2021	213	-	0.5	0.5	3578100	7406688
Kemijoki	Vääräjoki 1	2021	176	-	-	-	3564331	7358286
Kemijoki	Vääräjoki 2	2021	120	-	-	-	3558926	7359358
Kemijoki	Lauttajoki 1	2021	196	0.5	-	0.5	3565425	7370479
Kemijoki	Köykenejoki 1	2021	177	1.1	-	1.1	3569149	7371187
Kemijoki	Köykenejoki 2	2021	179	-	0.6	0.6	3568976	7371095
Kemijoki	Salmisenjoki 1	2021	121	0.8	-	0.8	3569489	7369468
Kemijoki	Salmisenjoki 2	2021	186	-	1.1	1.1	3569449	7369405
Koutajoki	Myllyoja 1	2020	280	-	-	-	3583861	7398657
Koutajoki	Myllyoja 1	2021	166	-	-	-		
Koutajoki	Myllyoja 2	2020	300	-	-	-	3584434	7398399
Koutajoki	Myllyoja 2	2021	246	-	-	-		
Vienan Kemi	Välijoki 1	2020	216	-	-	-	3591029	7323654
Vienan Kemi	Välijoki 1	2021	230	-	-	-		
Vienan Kemi	Juomajoki 1	2020	130	-	-	-	3587705	7325875
Vienan Kemi	Juomajoki 1	2021	122	-	-	-		
Vienan Kemi	Meskusjoki 1	2020	180	-	-	-	3594236	7322137
Vienan Kemi	Meskusjoki 1	2021	110	-	-	-		
Oulujoki	Korpijoki 1	2021	150	4.7	6.7	11.3	3581567	7196051
Oulujoki	Korpijoki 2	2021	203	0.5	9.9	4.4	3581567	7196051
Oulujoki	Lahnajoki 1	2021	244	-	-	-	3577900	7194748
Oulujoki	Lahnajoki 2	2021	173	-	-	-	3577795	7192899
Oulujoki	Leväjoki	2021	121	-	-	-	3582292	7200392

another tributary of River Kuusinki (Table 10). Moreover, in the River Merenoja, a tributary of River Oulanka, located in the Oulanka National Park, the brown trout density was clearly higher than the long-term average density in the mainstem River Oulanka (Table 10).

In the field surveys by Metsähallitus, a total of 15 FPM rivers, and 23 sites were electrofished in Kemijoki, Koutajoki, Vienan Kemi and Oulujoki river basins. Brown trout was caught from 13/23 sites where fish densities varied between 0.5–27.1 /100 m² (all size classes, one-pass electrofishing), including age-0+ densities between 0.0–5.7/100 m². Brown trout was absent at 10 studied sites.

Overall, the electrofishing results showed largely low abundance of juvenile salmonid fish in many rivers and sites. In areas located in the municipalities of Kuusamo, Salla, Posio and Puolanka (rivers Välijoki, Juomajoki, Meskusjoki, Myllyoja, Vääräjoki,

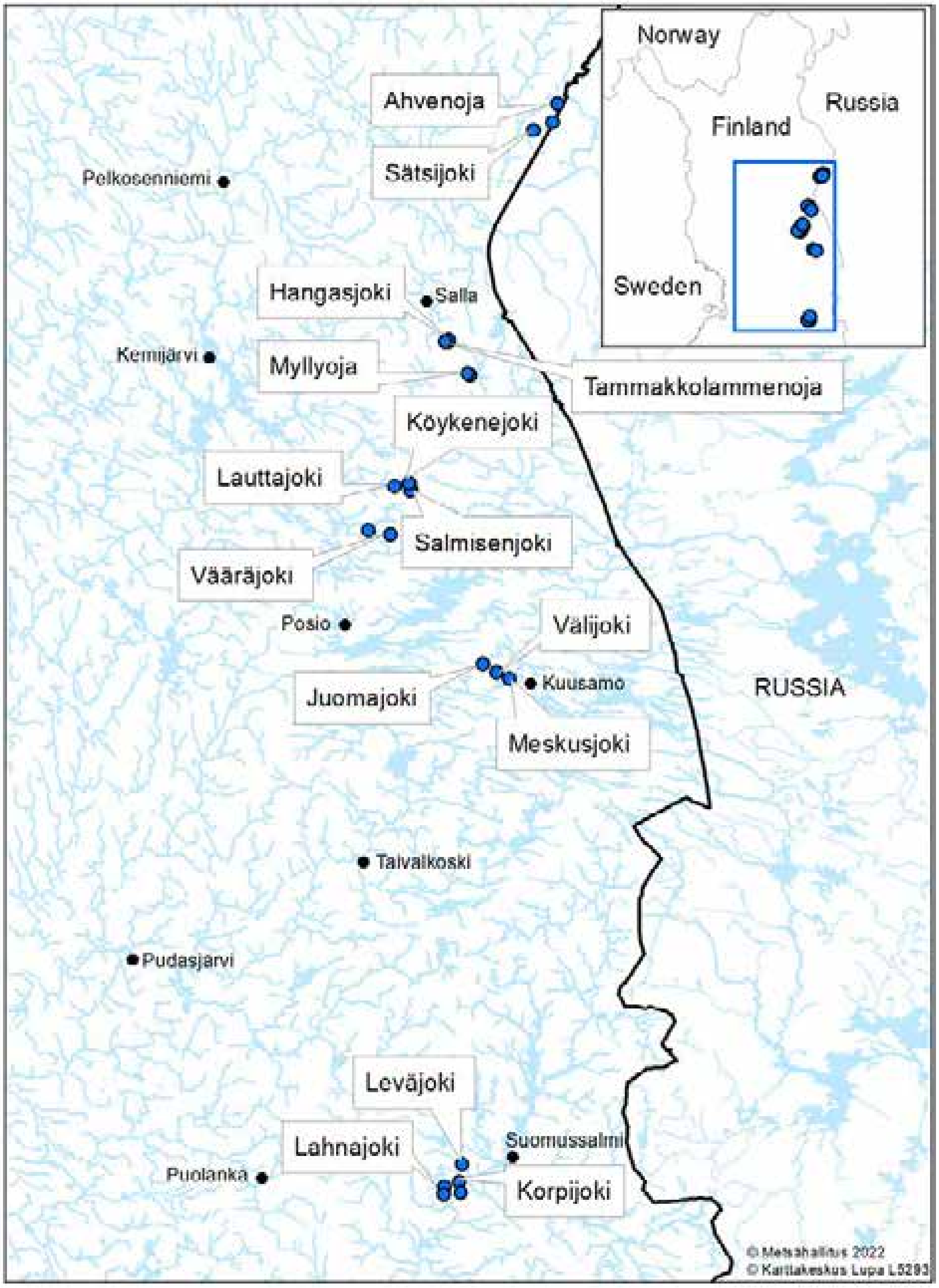

Fig 208. Location of electrofishing sites in the Kemijoki, Koutajoki, Vienan Kemi and Oulujoki river basins (field work conducted by Metsähallitus).

Lahnajoki, Leväjoki; Table 11), brown trout was not recorded at all. On the contrary, trout densities in the rivers Sätsijoki and Tammakkolammenoja were surprisingly high (Table 11).

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4.2 Invasive species – brook trout in the River Tuloma system

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A summary based on a report: Vuontela, A., Orell, P., Seppänen, M., Huusko, A. & Erkinaro, J. 2021: Brook trout in the Suomujoki catchment: Alternatives for managing an alien species. Natural Resources 71/2021. Natural Resources Institute Finland, Helsinki. 26 pp. (In Finnish with an English abstract)

4.2.1 Introduction

Brook trout (*Salvelinus fontinalis*), originally transferred from North America to Europe, was introduced in late 1970s to the Finnish headwaters of the River Tuuloma system, in the Kuutusoja tributary catchment, which drains into the River Suomujoki. The reasons behind the introduction included improving the recreational value of the area for fishing tourism. Brook trout is competing with native brown trout for habitat and food, and it has the potential to also threaten the local population of freshwater pearl mussel, which can use brown trout, but not brook trout, as a host for their early developmental stages.

A summary of results from test-fishing surveys by Metsähallitus and the Natural Resources Institute Finland (Luke) is presented below as part of the final report of the ENI Kolarctic CBC programme -funded SALMUS project. This summary is an extract of the full report on the introduced brook trout in the Kuutusoja system (Vuontela et al. 2021) which has been submitted as one of the outcomes of the SALMUS project.

4.2.2 Data, results

Investigations on brook trout distribution and abundance in the Kuutusoja catchment were started in 1993 by Metsähallitus. Different test fishing surveys using gillnetting and electrofishing have been organized in a number of years, but not in a regular, annual manner. Luke, in collaboration with Metsähallitus, conducted test fishing by electrofishing and gillnetting and carried out an environmental DNA (eDNA) study in the Kuutusoja catchment and in nearby areas under the SALMUS project in 2019. In addition, Luke and its predecessor Finnish Game and Fisheries Research Institute have monitored the fluvial fish populations in a number of tributaries of the Finnish parts of the Tuloma catchment since late 1980s. No brook trout have been detected outside the Kuutusoja catchment.

In early surveys in 1990s, no brook trout were captured in the Kuutusoja catchment, but since early 2000s brook trout have expanded their distribution in the system, especially in the streams draining into the Kuutusjärvi lake where tens or hundreds of individuals have been electrofished and removed in years when test fishing has been carried out. Experimental gill-net fishing in the lake has also resulted in some brook trout catches. Brook trout has dominated over brown trout in areas upstream of the lake, whereas the opposite was true downstream of the lake. Some brook trout have been encountered in the stream draining out of the lake, close to the barrier fence deployed in the outlet. Electrofishing in 2019 revealed generally low abundance of brook trout in streams running to the Kuutusjärvi lake, just a single specimen right below the barrier fence in the Kuutusoja main stem, and no brook trout further downstream or in a tributary running in the lower part of the Kuutusoja main stem. Gillnetting in 2019 resulted in catch of several native fish species but no brook trout. eDNA analyses in 2019 confirmed the results of electrofishing: brook trout DNA was found in streams running into the Kuutusjärvi lake but not further downstream than just below the fence, and no signs of brook trout were detected in two nearby control sites, the Suomujoki main stem, and another small tributary. In all, based on the latest test-fishing data, the brook trout population does not seem to be strong in the Kuutusoja catchment.

4.2.3 Conclusions, recommendations

Based on various test fishing sessions since 1990s and the recent eDNA study, it seems that still, after decades from the initial introduction, the distribution of brook trout still appears to be restricted to the Kuutusjärvi lake and the small tributaries running into it. No signs of distribution expansion downstream have been documented. The slow or non-existing expansion of brook trout downstream in the catchment and to other headwater tributaries of the Tuloma system is indicating little effect of the alien species to the native ecosystem, at least outside the Kuutusoja catchment. We also examined possibilities and methods to manage the brook trout, perhaps further restrict its distribution, decrease the abundance, or even erase the alien species from the system. The recommended method includes maintaining the barrier in the Kuutusjärvi lake outlet for preventing migration, combined with intensive electrofishing, and gillnetting to remove individuals from the system.

4.3 River origins of mixed-stock brown trout in the Lake Pyaozero Basin, eastern Fennoscandia

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A summary based on a manuscript "Fish know no borders – implications of the genetic structure and mixed-stock composition to cross-border management of adfluvial brown trout" by Huusko, A., Nikula, R., Tanhuanpää, P., Koljonen, M.-L. & Leinonen, T. sent to Fisheries Management and Ecology.

There are about ten large lake basins in Eastern Fennoscandia supporting adfluvial brown trout populations (Khalturin 1971, Huusko et al. 2017, Syrjänen et al. 2017) locating either in Finland or in Russia or being shared between the two countries. Lake Pyaozero Basin is a transborder basin of the latter type, locating south of the Arctic Circle in the Green Belt of Fennoscandia (Ministry of Environment 2014). It supports one of the most viable wild adfluvial brown trout population complexes in Eastern Fennoscandia. The central lake is Lake Pyaozero in Russia, where adfluvial brown trout, originating from their numerous spawning rivers in the Finnish and Russian territories, spend their lake-foraging phase before maturation and spawning run back to their natal rivers. Thus, the basin-wide population complex of adfluvial brown trout in Lake Pyaozero Basin consists of separate river-specific entities that gather in the lake and are harvested there as a mixed-stock, but also as river-specific stocks in their natal rivers.

The governance of the Lake Pyaozero Basin by two countries presents a challenge for management of its fish resources, and especially of migratory fish populations. Historical and present-day perceptions of the best practices used in conservation and utilization of natural resources may differ among the fisheries authorities of the different countries that set the fishing rules and regulations, and laymen practicing recreational fishing. Mutual understanding of the present state of the endangered brown trout populations is a crucial starting point for conservation and management actions. To this end, an important aspect in proper fisheries management of adfluvial brown trout populations is to know the basic structure of the mixed-stock in the lake, the extent to which the source populations contribute to it, and whether there are potential temporal variations in the production of the natal rivers into the mixed-stock.

Genetic stock identification (genetic mixed-stock analysis) has been applied to measure proportions of different river-specific salmonid fish populations in the mixed-stock samples both in marine (e.g. Koljonen et al. 2005) and freshwater environment (Swatdipong et al. 2013) during the last decades. In the method fish samples from the mixed-stock are assigned to the potential source-river populations based on their genotype information, derived for example from molecular markers such as microsatellites, either using individual assignment-based approaches or mixture modelling (Koljonen et al. 2005). In this study, a mixed-stock-analysis was carried out to estimate the composition of the mixed-stock of wild adfluvial brown trout in the Lake Pyaozero. To understand potential temporal variation in the mixed-stock composition in the lake, source-river population proportions in catch samples from two periods separated by two decades were assessed.

4.3.1 Brown trout samples

A baseline sample set of 515 young brown trout individuals that still resided in their natal rivers in Lake Pyaozero Basin in Russia and Finland was collected. The fish were captured from 13 rivers using electrofishing in the late summer in 2016 (Fig. 209). Earlier work (Huusko et al. 1990, Lemopoulos et al. 2018) and long-term field observations since the 1980s support the assumption that the baseline sample-set includes all significant spawning rivers of adfluvial brown trout in the basin. At every river-sampling site each caught brown trout juvenile was measured for its total length and a scale sample was taken and stored in a paper envelope for later genetic analysis.

Brown trout (catch) samples were collected from Lake Pyaozero in 1995 (N = 194) and 2016 (N = 246). Sampling was conducted on both occasions in autumn when the mature brown trout fit for spawning in that particular year had left the lake and ascended into the rivers for spawning. Thus, the mixed-stock in the lake mainly represented virgin brown trout in their lake-phase, with few large mature individuals spending a gap year in their biennial spawning run rhythm (Huusko et al. 2017). Each caught brown trout was measured for its total length and mass, and a scale sample was taken and stored in a paper envelope for later genetic analysis.

In addition to lake samples, a sample-set of brown trout caught from River Olanga, the basal mainstem river in the basin (Fig. 209), was analyzed to reveal a more detailed stock composition of the brown trout that ascend to spawn via this basal mainstem. Brown trout were fished by a fyke-net from the lower reach of River Olanga in the Russian territory between June and August in 2014. Analogously to lake samples, each caught brown trout was measured for its total length and mass, and a scale sample was taken and stored in a paper envelope for later genetic analysis. A total of 131 brown trout samples were included.

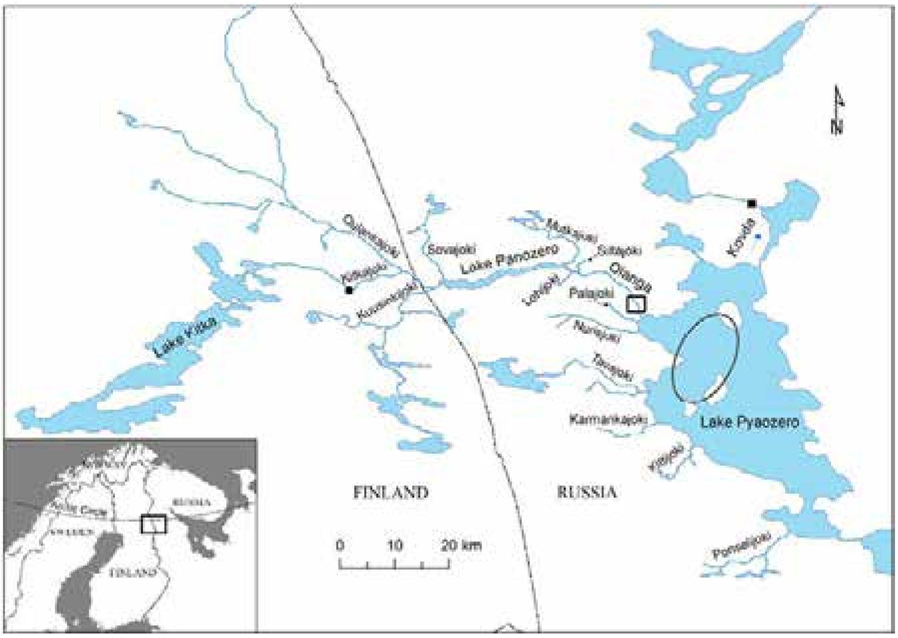

Figure 209. Map of the 13 baseline sample rivers in Lake Pyaozero Basin in Russia and Finland. Sampling areas of the brown trout mixed stock in Lake Pyaozero and in basal mainstem River Olanga are shown by an ellipse and a square, respectively. The Jyrävä Falls in River Kitkajoki (marked by a dot) form a complete natural migration barrier. The location of the hydropower plant in the outflowing River Kovda is indicated by a black square.

4.3.2 Laboratory methods

DNA was extracted from the scale samples and analyzed for variation at 16 microsatellite loci at the Natural Resources Institute Finland (Luke) using methods slightly modified by Tanhuanpää (2021) from the methods previously published for brown trout by Koljonen et al. (2014) and Koskiniemi (2020).

4.3.3 Genetic structure of brown trout populations

The results showed that there were three genetically distinct brown trout population groups with non-overlapping geographic locations: Western, Eastern, and Southern groups (Fig. 210). Among each of the groups, river-specific populations were also significantly differentiated from each other, thus showing high level of population genetic structuring, and further genetically independent river-specific management units. The Western group encompassed populations from the four rivers flowing into the western end of Lake Panozero (Fig. 210, see Fig. 209 for locations). The Southern group included the six rivers flowing directly into the Lake Pyaozero, together with river Siltajoki (Fig. 210). The brown trout stocks from the two relatively small rivers, Lohijoki, flowing to the basal mainstem river Olanga, and Mutkajoki, flowing to the eastern end of Lake Panozero, formed the Eastern group (Fig. 210). The Western and Southern groups were clearly genetically distinct from each other. The Eastern group with the rivers Mutkajoki and Lohijoki samples did not form as a distinct cluster as the Western and Southern groups did.

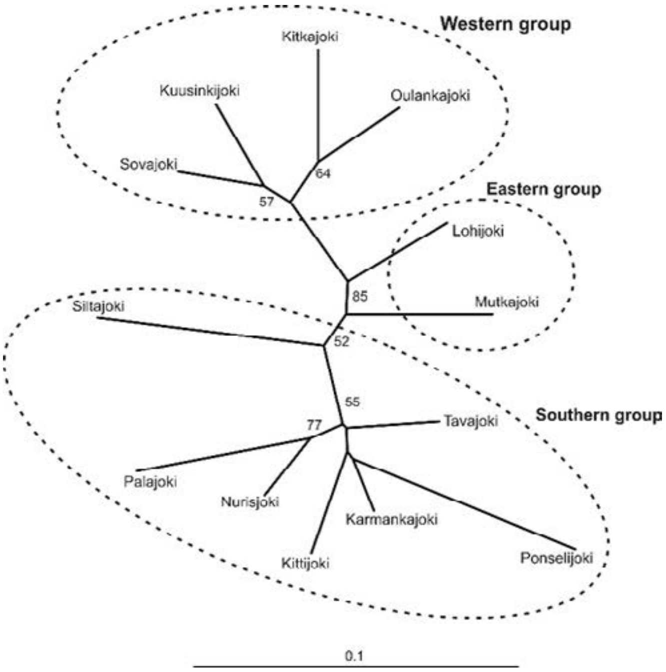

Figure 210. Unrooted dendrogram with genetic distances among the brown trout baseline river samples from the Lake Pyaozero Basin, with broadscale groups formed by them. The values next to each branch show the percentage of 1000 bootstrap replicates, where the branch is similar. For geographic locations of the rivers, see Fig. 209.

4.3.4 Stock composition of brown trout in Lake Pyaozero and the basal mainstem river Olanga

In general, the stock composition of brown trout in Lake Pyaozero was very similar between the temporal samples from 1995 and 2016 (Fig. 211) The proportion of the Southern group was slightly higher in 1995 (50.4%) than in 2016 (45.1%) (Fig. 211). The opposite was true for the Western group – its proportion was higher in 2016 (48.1%) than in 1995 (42.7%). The total proportion of brown trout originating from the Finnish rivers in the catches from the Lake Pyaozero was estimated at 39.7% in 1995 and at 43.1% in 2016. However, no statistically significant temporal shifts in the proportions of a river population or groups of populations in the mixed stock were detected.

In contrast to the Lake Pyaozero samples, the brown trout sampled in 2014 from the basal mainstem River Olanga (Fig. 209) by catching adult individuals on their spawning run belonged almost exclusively (95.4%) to the Western group, accompanied by a small proportion of Eastern group individuals that were most probably of river Mutkajoki population. In the catch from basal mainstem River Olanga, the total proportion of brown trout originating from Russian rivers was estimated at 11.9%, of which majority was contributed by river Sovajoki (8.2%) belonging to Western group.

As a conclusion, brown trout mixed stock in the Lake Pyaozero originated from two major population groups, (Western group (including 4 rivers) and Southern group (7 rivers)), with the third group (Eastern group (2 rivers)) contributing only a minor share to the mixed stock.

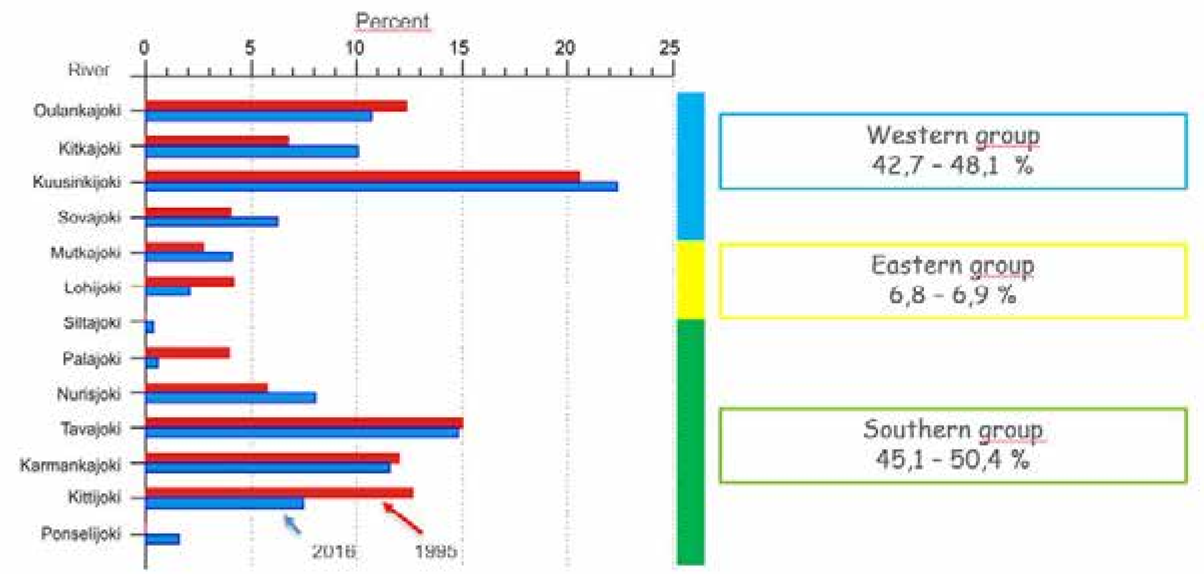

Figure 211. Brown trout river population proportions in the mixed-stock samples obtained from Lake Pyaozero in 1995 (N = 194, red) and in 2016 (N = 246, blue).). Estimates of river population proportions (%) are shown, with group-wise summaries on the right.

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5 Developing Conservation Methods

5.1 Captive breeding, case Lutto River

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5.1.1 Introduction

Lack of suitable host fish and/or degradation of pearl mussel habitats, mostly due to siltation and colmation of interstitial spaces which is detrimental for burrowing juvenile FPM, have resulted in a recruitment failure and declines of many pearl mussel populations (e.g., Geist & Auerswald 2007). Many FPM populations are over-aged and some of them expected to die, go to extinction, in near future. This has initiated artificial breeding programmes of FPM (Gum et al. 2011).

Lutto River in the northernmost Finland has a unique, salmon-dependent (Salonen et al. 2017) FPM population. Recruitment of new individuals of FPM in Lutto River has stopped for 60 years ago due to hydropower dam in lower reaches of the Tuloma River, Russia, which created a migration obstacle for Atlantic salmon, leaving the FPM of Lutto River without a suitable host fish. One of the aims in the SALMUS project was to assess and develop efficient practices for restoration of Atlantic salmon populations back to the upper reaches of the Tuloma River catchment. However, original plans to introduce Atlantic salmon individuals to Finnish Lutto river areas had to be abandoned after the occurrence of a devastating *Gyrodactylus salaris* parasite in the lower reaches of Tuloma river system. Thus, captive breeding of Lutto River FPM individuals was decided to be started in SALMUS project as a compensatory action to safeguard the existence of this valuable population.

5.1.2 Methods

Captive breeding of Lutto River FPM was accomplished at Konnevesi Research Station (Fig. 212), University of Jyväskylä. In early August 2020, 1-year old Atlantic salmon (n = 50) were purchased from Savon Taimen, Venekoski fish farm, and transported to Konnevesi Research station where they were kept in 163 L flow-through tanks supplied with water from Lake Konnevesi (Fig. 213).

5.1.2.1 Collection of glochidia and infection of fish

Between 3rd and 7th of September 2020, glochidia of Lutto River FPM were collected from a site 600 m below Luttojärvi (Fig. 214). Annual timing of glochidia release of FPM in Lutto River starts in turn of August-September (Salonen et al. 2017). Every second day, 30 adult FPM were collected and kept in buckets with river water for 30 min., after which the water was inspected for glochidia. Water temperature increased during that period from 8.5 to 10.0 °C. Glochidia collection was not successful. Therefore, 60 Lutto River FPM were collected and transported to Konnevesi Research Station on 7–8th of September 2020. Transportation was performed using Lutto River water in a 50-L bucket provided with cooling and aeration. It appeared that the mussels had released viable glochidia during the transportation, thus, salmon were infected with the released glochidia. Infection took place by reducing water volume in fish tank to 60 L, stopping water flow, adding aeration, and adding the glochidia suspension (Fig. 213). After 2 h exposure, water flow was turned on and water volume restored to 163 L. The fish were then maintained at the research station throughout the winter 2020–2021. Attached FPM glochidia in the gills of fish are shown in Figure 215.

5.1.2.2 Collection and maintenance of juvenile mussels

In June-July 2021, glochidia-infected salmon were moved to special collection tanks (Fig. 216) where the water temperature was increased to accelerate glochidia development and to trigger the excystment of juveniles from the gills of fish. By 5th of July 2021, ca. 6,000 Lutto River FPM juveniles were collected. The newborn juveniles were kept in 4 L plastic boxes and fed with a mixture of Nanno 3600 and Shellfish Diet 1500 algae products (Reed Mariculture, CA, USA, Fig. 217). On Monday, Wednesday and Friday, the juveniles from each box were sieved to a petri dish where dead and poor-condition or fungus-infected individuals were microscopically picked and removed (Fig. 218), and the water-food suspension was changed. By the end of August, the number of juveniles in culture boxes had decreased from ca. 6,000 to 3,500 due to fungal infections and due to the fact that the juveniles released in the beginning and in the end of the juvenile release period were not of good quality. It appeared that the highest proportion of the best quality, viable juveniles are produced during the peak release of juveniles from fish — in the middle of the release period.

5.1.2.3 Transplantation of cultured juvenile mussels into river

On 30 and 31st of August 2021, two thousand 2-month-old juveniles (Fig. 219) were transplanted back to Lutto River. One liter plastic boxes covered with 200 µm plastic mesh and metal protection net (Fig. 220) were filled with sieved gravel collected from the site (Fig. 221). Ten gravel boxes were filled with 200 FPM juveniles each. Boxes were fixed to the bottom river with metal poles (Fig. 220, Fig. 222). Five of the boxes were installed to the site from where the glochidia were collected a year earlier, the other five boxes one kilometer downstream. Transplantation sites were selected so that water was enough deep to prevent ice damage and so that adult mussels already occupied the sites (Fig. 220).

5.1.2.4 Monitoring of juveniles and maintenance of boxes

The net of the boxes was not changed (into a larger size) but the boxes and nets were cleaned from periphyton and possible accumulated debris twice – on 7th of October 2021 and 16th of June 2022. Five of the 10 gravel boxes were inspected for survival and growth of mussels on 2–4 August 2022, roughly after 11 months in river: four boxes from the downstream site and one box from the upstream site.

5.1.3 Results and discussion

Numbers of the FPM juveniles that were found alive were 164, 155, 135 and 92 individuals from the four downstream boxes, equaling, respectively, 82%, 78%, 68% and 46% of the 200 individuals originally placed in each box (Table 12). The highest rates of juveniles found alive, 82 and 78%, were observed in boxes number 1 and 2, which had intact net (Table 12). The lowest rates of juveniles found alive, 46 and 68%, were observed in boxes number 3 and 4, which had the net partly loosened (Table 12). Thus, we have a good reason to believe that the low "survival" rates in boxes 3 and 4 were contributed by escaped juveniles. Support for this is given by the proportion of juveniles found dead, which was actually lower (1.5 and 3%) in "low survival" boxes 3 and 4 than in the "high survival" boxes 1 and 2 (3 and 4.5%), although it should have been higher in the "low survival" boxes 3 and 4. The only box inspected from the upstream site, box number 5, had relatively low proportion of alive-found individuals, 49% (Table 12). Net of the box 5 was intact but the box was located in clearly shallower water than the other boxes, which may have contributed to the moderately low survival of FPM juveniles in this box. However, the data do not allow in depth comparison of the success of FPM juveniles in the upstream and downstream site.

Mean box-specific length of the 30 juveniles measured in early August 2022 varied from 1.72 to 2.2 mm, so that the average size over the five boxes was 1.91 mm. Thus, the mussels were ca. 2.5 times longer in early August 2022 that they were in the beginning (0.5 mm; late August 2021).

Survival rate and growth of juveniles could have been better with a more frequent cleaning and with changing a larger sized net enabling higher water flow and better feeding conditions in boxes. Also, the adhesion of net to the box must be secured in the future, as juveniles may have escaped due to the loosened net. Attachment of the boxes to the bottom was successful since all the 10 boxes themselves were found intact, even though one of the anchors keeping boxes from moving had disappeared.

This Lutto River captive breeding action was a fruitful test of the methodology, from glochidia collection to the transplantation of juveniles. It showed the potential of captive breeding in conservation of Lutto River FPM as there is no alternative way to save this valuable, unique FPM population from eventual extinction. Captive breeding of Lutto River FPM will continue in the new LIFE Revives project (2021–2027).

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Table 12. Survival and size of the 200 FPM juveniles kept for 11 months (from 30-31st of August 2021 to 2-4th of August 2022) in five gravel boxes in two sites (upstream – Up and downstream – Down) of Lutto River. Box number is given in column "N". *Mean length of juveniles in the beginning was 0.5 mm. **Lower water depth.

N	Site	Found alive	Found alive %	Found dead	Found dead %	Not found	Length (mm)*	Net
1	Down	164	82%	6	3%	30	1.93	intact
2	Down	155	78%	9	4.5%	36	2.2	intact
3	Down	135	68%	3	1.5%	62	1.72	loosen
4	Down	92	46%	6	3%	102	1.85	loosen
5	Up	98	49%	7	3.5%	95	1.83	intact**
Mean	-	-	**64%**	-	-	-	**1.91**	-

Figure 212. Konnevesi Research Station, University of Jyväskylä. Photo: Jouni Taskinen.

Figure 213. 163-L flow-through tanks where fish were kept and infected with FPM glochidia. Jouni Salonen adding glochidia suspension to fish tank (infection of salmon with glochidia of FPM of Lutto River). Photo: Jouni Taskinen.

Figure 214. Lutto River close to the lower transplantation site. Photo: Jouni Taskinen.

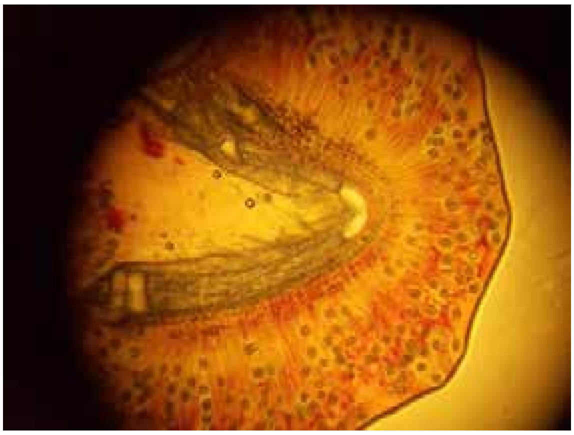

Figure 215. Attached, almost fully developed FPM glochidia (length 350–400 µm) in the gills of fish. Photo: Jouni Salonen.

Figure 216. Juvenile collection tanks, enabling emptying from bottom and sieving of out-flowing water for freshwater pearl mussel glochidia. Photo: Jouni Taskinen.

Figure 217. Nanno 3600 and Shellfish Diet 1800 algae products – feed of juvenile FPM. Photo: Jouni Taskinen.

Figure 218. Separation of dead, poor-condition and/or fungus-infected from viable FPM juveniles by research assistants. Photo: Jouni Taskinen.

Figure 219. Viable 2-month-old juveniles of Lutto River FPM, cultivated at Konnevesi research Station. Photo: Jouni Taskinen.

Figure 220. One-liter plastic box with large holes in the sides and lid covered with 200 µm plastic mesh to provide flow of fresh river water into the box. The box is kept in a metal protection net to protect the box against physical damage. Metal pole with associated fixing elements, which anchors the box to the bottom is on the right side of the box. Photo: Jouni Taskinen.

Figure 221. Transplantation box filled with gravel collected and sieved from the bottom of Lutto River. Photo: Jouni Taskinen.

Figure 222. Transplantation box (gravel box) installed on the bottom of Lutto River. Photo: Aune Veersalu.

5.2 Improvement of juvenile habitats

5.2.1 Sensitivity of juvenile freshwater pearl mussel to low oxygen

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5.2.1.1 Background

Siltation caused by fine sediment depositions is considered as one of the main reasons for juvenile FPM mortality (e.g., Lummer et al. 2016, Österling et al. 2008, 2010, Österling & Högberg 2014). Fine particles clog the top layer of the stream substrate obstructing water exchange between the free water body and the interstitial microhabitats of juvenile FPM (Munn & Meyer 1988, Ryan 1991, Wood & Armitage 1997). This results in low oxygen conditions within the interstitial which is presumably fatal to juvenile FPM (Buddensiek et al. 1993, Hastie et al. 2000, Geist & Auerswald 2007). The aim of the following studies was to investigate the effect of available dissolved oxygen to juvenile FPM viability and survival.

5.2.1.2 Methods

In April–June 2021 and January–March 2022 we conducted laboratory experiments, where we exposed < 1 year-old FPM individuals to a range of different oxygen concentrations for 10 days. The oxygen concentration levels were low (close to zero), medium and high (close to fully saturated). Dissolved oxygen was measured using PreSens Microx 4 Fiber Optic Oxygen Transmitter (PreSens, Regensburg, Germany) with either a compatible oxygen dipping probe or non-invasive oxygen sensor spots. The water used in these experiments was lake water from Lake Konnevesi, filtered using a FSPT-WBW 114304-MR self-cleaning filter (Filterit, Helsinki, Finland) to remove excess particulate matter and algae, and UV-radiated to disinfect (ULTRAAQUA MR6-350 SS 316 LUVT, Filterit). To obtain low and medium dissolved oxygen (DO) water, oxygen was removed from water by bubbling nitrogen gas through it until a desired oxygen level was reached. The water in the high dissolved oxygen treatment was naturally high in oxygen. Once the intended DO level was obtained water was poured to a measuring flask (25 ml flask, filled to the brim), a single juvenile was added to it with a pipette and the flask was sealed. Juveniles were moved to the flask directly from their culture conditions and were maintained in the flasks, without feeding, for up to 10 days.

Healthy juveniles are typically active and move within seconds or minutes after being placed on a petri dish. The viability (ability to continue living, grow and function successfully) of juveniles was determined by reference to foot movement or valve adduction, like in Bringolf et al. (2007). The visual inspection was done through the flask wall with a magnifying glass. Juveniles that did not display movement in a 10-minute observation period were taken out of the flask and inspected with microscope on a petri dish. If the juvenile did not move on the petri dish it was determined non-viable.

5.2.1.3 First hypoxia tolerance experiment (April–June 2021)

In high oxygen treatment flask-specific oxygen concentrations ranged between 8.8–6.2 mg L^{-1}, in medium 5.0–0.4 mg L^{-1} and in low 1.3–0.04 mg L^{-1}. The oxygen concentration tended to decrease towards the end of the experiment. The concentration decreased more ($t = 3.80$, $df = 28$, $p = 0.001$) in medium (mean decrease 2.0 mg L^{-1} S.E. = 0.11) oxygen treatments than in high (mean decrease 1.2 mg L^{-1} S.E. = 0.19). Water temperature was +19 °C throughout the experiment. Juveniles used in this experiment were 9–11 months old and originated from River Ähtävänjoki, Finland. There were 18 replicate units (flasks), one juvenile per replicate.

We found that juvenile FPM tolerated rather low oxygen conditions (medium O_2 concentration 5.0–0.4 mg L^{-1}) for up to 10 days. All juveniles exposed to near anoxic conditions were determined as non-viable within 10 days, while all mussels exposed to high (control) and medium concentration of oxygen were alive at the end of the 10-day experiment.

The manuscript based on this study "Effect of low dissolved oxygen on the viability of juvenile *Margaritifera margaritifera*: hypoxia tolerance ex situ" (Hyvärinen, H., Sjönberg, T., Marjomäki, T. & Taskinen, J.), was published in July 2022.

5.2.1.4 Second hypoxia tolerance experiment (January–March 2022)

The second hypoxia tolerance experiment was conducted using the methods described above in January–March 2022. Juveniles used in this experiment were 7–8 months old and originated from River Luttojoki, Finland. There were 15 replicate units (flasks), one juvenile per replicate. In the high oxygen treatment flask-specific oxygen concentrations ranged between 11.9–6.7 mg L^{-1}, in medium 5.8–2.1 mg L^{-1} and in low 1.4–0.02 mg L^{-1}. All oxygen treatments were conducted at +5, +10 and +17 °C.

Live vs. dead juveniles were separated by reference to foot movement and valve adduction. Mussels that were alive extended their foot immediately or quite quickly after being placed on a Petri dish. Dead juveniles had an immobile foot and did not retract it upon stimulation with a pipette head. Foot movement of juveniles with separated valves and retracted foot was inspected through the valve opening. Unmoving juveniles with closed or nearly closed valves and a retracted foot were inspected individually for a minimum of 40 minutes. After 40 minutes their valves were gently probed with a pipette head. If a juvenile was dead, its foot protruded outside the shell upon pressing and stayed still. As in this experiment juveniles were observed for a longer time and probed with a pipette head, we believe using survival instead of viability is a reasonable definition in this context.

All juveniles in high and medium oxygen concentrations at all three temperatures survived the 10-day experiments. 100% of juveniles died in the low oxygen treatment at 17 °C, while 80% of juveniles died in low oxygen at 5 °C and only 13% in low oxygen at 10 °C.

5.2.1.5 Conclusions

Poor oxygen conditions in the stream substrate resulting from sedimentation is considered one of the main reasons for the decline of FPM (e.g., Buddensiek et al. 1993, Hastie et al. 2000, Geist & Auerswald 2007, Österling & Högberg 2014). To our knowledge, our studies provide the first direct experimental evidence on the oxygen sensitivity of FPM juveniles and suggest that juvenile FPM cannot tolerate > 10-day events of very low dissolved oxygen at summer temperatures (≥ +17 °C). This finding highlights the importance of actions preventing low oxygen episodes in the substrate, such as substrate restoration and structural restoration (stones and wooden structures) of FPM streams. Our results also support the inclusion of dissolved oxygen to FPM monitoring programs, in accordance with the CEN (European Committee for Standardization) standard protocol for monitoring FPM (Boon et al. 2019).

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5.2.2 Importance of substrate size for burrowing of juvenile freshwater pearl mussel

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The manuscript based on this study "Hyvärinen, H., Saarinen-Valta, M., Mäenpää, E. & Taskinen, J. (2021). Effect of substrate particle size on burrowing of the juvenile freshwater pearl mussel *Margaritifera margaritifera*. Hydrobiologia 848(5): 1137–1146. <doi.org/10.1007/s10750- 021-04522-z>" was published in February 2021.

5.2.2.1 Background

FPM juveniles live burrowed in stream substrate for the first years of their life. Ability to burrow is essential for the survival of juvenile mussels – juveniles that do not burrow are more susceptible to predators and may be dislodged and washed away with the stream current. This could be fatal to juveniles but could also provide a chance to drift to a more suitable site. Decreased substrate permeability due to fine sediment loading is regarded as one of the main reasons for the decline of FPM (e.g., Geist & Auerswald 2007, Österling et al. 2010, Denic & Geist 2015) – stream beds that consist of coarse substrates with low quantities of fine sediment have been associated with good FPM recruitment (e.g., Buddensiek et al. 1993, Geist & Auerswald 2007, Österling & Högberg 2014). Thus, there is strong evidence for the negative dependence between the recruitment of juvenile FPM and fine sediment, but juvenile FPM burrowing behavior when exposed to substrates of varying particle size has not been studied. We set out to investigate the effect of substrate particle size on burrowing behavior of FPM juveniles that have been recently detached from the host fish. We aimed to determine how fast FPM juveniles burrow into substrates of varying sizes and do they remain burrowed or resurface once again.

5.2.2.2 Methods

Newly detached FPM juveniles, originating from River Haapuanoja, Finland, were placed in a 60 mm (diameter) x 15 mm (height) plastic dish with a 12 mm layer of sand and water of which 7 mm was sand. The sand was collected from Lake Jyväsjärvi, Finland and water from River Ähtävänjoki, Finland. The sand was washed and sorted into five sizes (< 120, 120–200, 200–250, 250–500 and 500–650 µm. Each treatment consisted of 10 replicate dishes, 10 juveniles per dish. Experiment was performed at +17–18 °C in 12 h dark:12 h light condition. After placing juveniles on the substrate, they were monitored under a dissection microscope. The juveniles that were visible (not burrowed) were counted at 0.5, 1, 2, 4, 72, and 96 h time points. At the end of the experiment juvenile survival was checked and there was only one dead individual.

5.2.2.3 Results and discussion

Most of the juveniles burrowed within the first 30 minutes of the experiment, such that the mean ± S.E. proportion of burrowed individuals over all replicates was 80.6 ± 2.4%, ranging from 65 ± 5.4% in the finest sand to 95 ± 5.4% in the coarsest sand (Fig. 223). The effect of substrate size on juvenile burrowing was statistically significant (RM-ANOVA, F4, 45 = 127.77, P \ 0.001). The highest mean (± S.E.) proportions of burrowed individuals over the 96-h experiment, 94.2 ± 1.2% and 98.0 ± 0.7%, were in the coarsest substrate size classes, 250–500 µm and 500–650 µm, respectively (Fig. 223).

We found that the proportion of burrowed juvenile FPM was dependent on the size of the available substrate. Although over 60% of juveniles were able to burrow into the finest substrate within the first 30 minutes a large proportion of these mussels resurfaced after a couple of hours. Sparks & Strayer (1998)

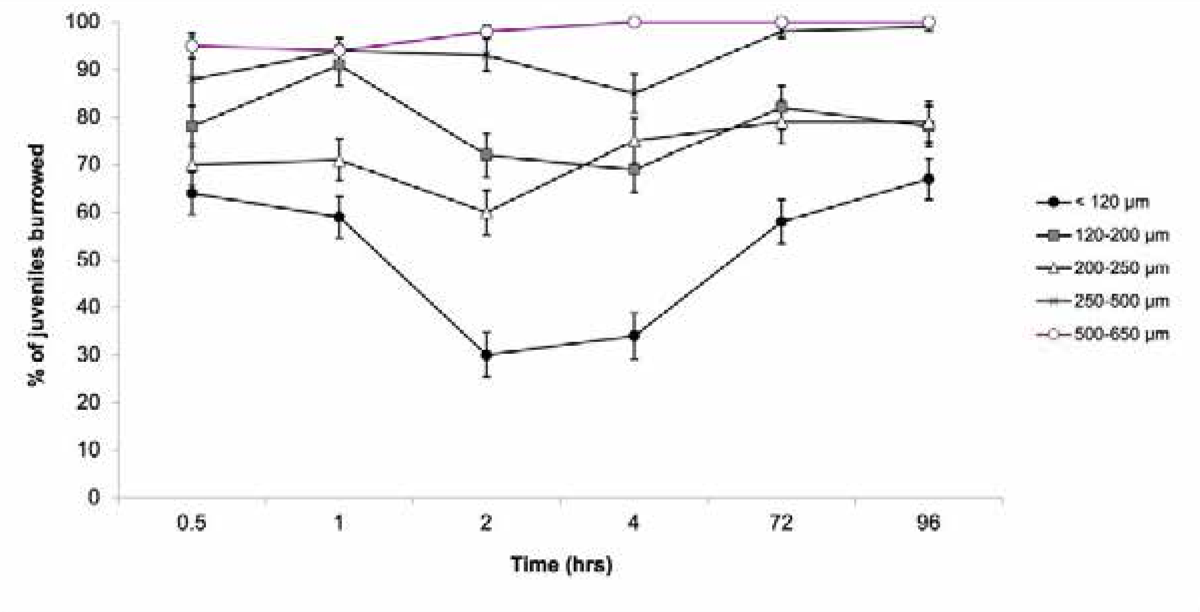

Fig. 223. Proportion (%) of burrowed juvenile FPM in five substrate sizes at six time points.

and Archambault et al. (2013, 2014) suggest that juveniles´ surfacing behaviour is a sign of stress, while Bíly et al. (2020) suggested that juveniles can avoid oxygen poor or otherwise unsuitable habitats by moving towards surface. Thus, the surfacing behaviour observed in the finest substrate may indicate that juveniles were more stressed in the finest sand than in the coarser sands of this study. This would suggest that juvenile FPM are, to certain extent, able to sense environmental cues and to avoid adverse conditions by surfacing at unsuitable sites.

Our results show that substrate particle size is a highly important indicator of FPM habitat quality. As burrowing is considered an essential feature of FPM behaviour, it was evident that in the range of tested particle sizes, the coarsest sand (500–650 µm) was the most suitable substrate for newly detached juveniles. In the coarsest sand 100% of juveniles were burrowed by four hours from the start of the experiment and juveniles did not surface once they had burrowed. This finding supports the view that stream substrate restoration is likely to be the most important conservation action for restoring FPM populations with poor or non-existent recruitment. As stream restoration is costly and time-intensive, captive-breeding may be the only way to conserve the most endangered populations until restoration has sufficiently improved the mussel habitat. The findings of this study help identifying sites with favorable substrate conditions where to introduce captive-bred individuals.

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5.3 e-DNA method

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5.3.1 Introduction

Aquascoping and diving are the traditional and common methods in use for detection of freshwater pearl mussel, *Magaritifera margaritifera*, populations in rivers and streams. These methods, however, are laborious and time consuming, and may also cause physical harm to sensitive mussels and their habitats. eDNA method was tested in this study to estimate whether it could be used as an alternative to detect *M. margaritifera* populations or as a confirmatory method aside of above-mentioned visual observation methods.

5.3.2 Materials and methods

5.3.2.1 Sampling

Three replicate one-litre water samples were collected to plastic bottles from 52 locations covering four water systems in Finland (Table 13) during September and October 2019. Each replicate water sample was sucked through a glass fibre filter (mesh size 0.7 µm, Ø2.5 cm) using battery-powered field pump, and the filters preserved in 2-ml tubes with 99% ethanol. Filter samples were stored in a freezer (−20 °C) in the laboratory before further analysis. All the field equipment and sampling ware were handled with bleach and rinsed carefully before and after sampling to avoid any DNA contamination.

5.3.2.2 eDNA extraction

The filters were dried on petri dishes at a room temperature (RT, 21−23 °C), and eDNA extracted with DNeasy Blood & Tissue Kit

(Qiagen) with some modifications to the protocol: filters were placed in 540 µl of ATL buffer and 60 µl of proteinase K and incubated at 56 °C overnight (o/n, about 17 hours). After this, 60 µl of RNase A (10 mg/ml) was added and suspension incubated for an hour at RT. Buffer AL was added at 600 µl volume, and after vortexing, the liquid part (about 600 µl) added to a new 1,5 ml tube. EtOH was added at 300 µl volume, and after vortexing, the extraction continued according to kit's protocol. eDNA was eluated from spin filters with 75 µl of AE buffer, and DNA concentration measured using either NanoDrop or Qubit.

5.3.2.3 PCR

Five primer pairs (Table 14) were tested for their specificity to mitochondrial DNA of *M. margaritifera*. Tissue DNA and eDNA from water of cultivation tank of *M. margaritifera* were used as positive controls. Similarly, Tissue DNA and eDNA from water of cultivation tank of *Anodonta anatina* and *Unio* sp. were used as negative controls. Based on PCR amplification efficiency, primer specificity and PCR product separation in agarose gel electrophoresis (AGE) primer pair MmarForfF1/MmarForfR1 was chosen for eDNA analysis from the water samples. Each PCR reaction contained 1 µM of both forward and reverse primer, 0.2 mM of dNTP mix (Thermo), 1x DreamTaq Green buffer (Thermo), 0.5 U of DreamTaq polymerase (Thermo) and PCR grade water (VWR) the reaction volume being 20 µl. eDNA was diluted to PCR grade water 1/2, 1/6, 1/10 and 1/20. One microlitre of undiluted eDNA and each dilution was use as template in PCR. Same positive and negative eDNA controls were used as in primer testing. For negative PCR control, reaction mix without the template was used. Reactions were run according to following PCR program: 95 °C for 3 min; 35 cycles of 94 °C for 1 min, 60 °C for1 min and 72 °C for 1 min; 72 °C for 7 min; stay at 15 °C. PCR product were run in AGE immediately or stored in a fridge (4 °C) until AGE.

5.3.2.4 Detection

Ten microlitres of PCR products and GeneRuler™ 1 kb Plus DNA Ladder (Thermo) were run in 0.8%, SYBR™ Safe DNA Gel Stain containing AGE for 45 min and visualized under UV light.

5.3.3 Results and discussion

Based on the field observation, *M. margaritifera* populations were found from eight locations studied (Table 13). Of these, PCR/AGE method could detect five populations. Of the three not detected populations, one was located 5 km upstream of the sampling point and two were non-viable. Of the 44 sites that were found to be free from *M. margaritifera* populations, PCR/AGE method detected one *M. margaritifera* eDNA positive site, and two sites gave an uncertain eDNA signal. That particular eDNA positive site (River Purkaoja, Table 13) appeared to host FPM as a later thorough on-site inspection revealed alive mussels from that site. Thus, eDNA method found mussels from this site although conventional investigation did not.

PCR/AGE method could detect five out of eight *M. margaritifera* populations on tested sites. The result that the three not detected populations were either non-viable or further (5 km) upstream of the sampling site indicate that the PCR/AGE method is suitable for robust and preliminary analysis of *M. margaritifera* eDNA. However, more sensitive qPCR or ddPCR methods could have given more accurate results. These methods were not used in this study, since totally *M. margaritifera* specific PCR primers were not available. Thus, PCR/AGE was chosen here for us to be able to detect false positive results more easily (i.e., unspecific binding of the primers) when visualizing the gels. The uncertain results (marked with question mark in Table

13), however, could have remained also in the qPCR and ddPCR.

In the future, PCR/AGE method presented here, can be used for basis in development of qPCR or ddPCR method for detecting *M. margaritifera* populations, and also for preliminary detection method of *M. margaritifera* eDNA.

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Table 13. Water sampling sites for eDNA extraction, and results of PCR/AGE analysis and field observation for *Margaritifera margaritifera* detection. AGE: agarose gel electrophoresis; + = *M. margaritifera* detected; - = *M. margaritifera* not detected; * = PCR/AGE result based on one water sample replicate; ˆ = results differ between PCR/AGE analysis and field observation; NK = not known; ? = result not clear, result uncertain.

Sampling site Main water system	Sampling site River	Coordinates Sampling site (WGS-84)	Sampling site Location tag	PCR and AGE Result I (+/-)	PCR and AGE Result II (+/-)	Field observation Result (+/-)	Field observation Note
Kemijoki	Sorsajoki	N 67.36985° E 029.37103°	SITE # 32	-		-	
Kemijoki	Rovakaltionoja	N 67.33463° E 029.35426°	SITE # 14	-		-	
Kemijoki	Majavaoja	N 67.28040° E 029.24337°	SITE # 15 *	-		-	
Kemijoki	Naruskajoki	N 67.27584° E 029.18316°	SITE # 16	-		-	
Kemijoki	Muotkaoja	N 67.30443° E 029.36330°	SITE # 29 *	-		-	
Kemijoki	Vasa-aavanoja	N 67.29038° E 029.44988°	SITE # 27	-		-	
Kemijoki	Ahvenoja	N 67.26807° E 029.45232°	SITE # 28	+		+	Viable?
Kemijoki	Kapujängänoja	N 67.29039° E 029.39872°	SITE # 26 *	-		-	
Kemijoki	Purkaoja ˆ	N 67.26099° E 029.34052°	SITE # 66 *	+	+	-	
Kemijoki	Saukko-oja	N 67.25614° E 029.36706°	SITE # 65	+		+	
Kemijoki	Sätsijoki	N 67.20600° E 029.30760°	SITE # 24	+		+	Viable, 1 km upstream
Kemijoki	Sätsijoki ˆ	N 67.19853° E 029.24544°	SITE # 18	-	-	+	Viable, 5 km upstream
NK	NK	NK	SITE # 23	-		NK	
Kemijoki	Tuohioja	N 66.99993° E 028.94134°	SITE # 20 *	-		-	
Kemijoki	Pyhäjoki	N 66.80788° E 028.71898°	SITE # 63	-		-	
Kemijoki	Ruuhijoki	N 66.75730° E 028.72610°	SITE # 60	-		-	
Kemijoki	Tammakkolamminoja ˆ	N 66.74118° E 028.78882°	SITE # 54	+	-	+	Non-viable
Kemijoki	Aatsinginjoki	N 66.78435° E 028.91351°	SITE # 51	-		-	

Sampling site Main water system	Sampling site River	Coordinates Sampling site (WGS-84)	Sampling site Location tag	PCR and AGE Result I (+/-)	PCR and AGE Result II (+/-)	Field observation Result (+/-)	Field observation Note
Kemijoki	Tuohilusikanoja	N 66.72934° E 028.83267°	SITE # 59	-		-	Shell parts
Kemijoki	Hangasjoki ˆ	N 66.74035° E 028.78280°	SITE # 55	?+	?+	-	
Kemijoki	Hangasjoki	N 66.75592° E 028.73443°	SITE # 62	+		+	Non-viable
Koutajoki	Tunturioja ˆ	N 66.74426° E 028.84138°	SITE # 81	?+	-	-	
Koutajoki	Hanhioja	N 66.74461° E 028.83889°	SITE # 82	-		-	
Koutajoki	Hanhioja	N 66.74194° E 028.84359°	SITE # 80	-		-	
Koutajoki	Possolinoja	N 66.67248° E 029.26854°	SITE # 78	-		-	
Koutajoki	Kutuoja	N 66.66453° E 029.29707°	SITE # 79	-		-	
Koutajoki	Ylikieskisenoja	N 66.56801° E 029.42139°	SITE # 72	-		-	
Koutajoki	Sorsaoja	N 66.55998° E 029.41405°	SITE # 73	-		-	
Koutajoki	Yli-Kieskisjoki	N 66.60842° E 029.30858°	SITE # 76	-		-	
Koutajoki	Nilijoki	N 66.57765° E 029.35194°	SITE # 75	-		-	
Koutajoki	Saarioja	N 66.55943°E 029.33613°	SITE # 74	-		-	
Koutajoki	Saarioja	N 66.55703°E 029.31302°	SITE # 77	-		-	
Oulujoki	Vieremänjoki	N 65.40326°E 029.56860°	SITE # 3	-		-	
Oulujoki	Venäjän Naavajoki	N 65.39834°E 029.66353°	SITE # 5	-		-	
Oulujoki	Matalajoki	N 65.01635°E 029.54380°	SITE # 107	-		-	
Oulujoki	Raatepuro	N 65.00648°E 029.33077°	SITE # 106	-		-	
Oulujoki	Purasjoki	N 64.82978°E 029.51609°	SITE # 110	-		-	
Oulujoki	Kapajoki/ Viianginjoki	N 64.76165°E 029.98361°	SITE # 103	-		-	
Oulujoki	Kauronjoki	N 64.27093°E 030.15042°	SITE # 98	-		-	
Oulujoki	Puhtaanpuro	N 64.28726°E 030.26367°	SITE # 99	-		-	
Oulujoki	Kesselinjoki	N 63.99114°E 030.09594°	SITE # 93	-		-	
Vienan Kemijoki	Ölkynoja	N 65.69887°E 029.63395°	SITE # 1	-		-	
Vienan Kemijoki	Tervajoki	N 65.69046°E 029.60882°	SITE # 2	-		-	
Vienan Kemijoki	Säynäjäjoki	N 65.95924°E 029.07733°	SITE # 42	-		-	
Vienan Kemijoki	Välijoki ˆ	N 65.99340°E 028.99981°	SITE # 34	-	-	+	Non-viable
Vienan Kemijoki	Meskusjoki ˆ	N 65.97599°E 029.07983°	SITE # 35	-	-	+	Non-viable
Vienan Kemijoki	Matkajoki	N 65.99834°E 029.11642°	SITE # 36	-		-	
Vienan Kemijoki	Rajapuro	N 66.02319°E 029.03803°	SITE # 38 *	-		-	
Vienan Kemijoki	Ylijoki	N 66.03061°E 029.03210°	SITE # 37	-		-	
Vienan Kemijoki	Kotijoki	N 66.05760°E 029.03352°	SITE # 39	-		-	
Vienan Kemijoki	Nissinjoki	N 66.02659°E 029.17867°	SITE # 41	-		-	
Vienan Kemijoki	Pulkkaoja	N 66.07241°E 029.06559°	SITE # 40	-		-	

Table 14. PCR primers tested for *Margaritifera margaritifera* eDNA detection. Results are based on visual observations of AGE. mt: mitochondrial; COI: cytochrome oxidase *c* subunit I; F-ORF: female open reading frame; +++: strong PCR amplification; ++: intermediate PCR amplification; +: weak PCR amplification; NT: not tested.

PCR primers Spesificity	PCR primers Target (gene)	PCR primers Name	PCR primers Sequence	PCR primers Direction	PCR primers Product length (bp)	PCR primers Reference	Result in this study *M. margaritifera* Tissue	Result in this study *M. margaritifera* eDNA	Result in this study *A. anatina* Tissue	Result in this study *A. anatina* eDNA	Result in this study *Unio* sp. Tissue	Result in this study *Unio* sp. eDNA
Universal	mt COI	LCO1490	5'-GGT CAA CAA ATC ATA AAG ATA TTG G-3'	for	658	Folmer et al. 1994	+++	+++	+++	+++	+++	+++
Universal	mt COI	COI-H	5'-TCA GGG TGA CCA AAA AAT CA-3'	rev	658	Machordom et al. 2003	+++	+++	+++	+++	+++	+++
M. margaritifera	mt COI	Mm-COI-for	5´-TTG TTG ATT CGT GCT GAG TTA GG-3'	for	86	Carlsson et al. 2017	++	+	+	NT	+	NT
M. margaritifera	mt COI	Mm-COI-rev	5'-CGA TGA GCC GTA ACA ATA ACA TGG-3'	rev	86	Carlsson et al. 2017	++	+	+	NT	+	NT
M. margaritifera	mt 16S	MarMa_16S2.1	5´-GCA ACA CGG AAA ACC CCT G-3'	for	about 331	Stoeckle et al. 2015	+++	NT	++	NT	++	NT
M. margaritifera	mt 16S	MarMa_16S1.2	5'-GGC TGC GCT CAT GTG GAA TTA-3'	rev	about 331	Stoeckle et al. 2015	+++	NT	++	NT	++	NT
M. margaritifera	mt 16S	MarMa_16S1.1	5'-CAA CCC TGG AAC CGC TAA AG-3'	for	about 165	Stoeckle et al. 2015	+++	NT	++	NT	++	NT
M. margaritifera	mt 16S	MarMa_16S1.2	5'-GGC TGC GCT CAT GTG GAA TTA-3'	rev	about 165	Stoeckle et al. 2015	+++	NT	++	NT	++	NT
M. margaritifera	mt F-ORF	MmarForfF1	5´-CAC CGA GCA TCT TTC AAC GC-3'	for	253	Välilä and Knott, unpublished	+++	++	+	-	+	-
M. margaritifera	mt F-ORF	MmarForfR1	5'-TCT GTG GAC GCT TTG CTC TT-3'	rev	253	Välilä and Knott, unpublished	+++	++	+	-	+	-

5.4 Shell-opening resistance – a measure of condition of individual mussels

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5.4.1 Introduction

There are various ways to evaluate the condition or status of Freshwater pearl mussel population, e.g., by studying the population size, age structure or density. However, there was no simple, non-destructive way to assess the condition of individual FPM, until Moorkens & Killeen (2018) described a method which was based on the shell opening resistance of mussels. The Shell Opening Resistance Method (SOR) utilizes the loss of adductor muscle tone as an indicator of stress.

In SALMUS project, we applied and tested the SOR (shell opening resistance) measurement to evaluate the condition and stress level of individual mussels via the strength of their adductor muscle — how strong was the resistance against a controlled attempt to open the shell of mussel.

5.4.2 Measurement of shell opening resistance (SOR)

Assessment of the condition of mussel is based on the resistance of shell opening and, in addition, to some degree, on the time it requires to close the valves when opened, as well as to the retraction of foot (Table 15).

A five-category scale is used to describe the response of the mussel, from 5 (good condition, unstressed) to 1 (moribund). The valves of an adult freshwater pearl mussel — from a field sample or from laboratory — are first tried to open by bare hands (fingers). If the shell can be opened by fingers, the mussel is weak (stressed, having low condition), belonging to SOR classes from 1 to 3.5, i.e., from moribund to quite poor condition (Table 15). If the mussel shell cannot be opened by fingers, it belongs to SOR class 4–5, i.e., from quite good to good condition. If the mussel shell cannot be opened by fingers, tongs (Figure 224) can be used to separate SOR classes from 4 to 5. SOR class 5 (unstressed, good condition) is usually so strong, and the valves are so tightly closed, that mussels cannot be opened even with tongs without extra force. Do not force-open such mussel.

If tongs cannot be quite easily inserted between valves, it should not be inserted by force. In addition, it is important not to open the shell with tongs for more than 3–4 mm to avoid damage to adductor muscles. It is possible to perform the SOR evaluation completely without tongs, but then the separation of SOR classes 4 and 5 is mainly not possible.

After the actual SOR measurement, place the mussel to a flat surface before returning to water in order to monitor the closing of valves, and the retraction of foot if the foot is out. In SOR class 5, the shell should close immediately, in class 4 in seconds, in class 3 in 1–2 minutes and in class 2 within 5 minutes approximately or do not close completely at all. After this the mussel can be returned to water. Moribund mussel does not close its valves and does not retract the foot.

5.4.3 Results and discussion

There was a considerable variation in the shell opening resistance scores of FPM individuals between rivers. In Figure 225, results of SOR measurements are given for FPM populations studied in 2020. In most of the populations, the median value was 5 (good condition, low stress). SOR score less than five was observed in River Myllyoja, River

Juomajoki, River Porontimajoki, River Mutajoki and in River Nuottijoki. A trend for lower SOR values (lower condition, higher stress) towards south was observed (Fig. 225).

Measurement of SOR was applied in SALMUS project when sampling FPM for genetic and isotope studies. The number of mussels measured per population was thirty (n = 30). The sampling was performed in pairs and inclusion of SOR measurement did not remarkably increase the time required for sampling. Even unexperienced investigator could perform the measurement according to guidelines above and by following the clas-

Table 15. Different Shell Opening Resistance (SOR) classes (1–5) and their definitions – to measure or evaluate the condition of individual mussel (modified from Moorkens & Killeen 2018).

Opening technique	SOR class	Definition
Can be opened with tongs	5 (unstressed = good condition)	Mussels have high resistance to opening with tongs and cannot be opened with fingers. Mussels are often so tightly closed that the tongs cannot be easily inserted. If the surveyor can open the shell, the valves close immediately after the pressure is removed.
Can be opened with tongs	4.5	Mussels have high resistance to opening with tongs and cannot be opened with fingers. Mussels are often so tightly closed that the tongs cannot be easily inserted. Valves close again relatively slowly (seconds).
Can be opened with tongs	4.5	Mussels show resistance to opening with either tongs or fingers. If the surveyor can open the shell, the valves close immediately after the pressure is removed.
Can be opened with tongs	4 (slightly stressed = quite good condition)	Mussels show resistance to opening with either tongs or fingers. Valves close again relatively slowly (seconds).
Can be opened with fingers/tongs	3.5	Mussels show resistance to opening with either tongs or fingers. Valves close over time (one minute or more).
Can be opened with fingers/tongs	3.5	Mussels show some resistance to opening but the surveyor could keep opening the shell easily with fingers. Valves close again relatively slowly (seconds).
Can be opened with fingers	3 (stressed = quite poor condition)	Mussels show some resistance to opening but the surveyor could keep opening the shell easily with fingers. Valves close over time (one minute or more).
Can be opened with fingers	2.5	Mussels show some resistance to opening but the surveyor could keep opening the shell easily with fingers. Valves may move back and forth, and they do not fully close in approximately 5 minutes.
Can be opened with fingers	2.5	Mussels show poor resistance to opening with fingers, very little pressure needs to be exerted. Valves close over time (one minute or more).
Can be opened with fingers	2 (very stressed = poor condition)	Mussels show poor resistance to opening with fingers, very little pressure needs to be exerted. Valves may move back and forth, and they do not fully close in approximately 5 minutes.
Can be opened with fingers	1.5 (extremely stressed)	Mussels may be gaping and show no/poor resistance to opening. The individuals can be defined as alive (some motion can be detected). Valves do not close fully, or it takes approximately over 5 minutes.
Can be opened with fingers	1 (moribund)	Mussels are gaping or show no resistance to opening, difficult to know if the individual is dead or alive.

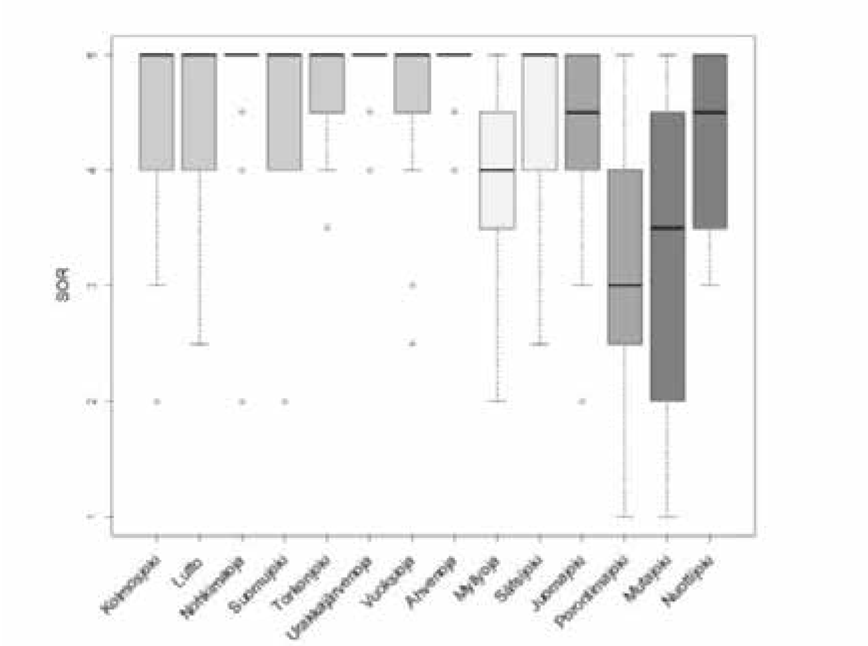

Figure 225. Box plot graph of shell opening resistance (SOR) results from year 2020. Thirty individuals were measured per population. Rivers are in latitudinal order from north (left) to south (right). For location of the rivers, see the map (Figure 229) in the chapter "Water quality parameters".

sification given in Table 15. Although we could not control possible confounding factors affecting the shell opening resistance among the populations, such as season or water temperature, a trend for decreasing SOR values (lower condition, higher stress) was observed in visual inspection of Fig. 225 results. This may hint that SOR can indicate a true condition/stress status of FPM and give useful information on FPM populations and individuals. In addition, very interesting results were obtained when shell opening resistance was studied against the genetic diversity of different FPM populations (see the chapter by Rautiainen below) — populations with very low genetic diversity exhibited low SOR scores. SOR measurements were also applied in the stable isotope study of SALMUS project (see the chapter by Nykänen and Hajisafarali below). Based on the promising experience gathered in SALMUS project, SOR measurement was included as a monitoring tool in the new LIFE Revives project (2021–2027).

References

Moorkens, E. A. & Killeen, I. J. 2018: Measurement and monitoring of sub-lethal damage (stress) to the freshwater pearl mussel *Margaritifera margaritifera*, a tool for conservation monitoring. – Tentacle 26, March 2018: 3–4.

Figure 224. Shell opening tongs specifically constructed to aid opening of the valves of *Margaritifera margaritifera* shell.

5.5 Age determination method and growth curves of FPM

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5.5.1 Introduction

Freshwater pearl mussel *Margaritifera margaritifera* (FPM) is widely distributed in Europe and is listed as one of the most endangered species. In most of the European countries many efforts are being done to rehabilitate the environmental conditions to recover the existing FPM populations. In order to achieve sustainable conservation of endangered species it is important to have scientific knowledge about the biology of these species. The shells of long-lived mussels can record the local environmental history and provide excellent archives of past climate, environmental conditions, and physiological changes. Mussels have impermeable shells with annual growth increments that maintain elements derived from the ambient water and their diets, making it possible to study paleoenvironmental changes and reconstruct environmental variables such as pH, temperature, salinity, and nutrient level.

In my PhD project as part of SALMUS ENI-CBC Kolarctic project I'm going to use the shells of FPM to track the environmental changes to see how these changes are linked to the mussel population. Age determination and annual growth estimation of FPM is necessary for finding out the link between the environment and the condition of the population. These also allow us to find a relationship between age and shell length of FPM to build the growth curves which provides an accurate age estimation by shell length measurement and better tool for environmental monitoring programs and conservation strategies. In addition, age estimation and growth curves provide a useful tool to monitor population dynamics to assess the recruitment.

5.5.2 Materials and methods

In the SALMUS project eighty-five specimens of FPMs were aged from 29 rives from Northern Finland. All the mussels were collected alive during summer between 2019–2021. Each shell was measured for length, width, and height. To determine the age of the mussels, thin section was made from one of the shell halves. One valve of each specimen was cut from umbo to the ventral margin (i.e., perpendicularly to the winter lines) and ~3-mm thick sections were made from the valve with a high-speed saw. The thin sections were mounted on glass slides and ground with grinding paper and then polished with 1 and 0.25 µm diamond paste. All the thin sections were cleaned in ultrasonic bath with 95% ethanol and air-dried. The polished specimens were immersed in Mutvei's solution to increase the visibility of the winter line, boost the accuracy of age estimation and to resolve inter- and intra-annual growth pattern in prismatic layer for 30 min. at 40 °C. Immediately after coloring the thin sections, they were rinsed with demineralized water and air-dried. The growth pattern of samples was viewed under reflective light microscope equipped with camera. Annual growth increments were measured as the shortest distance vertically to the winter lines in the prismatic layer, near to the border line to the nacreous layer. The growth curve was established based on shell length and age of the mussels.

5.5.3 Results and discussion

The shell length of all the 89 mussels examined in this study ranged between 25.8 and 140 mm and age (annual growth increments) between 10 and 254 years (Table 16). The relationship between age and shell length of mussels showed that the most of individuals were scattered between normal and low growth curve (Fig. 226). The results of age determination indicated that Vuoksioja had the youngest individuals (from the set with age determination) whereas Lovttajohka with an individual older than 250 had the oldest ones. The growth curves for these two populations are shown in Figures 227 and 228.

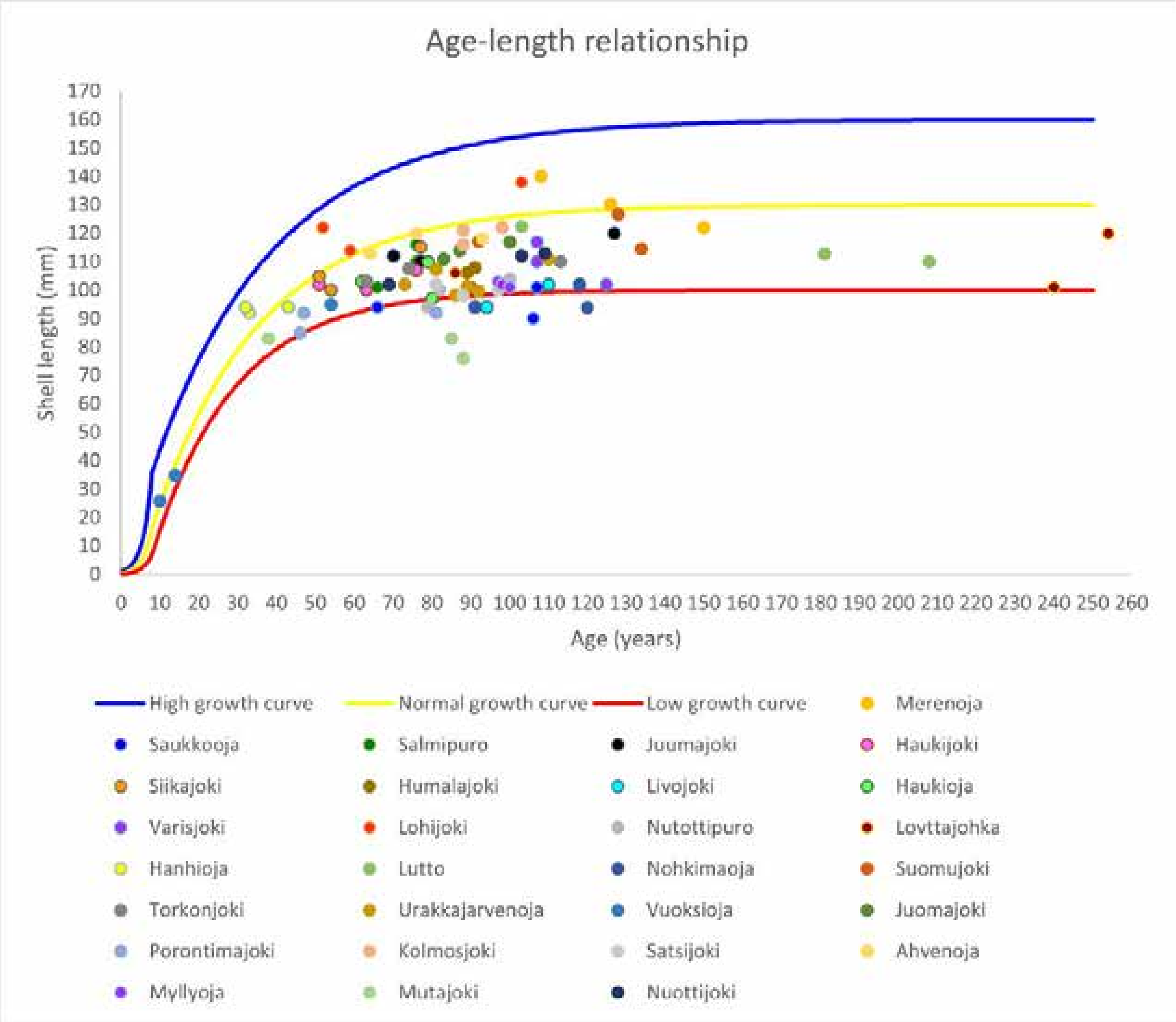

Figure 226. General growth curve that approximates the high, normal, and low shell growth in relation to the age of mussels in different populations. For location of the rivers, see the map (Fig. 227) in the chapter "Water quality parameters".

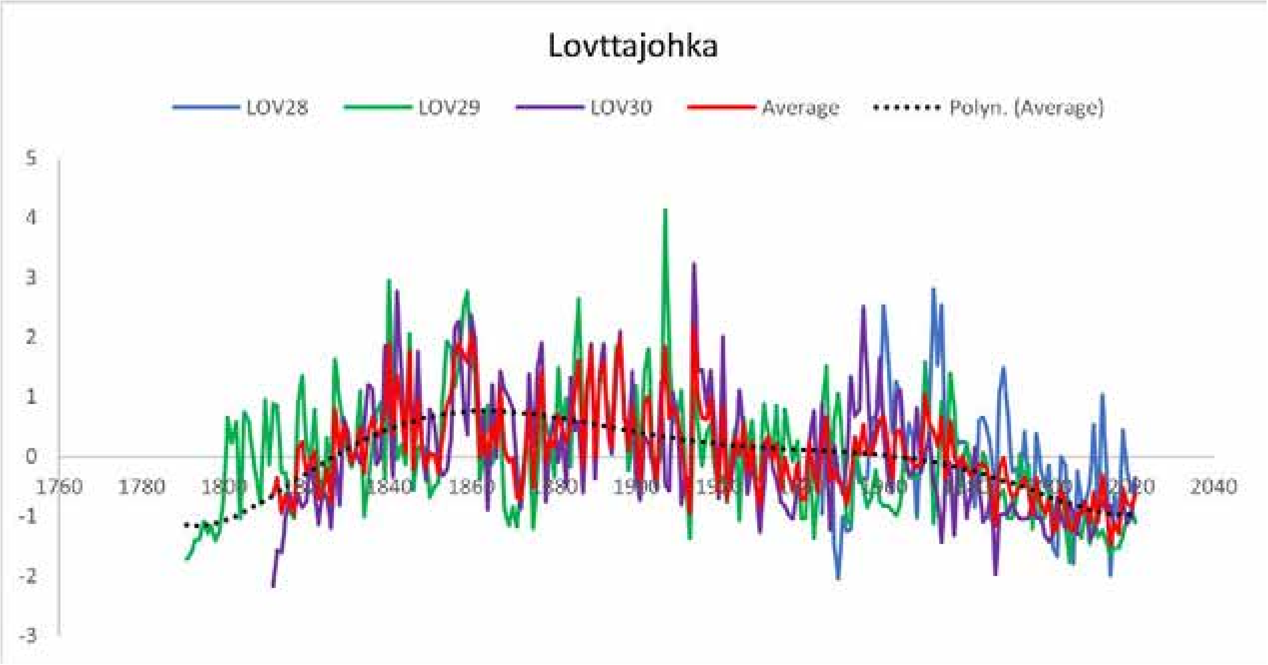

Figure 227. Growth curve of 3 individuals from Lovttajohka (population with the oldest age-determined individual) and the mean of growth rate for all shells.

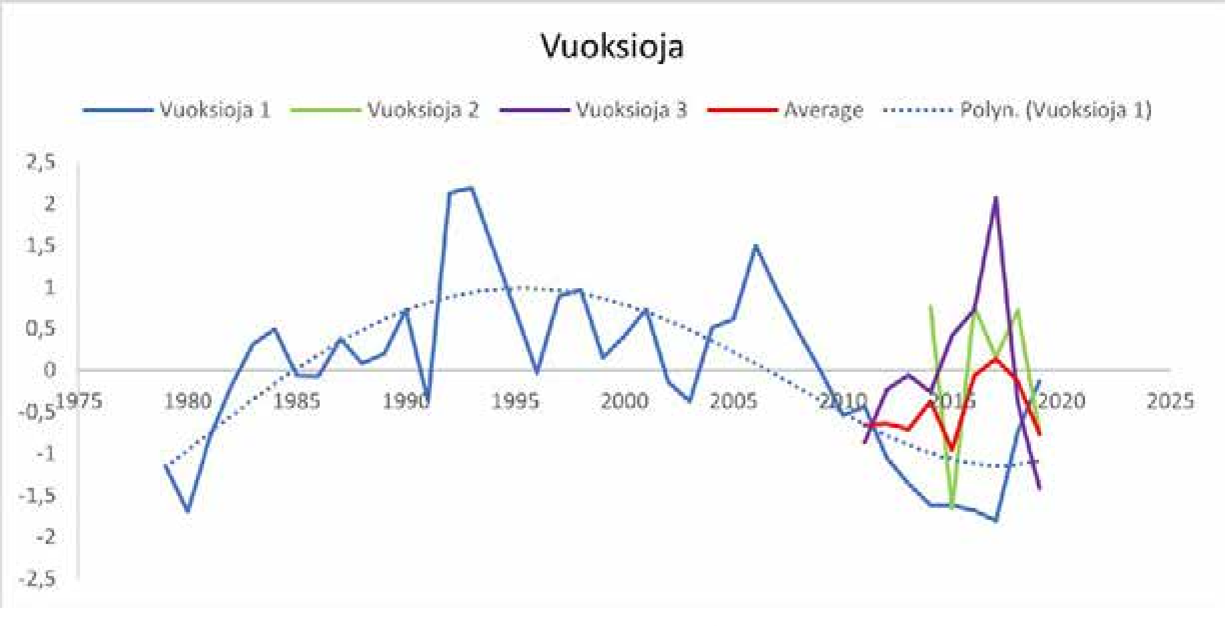

Figure 228. Growth curve of 3 individuals from Vuoksioja (population with the youngest age-determined individual) and the mean of growth rate for all shells.

Table 16. Shell length, age, number of counted growth rings in the studied section, length of eroded area in studied section and estimated number of growth rings in the eroded section of all mussels collected from different rivers from 2019 to 2021. For location of the rivers, see the map (Figure 231) in the chapter "Water quality parameters".

Collection date	River	Mussel number	Age (years)	Counted rings on section (years)	Shell length (mm)	Estimated Age of erosion (years)	Erosion length (mm)
25.9.2019	Lutto	1	208	189	110	19	53
25.9.2019	Lutto	2	103	87	122.4	16	44
25.9.2019	Lutto	3	181	163	112.8	18	51
18.9.2019	Nohkimaoja	1	91	79	94	12	24
18.9.2019	Nohkimaoja	2	118	105	101.9	13	29
18.9.2019	Nohkimaoja	3	120	107	93.8	13	29
3.9.2019	Suomujoki	1	134	115	114.5	19	53
3.9.2019	Suomujoki	2	92	74	117.1	18	49
3.9.2019	Suomujoki	3	128	110	126.7	18	49
18.9.2019	Torkonjoki	1	113	100	110	13	32
18.9.2019	Torkonjoki	2	63	51	103.2	12	28
18.9.2019	Torkonjoki	3	74	61	107.6	13	32
2.9.2019	Urakkajärvenoja	1	92	83	99.6	9	18
2.9.2019	Urakkajärvenoja	2	81	72	107.3	9	16
2.9.2019	Urakkajärvenoja	3	89	79	101.3	10	21
2.9.2019	Urakkajärvenoja	4	110	96	111	14	31
2.9.2019	Urakkajärvenoja	5	86	73	98.2	13	33
2.9.2019	Urakkajärvenoja	6	73	59	102	14	28
4.9.2019	Vuoksioja	1	54	41	95	13	33
4.9.2019	Vuoksioja	2	10	6	25.8	4	4.4
4.9.2019	Vuoksioja	3	14	9	34.8	5	7.9
10.6.2020	Juomajoki	3	100	84	117	16	43
10.6.2020	Juomajoki	9	87	73	114	14	38
10.6.2020	Juomajoki	15	83	69	111	14	36
13.6.2020	Porontimajoki	8	81	58	92	23	64
13.6.2020	Porontimajoki	13	47	33	92	14	38
13.6.2020	Porontimajoki	16	46	31	85	15	39
16.8.2020	Kolmosjoki	1	98	86	122	12	28
16.8.2020	Kolmosjoki	2	88	76	121	12	31
16.8.2020	Kolmosjoki	23	88	76	116	12	31
18.9.2020	Sätsijoki	1	88	73	98	15	34
18.9.2020	Sätsijoki	9	81	64	102	17	42
18.9.2020	Sätsijoki	13	97	79	100	18	45
19.9.2020	Ahvenoja	1	64	49	113	15	41
19.9.2020	Ahvenoja	2	76	60	120	16	44
19.9.2020	Ahvenoja	4	93	73	118	20	55
20.9.2020	Myllyoja	7	97	80	103	17	42
20.9.2020	Myllyoja	11	98	61	102	17	42
20.9.2020	Myllyoja	20	100	83	101	17	42
22.9.2020	Mutajoki	8	85	69	83	16	37
22.9.2020	Mutajoki	14	38	27	83	11	18
22.9.2020	Mutajoki	22	88	72	76	16	37
23.9.2020	Nuottijoki	1	109	97	113	12	30
23.9.2020	Nuottijoki	2	69	59	102	10	21
23.9.2020	Nuottijoki	3	103	91	112	12	31

Collection date	River	Mussel number	Age (years)	Counted rings on section (years)	Shell length (mm)	Estimated Age of erosion (years)	Erosion length (mm)
23.9.2020	Nuottijoki	dead	57	47	-	10	22
23.9.2020	Nuottijoki	E1	55	42	-	13	35
23.9.2020	Nuottijoki	E2	47	36	-	11	25
23.9.2020	Nuottijoki	E3	51	40	-	11	24
23.9.2020	Nuottijoki	E4	48	36	-	12	29
5.8.2021	Merenoja	18	150	97	122	53	107
5.8.2021	Merenoja	21	126	81	130	45	100
5.8.2021	Merenoja	27	108	91	140	17	67
6.8.2021	Saukko-oja	13	106	86	90	20	48
6.8.2021	Saukko-oja	21	66	47	94	19	44
6.8.2021	Saukko-oja	22	107	87	101	20	48
7.8.2021	Salmipuro	1	76	58	116	18	51
7.8.2021	Salmipuro	9	76	61	110	15	40
7.8.2021	Salmipuro	12	66	50	101	16	44
8.8.2021	Juumajoki	22	127	93	120	34	85
8.8.2021	Juumajoki	26	70	53	112	17	47
8.8.2021	Juumajoki	30	77	59	110	18	51
17.8.2021	Haukijoki	14	76	66	107	10	23
17.8.2021	Haukijoki	22	51	41	102	10	25
17.8.2021	Haukijoki	23	63	53	100	10	23
17.8.2021	Siikajoki	28	77	64	115	13	34
17.8.2021	Siikajoki	29	54	44	100	10	26
17.8.2021	Siikajoki	30	51	41	105	10	24
28.8.2021	Hanhioja	23	48	33	92	15	43
28.8.2021	Hanhioja	22	40	32	94	8	37
28.8.2021	Hanhioja	25	58	43	94	15	40
28.8.2021	Kivijoki	24	125	110	98	15	41
28.8.2021	Kivijoki	26	121	103	98	18	42
28.8.2021	Kivijoki	27	83	69	97	14	29
8.9.2021	Humalajoki	26	91	82	108	9	41
8.9.2021	Humalajoki	27	90	75	101	15	33
8.9.2021	Humalajoki	28	89	73	106	16	35
9.9.2021	Livojoki	1	94	77	94	17	38
9.9.2021	Livojoki	2	110	94	102	16	36
9.9.2021	Haukioja	28	62	47	103	15	40
9.9.2021	Haukioja	29	80	63	97	17	38
9.9.2021	Haukioja	30	79	63	110	16	45
11.9.2021	Varisjoki	25	107	94	110	13	35
11.9.2021	Varisjoki	26	125	109	102	16	36
11.9.2021	Varisjoki	29	107	92	117	15	41
11.9.2021	Lohijoki	28	59	49	114	10	25
11.9.2021	Lohijoki	29	52	45	122	7	25
11.9.2021	Lohijoki	30	103	91	138	12	33
13.9.2021	Nuottipuro	28	79	60	94	19	45
13.9.2021	Nuottipuro	29	82	64	100	18	42
13.9.2021	Nuottipuro	30	100	81	104	19	44
30.9.2021	Lovttajohka	28	86	77	106	9	21
30.9.2021	Lovttajohka	29	254	231	120	23	64
30.9.2021	Lovttajohka	30	240	210	101	30	67

6 Genetics

6.1 Genetic structure and diversity of freshwater pearl mussel populations

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6.1.1 Introduction

Freshwater pearl mussel *Margaritifera margaritifera* is considered as one of the most endangered freshwater mussels of the world (Machordom et al. 2003). During the last hundred years, *M. margaritifera* populations have declined significantly in its original distribution range (Young & Williams 1983, Bauer 1986, Lopes-Lima et al. 2017). The 1955 Conservation Act protected *M. margaritifera* from pearl fishing in Finland, but the habitat destruction remained as a threat. River clearings for timber floating, hydropower plant construction, eutrophication and pollution of the rivers and forestry operations such as ditching of forest and peat lands are threats to *M. margaritifera* in Finland (Oulasvirta et al. 2017).

Maintenance of genetic diversity is one of the key factors in the success of conservation programs (McNeely et al. 1990, Frankham et al. 2002). To protect and manage freshwater pearl mussel populations as well as possible, their genetic background must be known (Geist & Kuehn 2005, Geist 2010). Declining genetic diversity is linked to lower survival of populations in changing conditions, e.g., environmental changes caused by climate warming or other factors. Thus, low genetic diversity increases the risk of extinction (Frankham et al. 2002). Populations with high genetic diversity are targeted for conservation efforts, as these populations might contain unique alleles that are not present in other populations. On the other hand, populations having unique alleles, even though their diversity might be low, are also important as they may represent the only population having that particular allele.

Population genetic analyses provide information about past migration routes and present gene flows between populations, thus helping to recognize populations that suffer from inbreeding or have been near extinction (bottleneck effect). The knowledge of genetic structure and differentiation of *M. margaritifera* populations is important for example for planning the planting efforts of juvenile mussels, to increase genetic diversity or prevent inbreeding. Also, re-introduction of mussels from genetically incompatible sources breaking the locally developed genetic adaptations could be avoided by having sufficient information about the genetic structure of populations.

Focusing conservation efforts on populations with high genetic diversity and/or unique alleles is more advantageous than conserving several populations with low genetic diversity. In addition, if significant financial resources must be used to rehabilitate and conserve habitats, it would be more efficient to allocate conservation resources to specific populations that contain a significant proportion of the genetic diversity of *M. margaritifera*.

6.1.2 Materials and methods

6.1.2.1 Sampling of mussels and measuring of Shell opening resistance (SOR)

Samples were collected from 27 rivers in years 2020–2021 (Table 17). From each river, 30 mussels were collected and an appr. 3x3 mm tissue piece was cut from the edge of mantle. Length, height, and width were measured from each mussel. Physical condition of the mussels was estimated using a shell opening resistance (SOR) measure in which the condition of the mussels is estimated by the ability of the mussel to resist an attempt to open (carefully) its shell (max. 4 mm wide). A five-point scale is used to evaluate the stress level (Moorkens & Killeen 2018). These measurements are not harmful to the mussels. After sampling, mussels were returned alive to the spot from where they were collected.

Table 17. Sampled (tissue samples and SOR measures) rivers in 2020-2021. For location of the rivers, see the map (Figure 231) in the chapter "Water quality parameters".

River	Drainage basin	River ID
Torkojoki	Tuloma	TOR20
Nohkimaoja	Tuloma	NOH20
Kolmosjoki	Tuloma	KOL20
Vuoksioja	Tuloma	VUO20
Urakkajärvenoja	Tuloma	URA20
Luttojoki	Tuloma	LUT20
Suomujoki	Tuloma	SUO20
Sätsioja	Kemijoki	SAT20
Ahvenoja	Kemijoki	AHV20
Myllyoja	Kemijoki	MYL20
Mutajoki	Oulujoki	MUT20
Nuottijoki	Oulujoki	NUO20
Saukko-oja	Kemijoki	SAU21
Juumajoki	Koutajoki	JUU21
Salmipuro	Koutajoki	SAL21
Merenoja	Koutajoki	MER21
Haukijoki	Kemijoki	HAU21
Siikajoki	Kemijoki	SII21
Kivijoki	Tuloma	KIV21
Humalajoki	Oulujoki	HUM21
Haukioja	Iijoki	HAUK21
Nuottipuro	Iijoki	NUOT21
Varisjoki	Oulujoki	VAR21
Lohijoki	Iijoki	LOH21
Lovttajohka	Teno	LOV21
Hanhioja	Tuloma	HAN21

6.1.2.2 DNA extraction and molecular genetics methods

Tissue samples were stored in 2 ml tubes in absolute ethanol in -20 °C. DNA was extracted using commercial DNA extraction kit (Qiagen DNeasy Blood & Tissue Kit). Part of the mitochondrial cytochrome oxidase subunit I (*COI*) gene was used as a genetic marker. The *COI* fragments (appr. 650 bp) were amplified by polymerase chain reaction (PCR) using the following primers: 5'-GGTCAACAAATCATAAAGATATTGG-3' and 5'-TCAGGGTGACCAAAAAATCA-3' (Folmer et al. 1994, Machordom et al. 2003). The PCR master mix in total volume of 20.0 µl contained the following components: 2 µM of each primer, 0.2 mM of each dNTP, 10x DreamTaq buffer (includes 20 mM MgCl2) (Thermo Scientific), DreamTaq DNA polymerase (Thermo Scientific) 0.5 U.

PCR was carried out using a S1000 Thermal Cycler (Bio-Rad) under the following conditions: 94 °C (3 min), 34 cycles with denaturation at 94 °C (30 s), annealing at 50 °C (1 min), extension at 72°C (1 min) and a final extension at 72 °C (7 min)

PCR amplifications were verified using agarose gel electrophoresis on 0,75% agarose gel stained with SYBR Safe (Invitrogen). PCR products were purified using EXO-SAP method.

Sequencing PCR was carried out by using BigDye Terminator v3.1 cycle sequencing kit (Applied Biosystems) following the manufacturer's instructions. Purified sequencing reactions were sequenced using ABI PRISM 3130xl analyser.

6.1.2.3 Mitochondrial DNA sequences and haplotypes

The raw *COI* sequence data was edited and aligned with Sequencing Analysis Software 6 (Applied Biosystems) and BioEdit Sequence Alignment Editor. Multiple alignments were done using MEGA11 (Molecular Evolution and Genetic Analysis). Haplotype networks were obtained using R statistical software ((R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/). Additional genetic diversity indices were calculated in DnaSP version 6.12.03. The data is from two different datasets. The first one includes 9 populations and 12 haplotypes. Due to sequencing errors, the second dataset includes only 10 haplotypes from 16 rivers.

6.1.3 Results

A haplotype represents DNA variations which are inherited together, since there is no recombination between them. 10 haplotypes from 15 rivers were discovered (Fig. 229). Variable nucleotide positions are shown in Table 20. The highest haplotype diversity was discovered in Kolmosjoki (5 different HT), Lutto (6) and Nohkimaoja (5) (Table 18). Additional genetic diversity parameters are

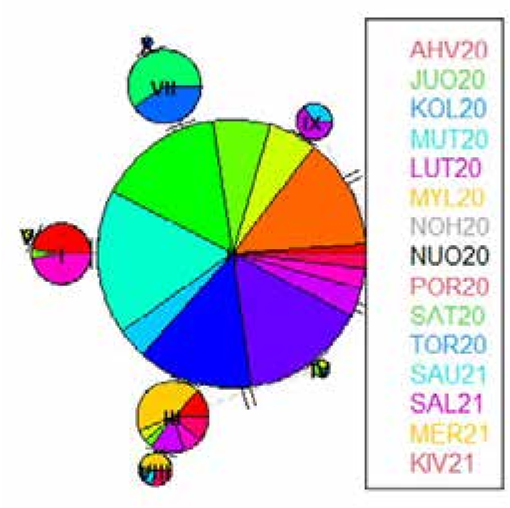

Fig 229. Haplotype network of 15 populations (rivers) and 10 haplotypes (the second dataset). Each circle represents one haplotype and coloured sections are individuals possessing that haplotype. HT2 is the most frequent haplotype.

Table 18. Haplotype frequencies (tot. ind./HT) and haplotype diversities for each river (tot. HT/pop.) (the second dataset).

River (ID)	HT1	HT2	HT3	HT4	HT5	HT6	HT7	HT8	HT9	HT10	Tot. HT/pop.
Ahvenoja (AHV20)	18	2	6	0	0	0	0	0	0	0	3
Juomajoki (JUO20)	0	23	0	0	0	0	0	0	0	0	1
Kolmosjoki(KOL20)	0	10	2	4	5	1	0	0	0	0	5
Luttojoki (LUT20)	2	12	2	4	1	0	0	1	0	0	6
Myllyoja (MYL20)	0	30	0	0	0	0	0	0	0	0	1
Nohkimaoja(NOH20)	0	6	0	2	0	1	0	4	8	0	5
Nuottijoki(NUO20)	0	0	0	0	0	0	19	0	0	8	3
Porontimajoki(POR20)	0	24	0	0	0	0	0	0	0	0	1
Sätsioja (SAT20)	0	6	7	0	0	0	0	0	15	0	3
Torkojoki(TOR20)	0	3	5	0	0	11	0	6	0	0	5
Saukko-oja (SAU21)	18	4	4	0	0	0	0	0	0	0	3
Salmipuro (SAL21)	0	26	0	0	0	0	0	0	0	0	1
Merenoja (MER21)	0	26	0	0	0	0	0	0	0	0	1
Kivijoki (KIV21)	0	0	20	0	0	0	0	10	0	0	2
Mutajoki (MUT20)	0	0	0	0	0	0	28	0	0	0	1
Tot. ind./HT	**38**	**172**	**46**	**10**	**6**	**13**	**47**	**21**	**23**	**8**	**-**

presented in Table 19, where is presented the first data set including 11 rivers and 12 haplotypes. Lowest haplotype frequencies were discovered in Juomajoki, Porontimajoki and Salmipuro. According to this, it seems that the genetic diversity is higher in populations of northern Lapland compared to southern ones in Kuusamo and Kainuu regions.

A positive correlation was found between number of haplotypes per population (haplotype diversity) and the mean SOR value in each population (Fig. 230: Spearman correlation coefficient 0.73, p = 0.02). The lowest mean SOR scores were observed in Rivers Porontimajoki, Mutajoki, Myllyoja, Nuottijoki and Juomajoki.

Table 19. Genetic diversity indices in 11 rivers (containing 12 haplotypes, the first dataset) N = number of individuals, H = number of haplotypes, h = haplotype diversity, π = average number of nucleotide differences, θW = degree of polymorphism.

River/population	N	H	h (S.D)	π (S.D)	θW (S.D)
Ahvenoja	26	3	0.480 (0.094)	0.00198 (0.00036)	0.00124 (0.00078)
Juomajoki	23	2	0.474 (0.067)	0.00075 (0.00011)	0.00043 (0.00043)
Kolmosjoki	22	6	0.823 (0.044)	0.00337 (0.00039)	0.00303 (0.00147)
Mutajoki	28	1	0.000 (0.000)	0.00000 (0.00000)	0.00000 (0.00000)
Lutto	22	8	0.810 (0.070)	0.00277 (0.00048)	0.00303 (0.00147)
Myllyoja	30	1	0.000 (0.000)	0.00000 (0.00000)	0.00000 (0.00000)
Nohkimaoja	21	6	0.805 (0.059)	0.00264 (0.00031)	0.00263 (0.00134)
Nuottijoki	27	2	0.433 (0.075)	0.00068 (0.00012)	0.00041 (0.00041)
Porontimajoki	24	1	0.000 (0.000)	0.00000 (0.00000)	0.00000 (0.00000)
Sätsioja	28	3	0.627 (0.061)	0.00143 (0.00015)	0.00081 (0.00060)
Torkojoki	25	4	0.723 (0.055)	0.00222 (0.00018)	0.00125 (0.00079)

Table 20. Variable nucleotide positions (VNP) in 10 haplotypes (the second dataset).

HT	No. of rivers	N (ind.)	VNP 34	VNP 82	VNP 110	VNP 190	VNP 205	VNP 244	VNP 347	VNP 370	VNP 397	VNP 511	VNP 571	VNP 583
HT1	3	38	C	A	T	C	C	T	T	T	T	A	T	A
HT2	12	170	C	A	T	C	C	T	T	T	T	A	T	A
HT3	6	26	C	G	T	C	C	T	T	T	T	A	T	A
HT4	3	10	C	A	T	C	C	T	T	T	T	A	T	A
HT5	2	6	C	A	T	C	C	T	T	T	T	G	T	A
HT6	3	13	C	A	T	C	C	T	C	T	C	A	C	A
HT7	0	47	C	A	C	C	C	T	T	T	T	A	T	A
HT8	5	58	T	A	T	C	C	A	T	C	T	A	T	A
HT9	2	23	T	G	T	C	C	T	T	T	T	A	T	A
HT10	1	8	C	A	T	C	C	T	T	T	T	G	T	A

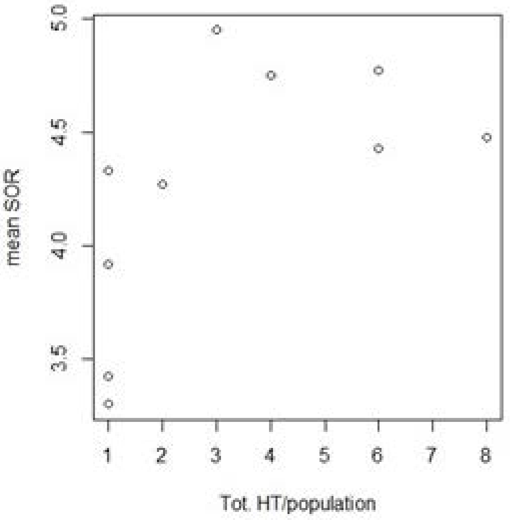

Figure 230. The positive correlation (Spearman correlation coefficient 0.73, p = 0.02) of mean SOR values and haplotype diversity.

6.1.4 Conclusions

The main trend of genetic diversity did not really differ between the datasets. The most genetically diverse populations seem to be in northern Finland, also highest SOR results are measured from northern Finland. A positive correlation was observed between number of haplotypes (haplotype richness) and SOR measurements, indicating that there is a possible connection between the condition of the mussels and genetic diversity. The highest haplotype richness and SOR results were met in rivers Lutto, Kolmosjoki and Nohkimaoja, all these rivers located in Tuloma river basin. Based on this, it would be recommended to value these populations for the future conservation acts. The rarest haplotypes were HT7 and HT10. Haplotype HT7 was found only from rivers Nuottijoki and Mutajoki in Oulujoki river basin. Haplotype HT10 was found only from Nuottijoki. Further studies about population structure and migration routes/barriers are needed to obtain a more comprehensive picture of the state of freshwater pearl mussel populations in northern Finland.

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7 Environmental Conditions

7.1 Water quality parameters

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7.1.1 Introduction

Water quality can affect the freshwater pearl mussel. For example, in Sweden, the study by population viability of FPM was affected by total phosphorus concentration and turbidity, so that nutrient-rich and turbid water had fewer populations with recruitment (Degerman et al. 2013). In another Swedish study, recruitment of FPM was negatively related to watercolor and turbidity (Österling & Högberg 2014). Therefore, the basic water quality parameters including chlorophyll-a, total suspended solids (TSS), DOC-concentration, total nitrogen (TN), dissolved oxygen concentration, pH, conductivity and total phosphorous (TP) were measured to see if these factors can affect the condition of populations.

7.1.2 Materials and methods

Water samples from each river were collected while sampling the mussel population. Map of sampling sites is given in Figure 231. All the water samples were collected from lake outlet (located upstream), from the river itself upstream where the mussels were collected and from a ditch nearby. One to two rivers were sampled per day. Temperature and dissolved oxygen were measured on site by submerging pre-calibrated Pro ODO optical handheld sensor (YSI Inc. / Xylem Inc., Yellow Springs, OH/USA) into surface water. Water sample for pH and conductivity was collected by submerging a 100 ml grinding-stopper glass bottle into water and filled to top with no air. Water samples for Chl-a and TSS (raw water), DOC and TN (pre-filtered in field with 100 µm sieve) were collected into 5-liter pre-rinsed canisters. A vial pre-filled with 500 µl of 4 mol/l sulfuric acid for TP sample was filled with 50 ml of sample water. Samples were kept in cool and dark prior to analysis/ further treatment at onsite accommodation. Samples for isotopes carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$) and hydrogen ($\delta^{2}H$) were collected simultaneously with water sampling.

Conductivity and pH were measured in room temperature with conductivity (Radiometer CDM2e, Copenhagen, Denmark) and pH (pH Meter 744, Metrohm, Herisau, Switzerland) meters. Conductivity of the sample is a product of electrical conductivity and flask media and was corrected for temperature (SFS-EN 27888).

Chl-a samples (up to 2 liters) were filtered with GF/C filters and stored in a freezer upon further analysis. Chl-a was measured spectrophotometrically after hot ethanol extraction (SFS-5772). TSS samples (up to 2 liters) were filtered with pre-burned GF/C filters and stored in a freezer upon further analysis (SFS-872). TP was analyzed spectrophotometrically (SFS–EN ISO 6878). DOC and TN were analyzed from raw water with Shimadzu TOC-V CSN Total Organic Carbon Analyzer (Kyoto, Japan) by taking 20 ml of the sample and filtering it with 0.45 µm CA syringe filter. Laboratory work was conducted at University of Jyväskylä.

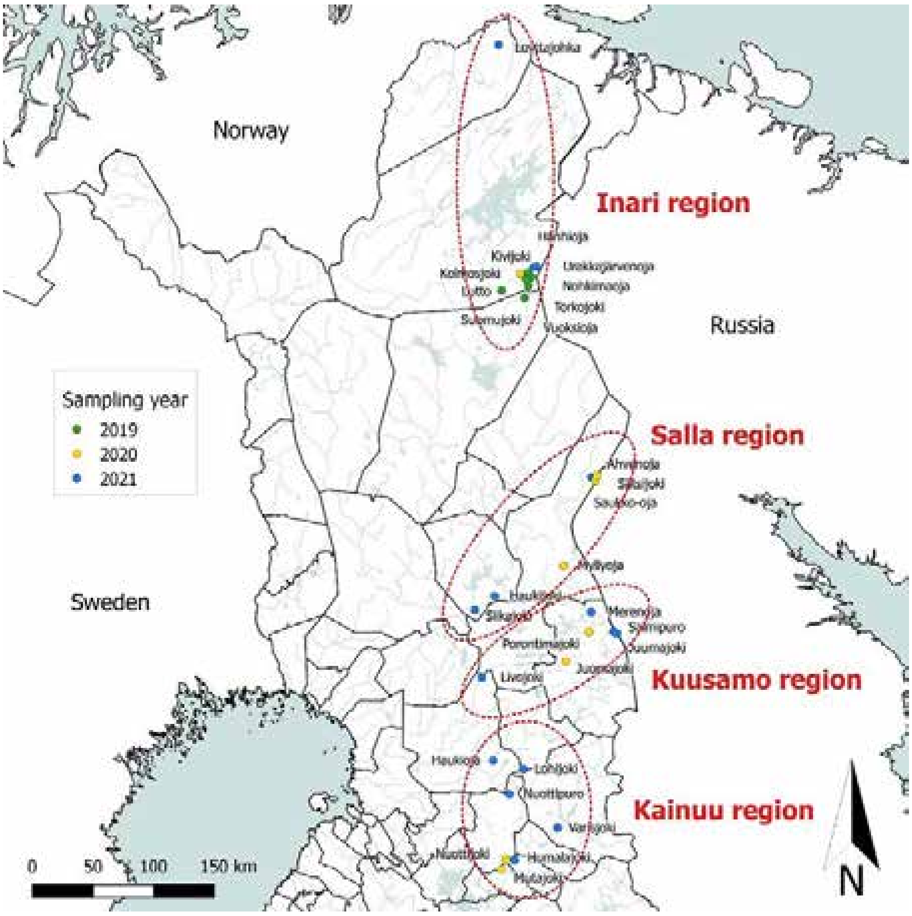

Figure 231. The red dashed circles indicate the study regions North Lapland ("Inari region"), South Lapland ("Salla region"), Kuusamo–North Otrobothnia ("Kuusamo region") and South/Kainuu ("Kainuu region"). Study regions do not necessarily follow province or catchment borders. The points indicate the location of the study rivers, and the color the sampling year (green = 2019, yellow = 2020, blue = 2021). Background map credits: Finnish administrative borders and waterways by National Land Survey of Finland (2020), International administrative borders by EuroGeographics (2020).

7.1.3 Results and discussion

The results of water quality parameters from the rivers are presented in Table 21 and most interesting environmental variables (Chl-a, TSS, DOC and TN) are shown in Figures 232–235.

Chlorophyll-a measures the amount of photosynthesizing cells in water. The results of Chl-a demonstrated decreasing trend towards north (except for Kuusamo–North Ostrobothnia region), as well as higher values in lakes above the FPM site than in the respective FPM rivers (Fig. 232), although the differences were not statistically analyzed. The higher Chl-a values of more southern rivers were expected, as in general the productivity of waters increase towards south.

Total Suspended Solids (TSS) represents the portion of fine particulate matter that remains in suspension in water and provides an actual weight of particulate matter for a given volume of water (usually mg/l). The highest TSS was observed in Kuusamo-North Ostrobothnia region (Fig. 233). The results of TSS showed the lowest values in the north, indicating the clearer water in the northern Lapland. There was no clear difference in TSS from the FPM river and respective lake above (Fig. 233).

The results for Dissolved Organic Carbon, DOC, indicated decreasing trend from south to north, signaling the less brown (less humic) waters in the north (Fig. 234). In addition, mussel sites in rivers showed higher value as compared to the respective lakes except for Salla area (southern Lapland) (Fig. 234).

Total nitrogen (TN) exhibited higher values in the two southern regions than in the two norther regions, corresponding with the results for Chl-a (Figs 232 and 235). There was no consistent difference in nitrogen concentration of water collected from the FPM river and from the respective lake above (Fig. 235).

Table 21. Water quality parameters from different rivers where the mussels were collected. Boxplot graphs of the values for different regions are given in Figures 234–237. For location of the rivers, see Figure 231.

North Lapland	Chl-a (µg/l)	TSS	DOC (mg/l)	TN (mg/l)	Do%	O2 mg/L	pH	Conductivity (µs/cm)	TP
Utsjoki Lovttajohka	1.13	1.56	1.54	0.09	101.5	12.70	7.64	41	0.01
Ivalo Kolmosjoki	1.56	1.42	1.97	0.06	97	9.25	7.35	24.5	0.09
Ivalo Lutto	0.86	1.40	1.70	0.05	102.7	9.96	6.59	25.5	0.02
Ivalo Nohkimaoja	0.90	0.90	8.06	0.17	98.3	10.42	7	33	0.04
Ivalo Suomujoki	0.56	0.57	0.71	0.04	109.7	10.02	6.86	25	0.04
Ivalo Torkojoki	0.58	0.83	4.06	0.23	99.8	10.34	7.27	33.5	0.03
Ivalo Urakkajärvenoja	1.71	1.07	3.34	0.11	101.3	9.91	7.34	28	0.02
Ivalo Vuoksioja	2.31	1.48	2.38	0.07	107	9.62	6.8	17	0.04
Ivalo Hanhioja	0.67	1.12	2.16	0.09	100.2	10.45	6.84	27	0.01
Ivalo Kivijoki	0.28	0.22	1.45	0.05	101.8	11.70	7.08	46	0.02

South Lapland	Chl-a (µg/l)	TSS	DOC (mg/l)	TN (mg/l)	Do%	O2 mg/L	pH	Conductivity (µs/cm)	TP
Salla Ahvenoja	2.01	0.55	3.10	0.08	98.5	11.97	6.98	30	0.05
Salla Myllyoja	1.18	1.49	3.12	0.06	95.8	11.99	7.31	50	0.03
Salla Sätsijoki	2.30	1.12	4.15	0.11	92.8	11.20	6.99	25	0.04
Salla Saukko-oja	10.79	5.90	2.33	0.11	99.6	10.57	6.61	24	0.08
Kemijärvi Haukijoki	0.38	2.12	2.42	0.17	98.8	9.91	6.17	15	0.10
Kemijärvi Siikajoki	0.91	1.84	2.44	0.09	97.7	9.79	6.39	16	0.02

Kuusamo–N.Ostrobothnia	Chl-a (µg/l)	TSS	DOC (mg/l)	TN (mg/l)	Do%	O2 mg/L	pH	Conductivity (µs/cm)	TP
Kuusamo Juomajoki	9.97	2.43	6.51	0.19	99	10.35	7.19	36	0.09
Kuusamo Porontimajoki	2.73	0.90	2.94	0.11	103.4	10.57	7.31	41.5	0.03
Kuusamo Juumajoki	3.45	4.11	3.19	0.11	99.7	9.85	7.47	62	0.03
Kuusamo Merenoja	1.24	0.82	3.41	0.14	89.9	9.26	6.76	65	0.02
Kuusamo Meskusjoki	4.14	1.83	4.75	0.21	99.3	9.70	7.16	24.5	0.05
Kuusamo Salmipuro	0.77	1.00	2.72	0.09	99.1	9.50	7.67	70	0.02

South/Kainuu	Chl-a (µg/l)	TSS	DOC (mg/l)	TN (mg/l)	Do%	O2 mg/L	pH	Conductivity (µs/cm)	TP
Kainuu Humalajoki	1.50	1.52	5.93	0.17	97.6	10.70	6.98	34	0.04
Kainuu Mutajoki	2.24	1.19	2.94	0.10	95.9	11.67	7.17	50	0.04
Kainuu Nuottijoki	3.21	1.53	5.17	0.13	89.2	10.75	6.76	37.5	0.05
Kainuu Nuottipuro	1.35	1.85	4.09	0.12	90.5	10.30	6.86	52.5	0.03
Kainuu Varisjoki	2.40	1.39	4.24	0.15	97.9	11.06	6.42	24.5	0.04
Taivalkoski Lohijoki	2.54	1.07	4.03	0.12	97.5	11.49	6.78	33	0.03
Pudasjärvi Livojoki	2.98	1.23	3.69	0.09	91.9	10.51	6.86	23	0.04

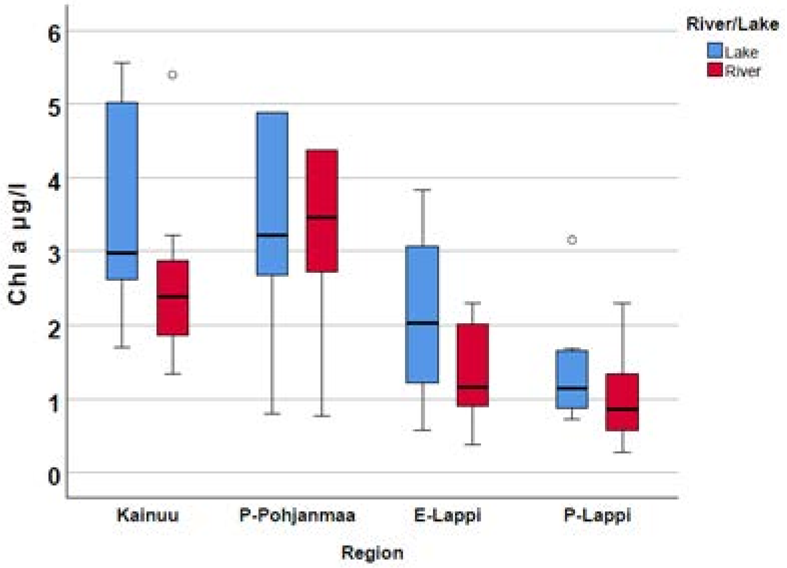

Figure 232. Boxplot of chlorophyll-a content of water from different geographic areas – South/Kainuu ("Kainuu"), Kuusamo–North Ostrobothnia ("P-Pohjanmaa"), South Lapland ("E-Lappi", "Salla region") and North Lapland ("P-Lappi", "Inari region") – for FPM rivers (right, red box) and for the lakes above the FPM sites (left, blue box). For the rivers belonging to each of the regions, see Figure 231 and Table 21.

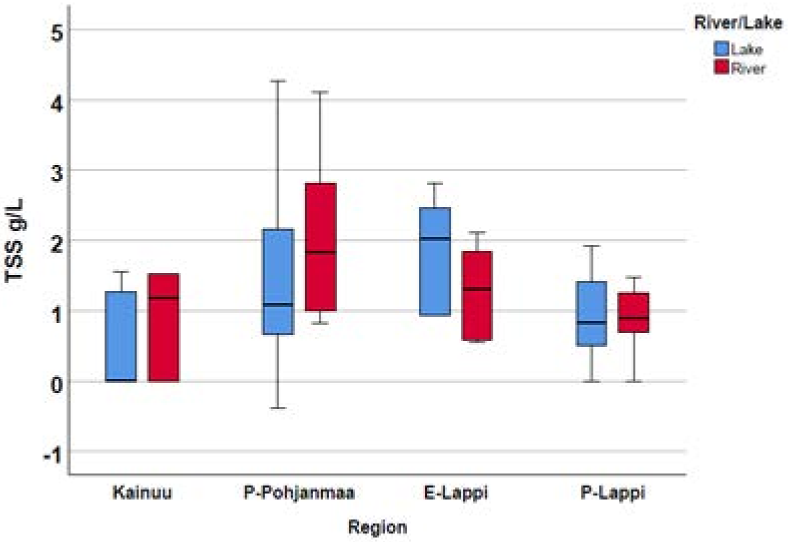

Figure 233. Boxplot of total suspended solids (TSS) of water from different geographic areas areas – South/Kainuu ("Kainuu"), Kuusamo–North Ostrobothnia ("P-Pohjanmaa"), South Lapland ("E-Lappi", "Salla region") and North Lapland ("P-Lappi", "Inari region") – for FPM rivers (right, red box) and for the lakes above the FPM sites (left, blue box). For the rivers belonging to each of the regions, see Figure 231 and Table 21.

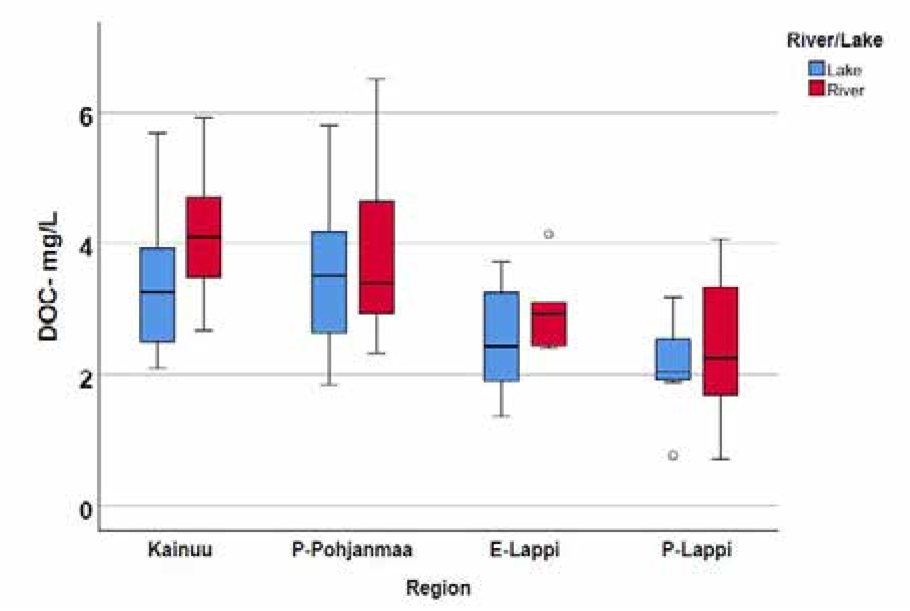

Figure 234. Boxplot of the dissolved organic carbon (DOC) of water from different geographic areas areas – South/Kainuu ("Kainuu"), Kuusamo–North Ostrobothnia ("P-Pohjanmaa"), South Lapland ("E-Lappi", "Salla region") and North Lapland ("P-Lappi", "Inari region") – for FPM rivers (right, red box) and for the lakes above the FPM sites (left, blue box). For the rivers belonging to each of the regions, see Figure 231 and Table 21.

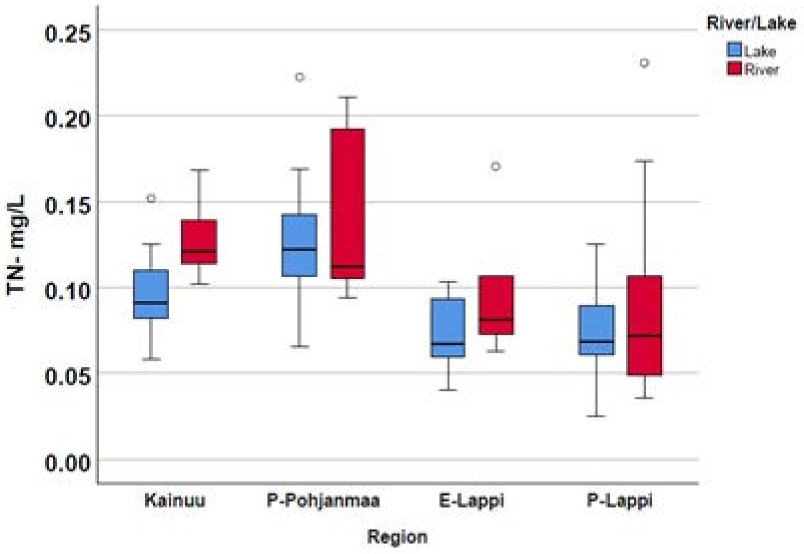

Figure 235. Boxplot of total nitrogen content (TN) of water from different geographic areas areas – South/Kainuu ("Kainuu"), Kuusamo–North Ostrobothnia ("P-Pohjanmaa"), South Lapland ("E-Lappi", "Salla region") and North Lapland ("P-Lappi", "Inari region") – for FPM rivers (right, red box) and for the lakes above the FPM sites (left, blue box). For the rivers belonging to each of the regions, see Figure 231 and Table 21.

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7.2 Elemental compositions in FPM's foot tissue and river water

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7.2.1 Introduction

Metals and other elements are introduced into aquatic ecosystems in many ways. Aquatic organisms such as fish and mussels may accumulate many of them, posing a potential risk to individual organisms. Metal mining, industrial wastes and catchment modification can pollute aquatic environments with heavy metals (Gumgum et al. 1994, Turkmen & Ciminli 2007). There is great concern over heavy metal discharges to the aquatic environment because of their toxicity and accumulative nature (Cevik et al. 2008). Various elements can be accumulated in mussels as filter-feeders, which make them bioindicators of heavy metal pollution (Cevik et al. 2008). In their soft tissues, mussels accumulate a variety of contaminants (Cevik et al. 2008). Biological systems depend on metals such as iron, copper, zinc, and manganese, whereas mercury, lead, and cadmium are toxic, even in trace amounts, so they are not considered essential metals (Cevik et al. 2008). Nevertheless, essential metals can also cause toxic effects if excessive amounts are consumed (Matta et al. 1999).

7.2.2 Materials and methods

The data including water and mussel samples was collected in 2020 and 2021 from 23 rivers located in 4 geographical regions Kainuu, Kuusamo, Salla and Inari. Water samples were filtered (Whatman filter paper no 41) and acidified with high-purity nitric acid prior to analysis. 20–200 mg of tissue samples were digested in 1.0 ml of nitric acid ≥ 65%, and 0.5 ml of hydrogen peroxide > 30% in 50 ml polypropylene centrifuge tubes. The samples were put in water bath (at 60 °C for 5–15 min) to ease the digestion of samples. The samples were diluted prior to analysis using high-purity water. Concentration of 28 elements in water and mussel's tissue (foot) were analyzed using ICP-OES (Inductively coupled plasma-optical emission spectrometry) and ICP-MS (Inductively coupled plasma-mass spectrometry). ICP-OES was used for determining Mg, Na, and K, and ICP-MS for Ag, Al, As, Ba, Be, Bi, Cd, Co, Cr, Cs, Cu, Fe, Ga, In, Li, Mn, Ni, Pb, Rb, Se, Sr, Tl, U, V, and Zn. Note that the 2019 samples from Inari region were not analyzed for elements because they were stored in ethanol.

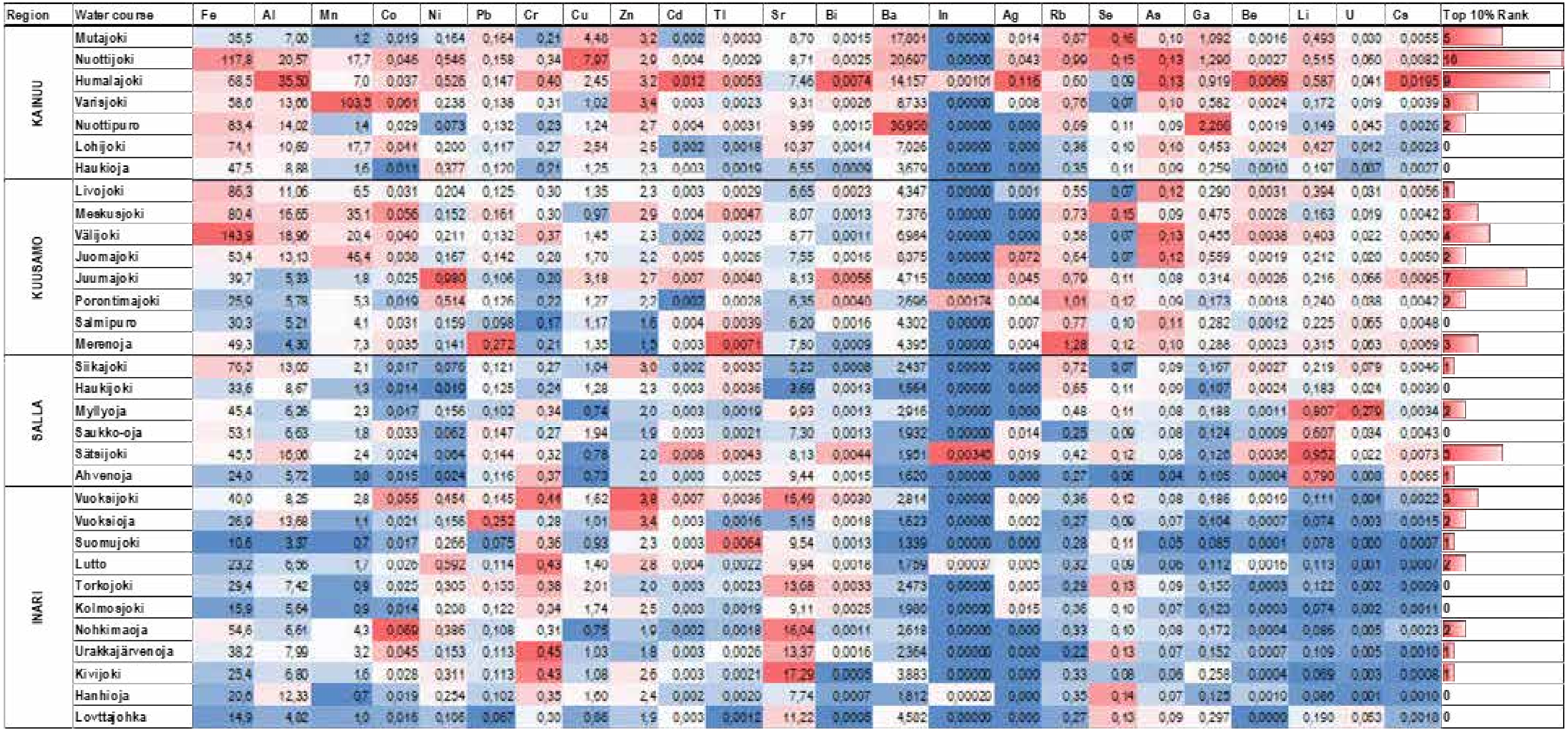
7.2.3 Results and discussion

Concentration of elements in the river water varied substantially between rivers. Among regions concentrations seemed to be higher in southernmost sites, particularly in Kainuu. For example, 10 out of 24 element concentrations in Nuottijoki exceeded the 10% quantile (Top 10% Rank) among rivers (Table 22). High values were also observed in Mutajoki and Humalajoki. In other areas concentrations were generally lower, but in some rivers such as Juumajoki and Sätsijoki in Kuusamo region concentrations of many elements were visibly higher compared to other rivers in the region (Table 22). Some spatial patterns were observed. Concentration of Fe, Al, Pd, Cu, Zn, Ba, Ag, Rb, As, Ga was notably higher in Kainuu region and in most southern rivers in Kuusamo region compared to Salla and Inari region. However, for some other elements such as Co, Pb, Zn, Cd, Sr and most notably Cr values were also high in Inari region rivers. Salla region had rivers which had notably high concertation of In and Li relative to other studied rivers. There was a general south to north decrease in "Top 10% Rank" value, indicating that more northern rivers' concentration of most elements was lower relative to more southern rivers (Table 22). When comparing concentrations of common metals among regions there was rather clear north to south increase in Fe, Al, Pb and Cd. Interestingly Cr showed opposite pattern, highest values found from Inari region (Fig. 236).

Concentration of elements in the mussel's tissue varied substantially between rivers. Among regions concentrations of some elements including Ni, Cd, and Pb seemed to be higher in northernmost sites, Salla and Inari in particular. For example, 9 out of 24 element concentrations in Lovttajohka exceeded the 10% quantile (Top 10% Rank) among rivers (Table 23). However, this can be connected to the high age of mussels in River Lovttajohka, having the oldest mussel individuals, as some elements may accumulate to mussel tissues by time. High values were also observed in Kivijoki and Haukijoki. Some spatial pattern was observed, and concentration of Fe, Cr, Zn, Cu and Mn showed higher values in Kuusamo and highest value of Al was observed in Kainuu (Fig. 238). In figure 239 the correlation between some elements in foot and water were shown which indicated strongest correlation in Chromium and radioactive elements such as Cesium and Uranium between water and FPM foot tissue (Fig. 239).

Some of the variability in metal concentration could partly be a result of surrounding landscape. In rivers and streams, many trace metals are carried in dissolved, colloidal, or particulate form primarily in association with organic matter (Jokinen et al. 2020). Indeed, we found notable association between amount of dissolved organic matter in the water and its Fe, Al, Mn, and Co concentrations (Fig. 237). This indicates that FPMs living in brown waters are more susceptible to some metals than those in clear water rivers. It should be noted that for most metals such

Table 22. Concertation of elements (µg/L) in the water samples collected from FPM sites. Sites are in order so that the southernmost rivers are on the top and northernmost river on the bottom. Highest values among the rivers are indicated in red and lowest in blue, white being the median. "Top 10% Rank" indicates the number elements in each river exceeding the 10% quantile concentration among rivers. Kainuu, Kuusamo, Salla and Inari regions correspond to "South/Kainuu", "Kuusamo-North Ostrobothnia", "South Lapland" and "North Lapland" in Table 20 of the preceding chapter "Water quality parameters", respectively.



Region	Water course	Fe	Al	Mn	Co	Ni	Pb	Cr	Cu	Zn	Cd	Tl	Sr	Bi	Ba	In	Ag	Rb	Se	As	Ga	Be	Li	U	Cs	Top 10% Rank
KAINUU	Mutajoki	35,5	7,00	1,2	0,019	0,164	0,164	0,21	4,40	3,2	0,002	0,0033	8,70	0,0015	17,001	0,00000	0,014	0,67	0,16	0,10	1,092	0,0016	0,493	0,000	0,0055	5
	Nuottijoki	117,8	20,57	17,7	0,046	0,546	0,158	0,34	7,97	2,9	0,004	0,0029	8,71	0,0025	20,607	0,00000	0,043	0,99	0,15	0,13	1,290	0,0027	0,515	0,060	0,0082	10
	Humalajoki	68,5	35,50	7,0	0,037	0,526	0,147	0,40	2,45	3,2	0,012	0,0053	7,46	0,0074	14,157	0,00101	0,116	0,60	0,09	0,13	0,919	0,0069	0,587	0,041	0,0195	9
	Varisjoki	58,0	13,00	103,5	0,061	0,236	0,138	0,31	1,02	3,4	0,003	0,0023	9,31	0,0026	8,733	0,00000	0,008	0,76	0,07	0,10	0,582	0,0024	0,172	0,019	0,0039	3
	Nuottipuro	83,4	14,02	1,4	0,029	0,073	0,132	0,23	1,24	2,7	0,004	0,0031	9,99	0,0015	30,950	0,00000	0,000	0,69	0,11	0,09	2,200	0,0019	0,149	0,045	0,0026	2
	Lohijoki	74,1	10,60	17,7	0,041	0,200	0,117	0,27	2,54	2,5	0,002	0,0018	10,37	0,0014	7,026	0,00000	0,000	0,38	0,10	0,10	0,453	0,0024	0,427	0,012	0,0023	0
	Haukioja	47,5	8,88	1,6	0,011	0,377	0,120	0,21	1,25	2,3	0,003	0,0019	6,55	0,0009	3,679	0,00000	0,000	0,35	0,11	0,09	0,250	0,0010	0,197	0,007	0,0027	0
KUUSAMO	Livojoki	86,3	11,06	6,5	0,031	0,204	0,125	0,30	1,35	2,3	0,003	0,0029	6,65	0,0023	4,347	0,00000	0,001	0,55	0,07	0,12	0,290	0,0031	0,394	0,031	0,0056	1
	Meskusjoki	80,4	16,65	35,1	0,056	0,152	0,161	0,30	0,97	2,9	0,004	0,0047	8,07	0,0013	7,376	0,00000	0,000	0,73	0,15	0,09	0,475	0,0028	0,163	0,019	0,0042	3
	Välijoki	143,9	18,96	20,4	0,040	0,211	0,132	0,37	1,45	2,3	0,002	0,0025	8,77	0,0011	6,984	0,00000	0,000	0,58	0,07	0,13	0,455	0,0038	0,403	0,022	0,0050	4
	Juomajoki	53,4	13,10	46,4	0,038	0,167	0,142	0,20	1,70	2,2	0,005	0,0026	7,55	0,0016	8,375	0,00000	0,072	0,64	0,07	0,12	0,559	0,0019	0,212	0,020	0,0050	2
	Juumajoki	39,7	5,33	1,8	0,025	0,980	0,106	0,20	3,18	2,7	0,007	0,0040	8,13	0,0056	4,715	0,00000	0,045	0,79	0,11	0,08	0,314	0,0026	0,216	0,066	0,0095	7
	Porontimajoki	25,9	5,78	5,3	0,019	0,514	0,126	0,22	1,27	2,7	0,002	0,0028	6,35	0,0040	2,696	0,00174	0,004	1,01	0,17	0,09	0,173	0,0018	0,240	0,038	0,0047	2
	Salmipuro	30,3	5,21	4,1	0,031	0,159	0,098	0,17	1,17	1,6	0,004	0,0039	6,20	0,0016	4,302	0,00000	0,007	0,77	0,10	0,11	0,282	0,0012	0,225	0,065	0,0048	0
	Merenoja	49,3	4,30	7,3	0,035	0,141	0,272	0,21	1,35	1,5	0,003	0,0071	7,80	0,0009	4,395	0,00000	0,004	1,28	0,12	0,10	0,286	0,0023	0,315	0,063	0,0069	3
SALLA	Siikajoki	76,3	13,00	2,1	0,017	0,076	0,121	0,27	1,04	3,0	0,002	0,0033	5,23	0,0008	2,437	0,00000	0,000	0,72	0,07	0,09	0,167	0,0027	0,219	0,079	0,0046	1
	Haukijoki	33,6	8,67	1,3	0,014	0,019	0,125	0,24	1,28	2,3	0,003	0,0036	3,69	0,0013	1,564	0,00000	0,000	0,65	0,11	0,09	0,107	0,0024	0,183	0,024	0,0030	0
	Myllyoja	45,4	6,26	2,3	0,017	0,156	0,102	0,34	0,74	2,0	0,003	0,0019	9,93	0,0013	2,916	0,00000	0,000	0,48	0,11	0,08	0,188	0,0011	0,807	0,279	0,0034	2
	Saukko-oja	53,1	6,63	1,8	0,033	0,062	0,147	0,27	1,94	1,9	0,003	0,0021	7,30	0,0013	1,932	0,00000	0,014	0,25	0,09	0,08	0,124	0,0009	0,607	0,034	0,0043	0
	Sätsijoki	45,3	16,06	2,4	0,024	0,064	0,144	0,32	0,78	2,0	0,008	0,0043	8,13	0,0044	1,951	0,00340	0,019	0,42	0,12	0,08	0,126	0,0036	0,952	0,022	0,0073	5
	Ahvenoja	24,0	5,72	0,6	0,015	0,024	0,116	0,37	0,73	2,0	0,003	0,0025	9,44	0,0015	1,620	0,00000	0,000	0,27	0,06	0,04	0,105	0,0004	0,790	0,000	0,0065	1
INARI	Vuoksijoki	40,0	8,25	2,8	0,055	0,454	0,145	0,44	1,62	3,8	0,007	0,0036	15,49	0,0030	2,814	0,00000	0,009	0,36	0,12	0,08	0,186	0,0019	0,111	0,004	0,0022	3
	Vuoksioja	26,9	13,68	1,1	0,021	0,156	0,252	0,28	1,01	3,4	0,003	0,0016	5,15	0,0018	1,623	0,00000	0,002	0,27	0,09	0,07	0,104	0,0007	0,074	0,003	0,0015	2
	Suomujoki	10,6	3,37	0,7	0,017	0,266	0,075	0,36	0,93	2,3	0,003	0,0064	9,54	0,0013	1,339	0,00000	0,000	0,28	0,11	0,05	0,085	0,0001	0,078	0,000	0,0007	1
	Lutto	23,2	6,06	1,7	0,026	0,592	0,114	0,43	1,40	2,8	0,004	0,0022	9,94	0,0016	1,709	0,00037	0,005	0,32	0,09	0,06	0,112	0,0016	0,113	0,001	0,0007	2
	Torkojoki	29,4	7,42	0,9	0,025	0,305	0,155	0,38	2,01	2,0	0,003	0,0023	13,68	0,0033	2,473	0,00000	0,005	0,29	0,13	0,09	0,155	0,0003	0,122	0,002	0,0009	0
	Kolmosjoki	15,9	5,64	0,9	0,014	0,200	0,122	0,34	1,74	2,5	0,003	0,0019	9,11	0,0025	1,980	0,00000	0,015	0,36	0,10	0,07	0,123	0,0003	0,074	0,002	0,0011	0
	Nohkimaoja	54,6	6,61	4,3	0,069	0,386	0,108	0,31	0,75	1,9	0,002	0,0018	16,04	0,0011	2,618	0,00000	0,000	0,33	0,10	0,08	0,172	0,0004	0,086	0,005	0,0023	2
	Urakkajärvenoja	38,2	7,99	3,2	0,045	0,153	0,113	0,45	1,03	1,8	0,003	0,0026	13,37	0,0016	2,364	0,00000	0,000	0,22	0,13	0,07	0,152	0,0007	0,109	0,005	0,0010	1
	Kivijoki	25,4	6,80	1,6	0,028	0,311	0,113	0,43	1,08	2,6	0,003	0,0021	17,29	0,0005	3,883	0,00000	0,000	0,33	0,08	0,06	0,258	0,0004	0,089	0,003	0,0008	1
	Hanhioja	20,6	12,33	0,7	0,019	0,254	0,102	0,35	1,60	2,4	0,002	0,0020	7,74	0,0007	1,812	0,00020	0,000	0,35	0,14	0,07	0,125	0,0010	0,080	0,001	0,0010	0
	Lovttajohka	14,9	4,02	1,0	0,016	0,106	0,067	0,30	0,86	1,9	0,003	0,0012	11,22	0,0006	4,582	0,00000	0,000	0,27	0,13	0,09	0,297	0,0000	0,190	0,053	0,0018	0

association was not found and variability in their concentration is probably related to other factors such as variability in the bedrocks or atmospheric deposition. Atmospheric deposition from Kola Peninsula metal industry could be one explanation for higher concentrations of Cr observed in northern regions (Fig. 236). Among all the environmental variables including Chlorophyll-a, dissolved organic carbon concentration (DOC), total suspended solids (TSS) and total nitrogen (TN), DOC showed correlation only with some elements (Fe, Al, Mn, Co).

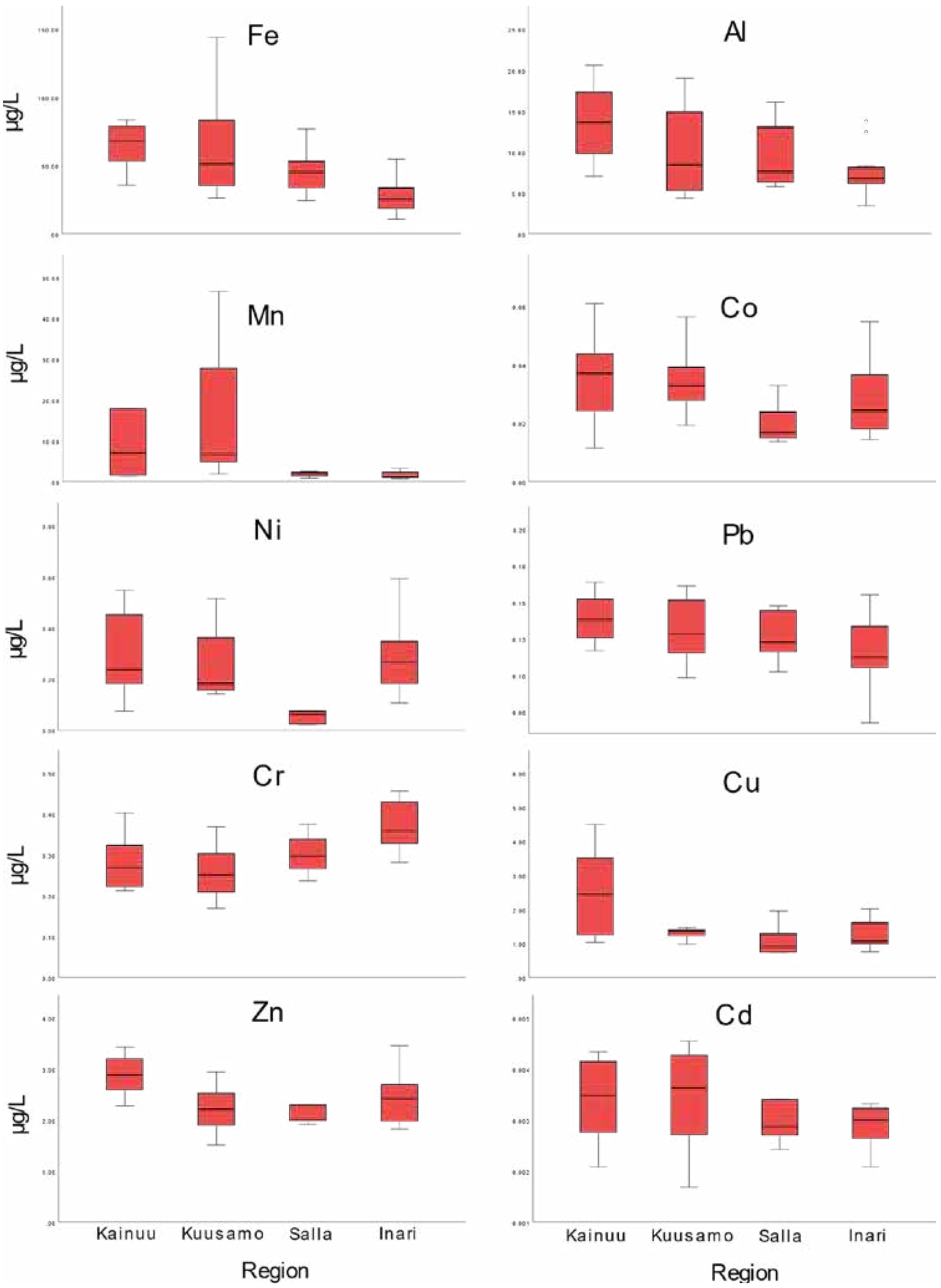


Figure 236. Concertation of some metals in water samples collected from rivers in different regions. The central box spans the interquartile range with the middle line denoting the median and whiskers defining minimum and maximum range. Kainuu, Kuusamo, Salla and Inari regions correspond to "South/Kainuu", "Kuusamo-North Ostrobothnia", "South Lapland" and "North Lapland" in Table 21 of the preceding chapter "Water quality parameters", respectively.

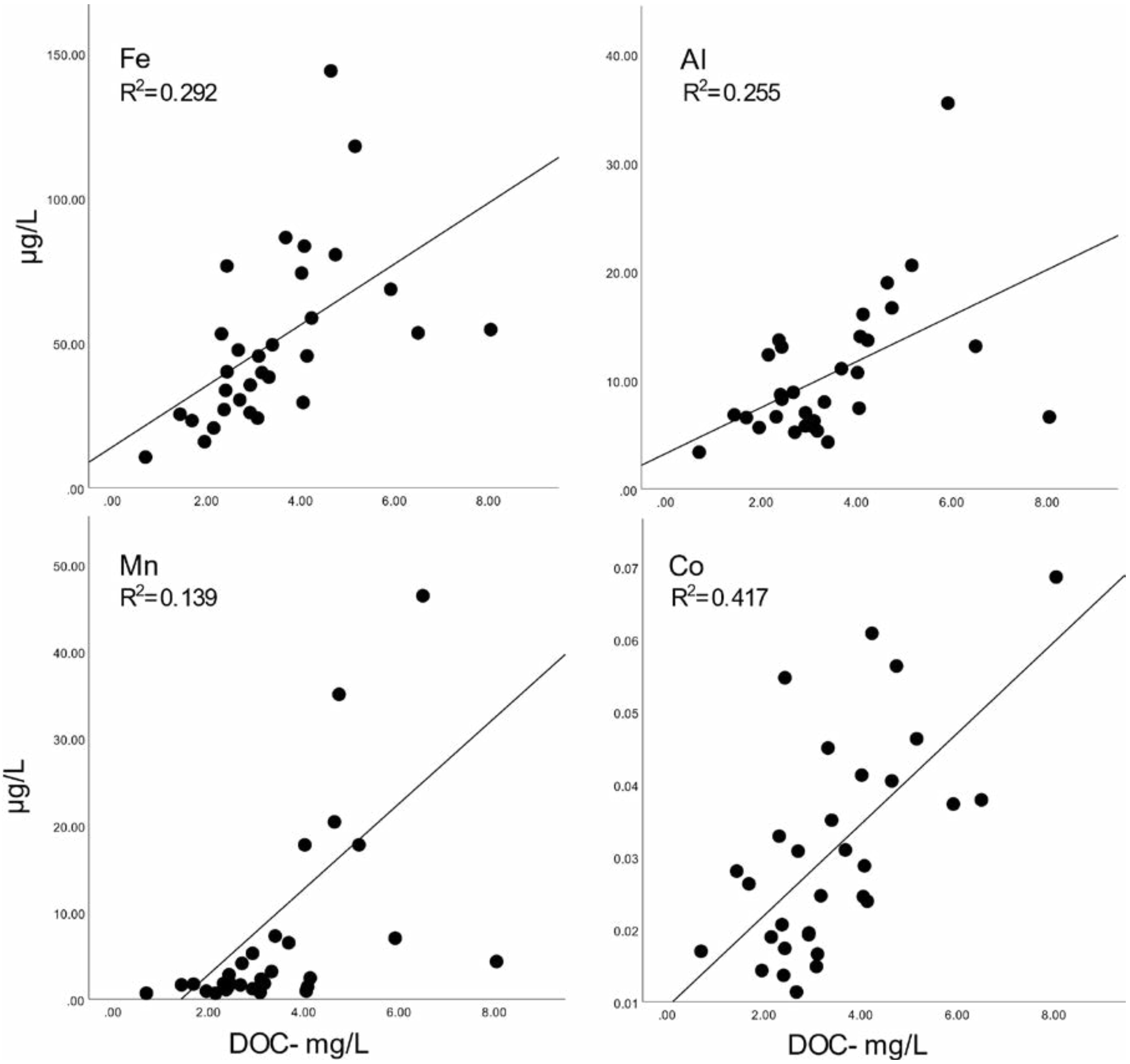
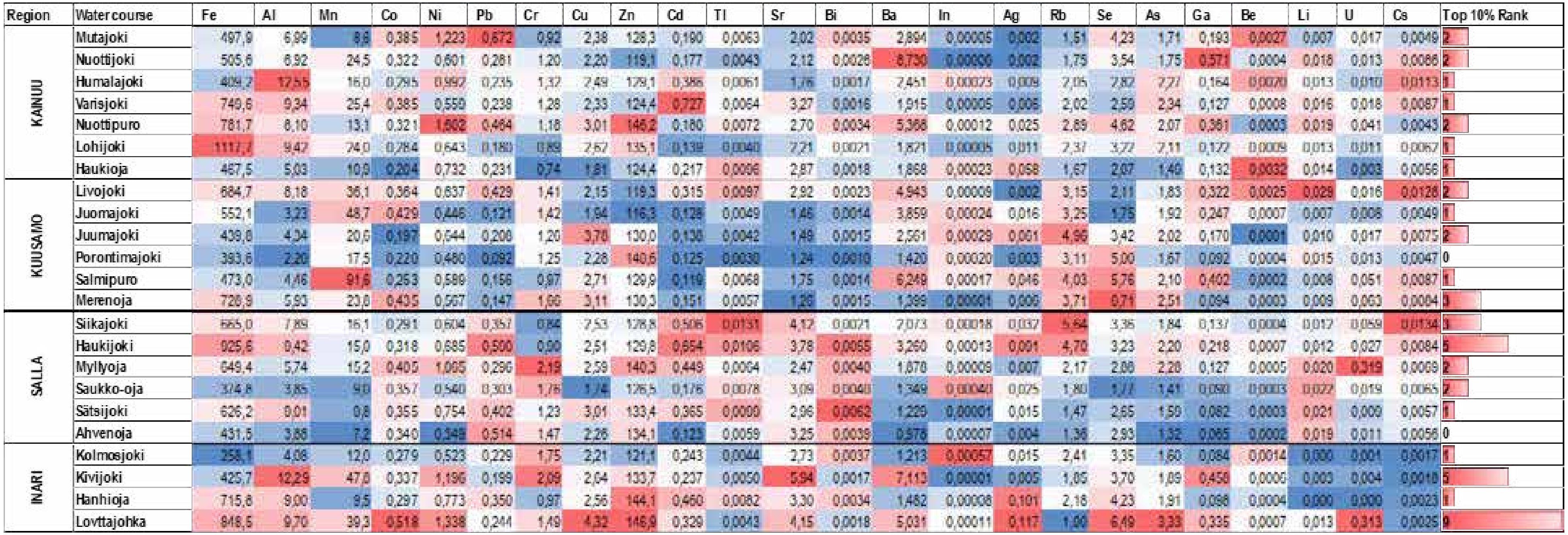


Figure 237. Relationship between dissolved organic carbon concentration (DOC) and some metals (Iron, Aluminum, Manganese and Cobalt) in water.

Table 23. Concertation of elements (µg/L) in FPM foot tissue of different study sites. Sites are in order so that the southernmost rivers are on the top and northernmost river on the bottom. Highest values among the rivers are indicated in red and lowest in blue, white being the median. "Top 10% Rank" indicates the number elements in each river exceeding the 10% quantile concentration among rivers. Kainuu, Kuusamo, Salla and Inari regions correspond to "South/Kainuu", "Kuusamo–North Ostrobothnia", "South Lapland" and "North Lapland" in Table 21 of the preceding chapter "Water quality parameters", respectively. Note that the 2019 tissue samples form Inari region were not analyzed for elements because they were stored in ethanol.



Region	Watercourse	Fe	Al	Mn	Co	Ni	Pb	Cr	Cu	Zn	Cd	Tl	Sr	Bi	Ba	In	Ag	Rb	Se	As	Ga	Be	Li	U	Cs	Top 10% Rank
KAINUU	Mutajoki	497,9	6,99	8,6	0,385	1,223	0,672	0,92	2,38	128,3	0,190	0,0063	2,02	0,0035	2,894	0,00005	0,002	1,51	4,23	1,71	0,193	0,0027	0,007	0,017	0,0049	2
	Nuottijoki	505,6	6,92	24,5	0,322	0,601	0,281	1,20	2,20	119,1	0,177	0,0043	2,12	0,0026	8,730	0,00000	0,002	1,75	3,54	1,75	0,571	0,0004	0,018	0,013	0,0086	2
	Humalajoki	409,2	17,55	16,0	0,295	0,992	0,235	1,37	2,49	129,1	0,386	0,0061	1,76	0,0017	2,451	0,00023	0,009	2,05	2,82	2,27	0,164	0,0020	0,013	0,010	0,0113	1
	Varisjoki	749,6	9,34	25,4	0,385	0,559	0,238	1,28	2,33	124,4	0,727	0,0064	3,27	0,0016	1,915	0,00005	0,006	2,02	2,59	2,34	0,127	0,0008	0,016	0,018	0,0087	1
	Nuottipuro	781,7	8,10	13,1	0,321	1,602	0,464	1,18	3,01	146,2	0,180	0,0072	2,70	0,0034	5,368	0,00012	0,025	2,89	4,62	2,07	0,361	0,0003	0,019	0,041	0,0043	2
	Lohijoki	1117,7	9,47	24,0	0,284	0,643	0,180	0,89	2,67	135,1	0,139	0,0040	2,21	0,0021	1,871	0,00005	0,011	2,37	3,22	2,11	0,122	0,0009	0,013	0,011	0,0067	1
	Haukioja	467,5	5,03	10,9	0,204	0,732	0,231	0,74	1,81	124,4	0,217	0,0096	2,87	0,0018	1,868	0,00023	0,068	1,67	2,07	1,40	0,132	0,0032	0,014	0,003	0,0056	1
KUUSAMO	Livojoki	684,7	8,18	36,1	0,364	0,637	0,429	1,41	2,15	119,3	0,315	0,0097	2,92	0,0023	4,943	0,00009	0,002	3,15	2,11	1,83	0,322	0,0025	0,029	0,016	0,0128	2
	Juomajoki	552,1	3,23	48,7	0,429	0,446	0,121	1,42	1,94	116,3	0,128	0,0049	1,46	0,0014	3,859	0,00024	0,016	3,25	1,75	1,92	0,247	0,0007	0,007	0,008	0,0049	1
	Juumajoki	439,8	4,34	20,6	0,197	0,644	0,208	1,20	3,70	130,0	0,130	0,0042	1,49	0,0015	2,561	0,00029	0,061	4,96	3,42	2,02	0,170	0,0001	0,010	0,017	0,0075	2
	Porontimajoki	393,6	2,20	17,5	0,220	0,480	0,092	1,25	2,28	140,6	0,125	0,0030	1,24	0,0010	1,420	0,00020	0,003	3,11	5,00	1,67	0,092	0,0004	0,015	0,013	0,0047	0
	Salmipuro	473,0	4,46	91,6	0,253	0,589	0,156	0,97	2,71	129,9	0,119	0,0068	1,75	0,0014	6,249	0,00017	0,046	4,03	5,76	2,10	0,402	0,0002	0,008	0,051	0,0087	1
	Merenoja	728,9	5,93	23,8	0,435	0,567	0,147	1,66	3,11	130,3	0,151	0,0057	1,26	0,0015	1,399	0,00001	0,006	3,71	6,71	2,51	0,094	0,0003	0,009	0,063	0,0094	3
SALLA	Siikajoki	665,0	7,89	16,1	0,291	0,604	0,357	0,84	2,53	128,8	0,506	0,0131	4,12	0,0021	2,073	0,00018	0,037	5,64	3,36	1,84	0,137	0,0004	0,012	0,059	0,0134	3
	Haukijoki	925,6	9,42	15,0	0,318	0,685	0,500	0,90	2,51	129,8	0,654	0,0106	3,78	0,0055	3,260	0,00013	0,081	4,70	3,23	2,20	0,218	0,0007	0,012	0,027	0,0084	5
	Myllyoja	649,4	5,74	15,2	0,405	1,065	0,296	2,19	2,59	140,3	0,449	0,0064	2,47	0,0040	1,878	0,00009	0,007	2,17	2,88	2,28	0,127	0,0005	0,020	0,319	0,0069	2
	Saukko-oja	374,8	3,85	9,0	0,357	0,540	0,303	1,76	1,74	126,5	0,176	0,0078	3,09	0,0040	1,349	0,00040	0,025	1,80	1,77	1,41	0,090	0,0003	0,022	0,019	0,0065	2
	Sätsijoki	626,2	9,01	8,8	0,355	0,754	0,402	1,23	3,01	133,4	0,365	0,0099	2,96	0,0062	1,229	0,00001	0,015	1,47	2,65	1,50	0,082	0,0003	0,021	0,009	0,0057	1
	Ahvenoja	431,5	3,86	7,2	0,340	0,348	0,514	1,47	2,26	134,1	0,123	0,0059	3,25	0,0039	0,978	0,00007	0,004	1,36	2,93	1,32	0,065	0,0002	0,019	0,011	0,0056	0
INARI	Kolmosjoki	258,1	4,08	12,0	0,279	0,523	0,229	1,75	2,21	121,1	0,243	0,0044	2,73	0,0037	1,213	0,00057	0,015	2,41	3,35	1,60	0,084	0,0014	0,000	0,001	0,0017	1
	Kivijoki	425,7	12,29	47,8	0,337	1,196	0,199	2,09	2,04	133,7	0,237	0,0050	5,94	0,0017	7,113	0,00001	0,005	1,05	3,70	1,09	0,458	0,0006	0,003	0,004	0,0018	5
	Hanhioja	715,8	9,00	9,5	0,297	0,773	0,350	0,97	2,56	144,1	0,460	0,0082	3,30	0,0034	1,482	0,00008	0,101	2,18	4,23	1,91	0,098	0,0004	0,000	0,000	0,0023	1
	Lovttajohka	848,5	9,70	39,3	0,518	1,338	0,244	1,49	4,32	146,9	0,329	0,0043	4,15	0,0018	5,031	0,00011	0,117	1,00	6,49	3,33	0,335	0,0007	0,013	0,313	0,0025	9

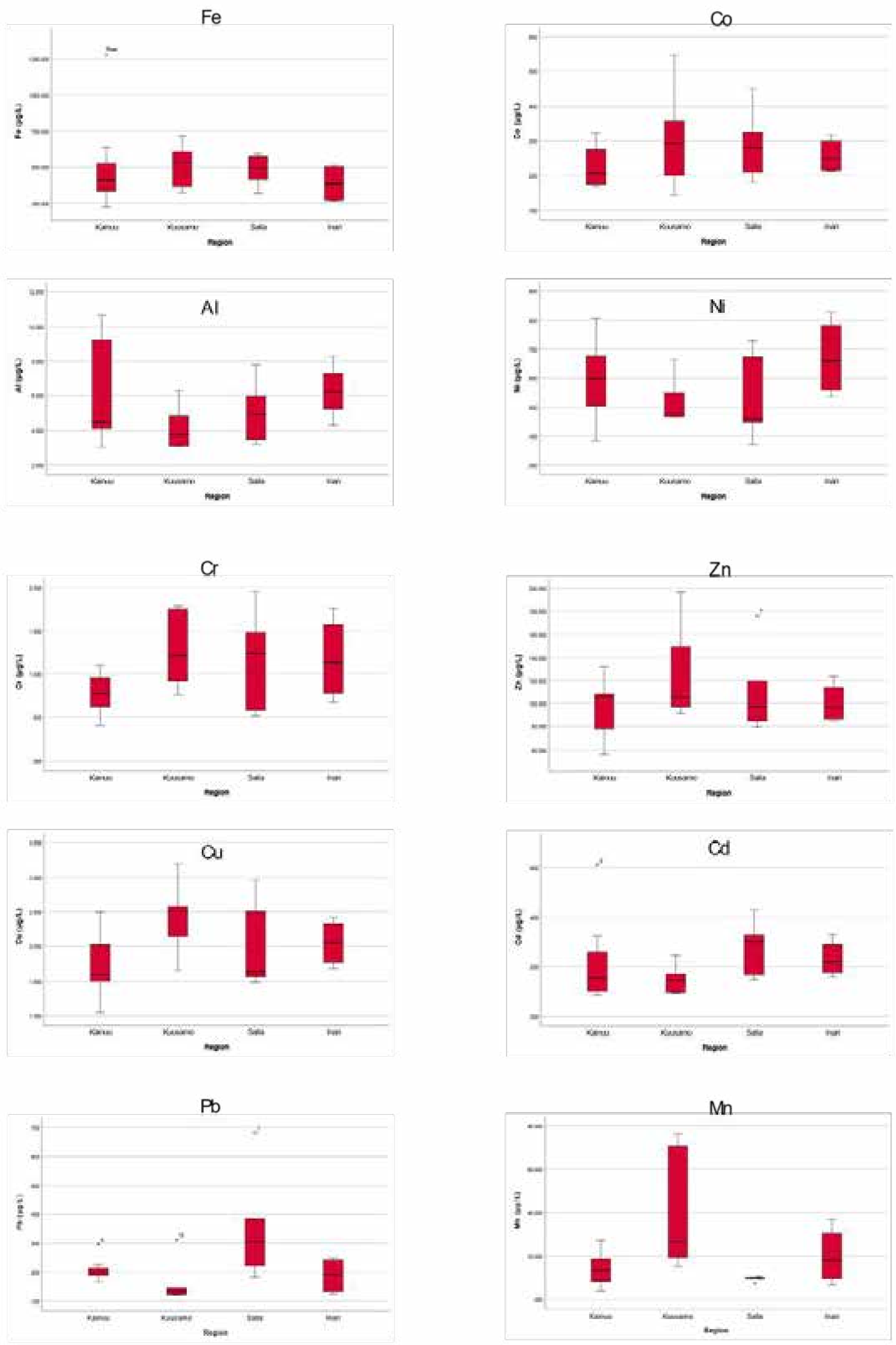


Figure 238. Concentration of some metals in FPM foot tissue in rivers from different regions. The central box spans the interquartile range with the middle line denoting the median and whiskers defining minimum and maximum range. Kainuu, Kuusamo, Salla and Inari regions correspond to "South/Kainuu", "Kuusamo–North Ostrobothnia", "South Lapland" and "North Lapland" in Table 21 of the preceding chapter "Water quality parameters", respectively.

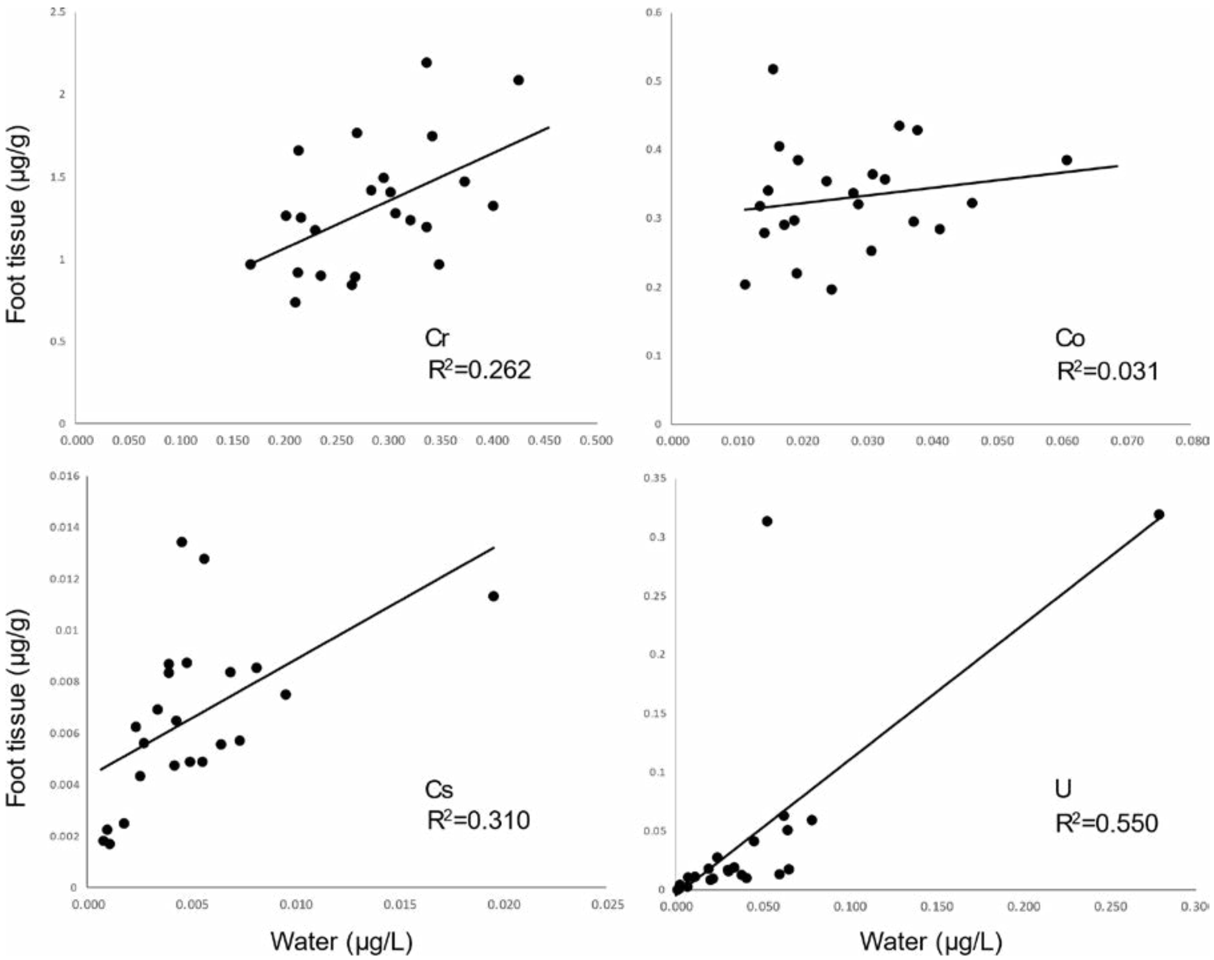


Figure 239. Relationship between concentration of some elements (Chromium, Cobalt, Cesium and Uranium) in water samples and FPM foot tissues.

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7.3 Aquatic and terrestrial food sources, and their influence on the wellbeing of *Margaritifera margaritifera*

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7.3.1 Introduction

The basic energy sources that sustain lotic food webs can be divided in autochthonous and allochthonous sources based on their origin (Doucett et al. 2007). The autochthonous source, hereinafter referred as aquatic source, is that provided by the primary production within the aquatic ecosystems (Allan & Castillo 2007). The allochthonous source, hereinafter referred as terrestrial source, is the organic matter input which origins from the terrestrial ecosystems. These energy sources are usually measured from the water in the form of particulate organic matter (POM) and dissolved organic matter (DOM).

In small, forested headwater streams the terrestrial sources can form most of the energy source base, because the shading of the riparian forest limits the primary production in the stream and at the same time provides energy in the form of leaf litter (Hill et al. 1995, Vannote et al. 1980, Wallace et al. 1997, Wallace et al. 2015). However, the presence of an upstream lake may increase the number of aquatic food sources that end up in the streams (Richardson & Mackay 1991). The lake outflow water contains plankton and other suspended material which are considered high-quality food items especially for filter feeders (Fuller & Mackay 1981, Brönmark & Malmqvist 1982, Richardson 1984, Valett & Stanford 1987, Brett et al. 2017). Some studies have suggested that the aquatic source may be better than the terrestrial source, as it may contain food items high in essential nutrients, which are important for the growth and physiology of consumers (Lau et al. 2007, Brett et al. 2009, Gladyshev et al. 2009).

Freshwater mussels eat mainly fine particulate organic matter (FPOM), which can include different amounts of algae, bacteria, detritus, and zooplankton depending on the habitat (Vaughn et al. 2008). Studies concerning the diet of freshwater pearl mussel (FPM) are rare, and the relative role of the aquatic and terrestrial food sources in it is largely unstudied. In the previous studies the terrestrial sources have been addressed of major importance in the diet of FPM, but the relationship between the food sources and the condition of the populations have not yet been addressed (Geist et al. 2005, Brauns et al. 2021). The aim of this study was to investigate the origin of the food sources composing the diet of adult FPM in the northern Finland and the relationship between the diet and the condition of the populations. The research questions were:

1. What are the relative proportions of aquatic and terrestrial sources in the diet of FPM?
2. Do the relative proportions of aquatic and terrestrial sources in the diet of FPM affect the condition of the populations?

These questions were studied with stable isotope analysis and by fitting Bayesian mixing models. The shell opening resistance (SOR) and the FPM density were used as indicators of the condition of the FPM populations.

7.3.2 Methods

The data were collected in 2019 and 2020 from 14 rivers situating in 4 geographical areas in the northern Finland: Inari region (Kolmosjoki, Lutto, Nohkimaoja, Suomujoki, Torkojoki, Urakkajärvenoja, Vuoksioja), Salla region (Ahvenoja, Myllyoja, Sätsijoki), Kuusamo region (Juomajoki, Porontimajoki), and Kainuu region (Mutajoki, Nuottijoki) (see the map of Fig. 231 in the chapter "Water quality parameters").

Stable isotope ratios can be used as tracers that allow us to follow the origins and fates of many elements as they circulate in the biosphere (West et al. 2006, Fry 2008). In dietary studies the stable isotope ratios are measured from the consumer organism and its food sources. The basic concept in stable isotope analysis is that "*you are what you eat*" as the stable isotope ratios of the consumer reflect its assimilated diet (Fry 2008, Layman et al. 2012, Phillips et al. 2014). In other words, the consumer's stable isotope ratios are a mixture of the stable isotope ratios of its food sources, and by studying these ratios we can estimate the contribution of different food sources to the diet of the consumer, as illustrated in Figure 240 (Phillips et al. 2014). We used the open-source MixSIAR (Mixing Stable Isotope Analysis in R) package and models based on the Bayesian framework (Stock et al. 2018) to study the contribution of the aquatic and terrestrial food sources to the diet of FPMs and the effect of the diet on the condition of the populations.

Samples were collected from three sampling sites in each river: next to the mussel bed in the river, the lake outlet, and the tributary. We had the permission to collect three FPM individuals from each study river exceeding 1 000 individuals, and we used the foot tissue of these mussel individuals as the consumer samples in our models. The mussels that were collected in 2019 in Inari region (all rivers except Kolmosjoki) were preserved in ethanol, which alters the isotopic composition of the tissue because of leak of lipids (Hetheringthon et al. 2019, Hajisafarali et al. 2023). The mussels collected in 2020 were transported alive in a 100-L cool box filled with ice to Jyväskylä. All the mussels were dissected in the laboratory within 2-10 days after sampling. To normalize the effect of the preserving methods all the foot tissue $\delta^{13}C$ was lipid corrected according to Kiljunen et al. (2006).

The aquatic food source was collected from the lake as fine particulate organic matter (FPOM, 0.22–50 μm). Previous studies have shown that 45–90% of the organic matter content of lake FPOM is of aquatic origin and the rest of it is of terrestrial origin (Kankaala et al. 1996, Wilkinson et al. 2013).

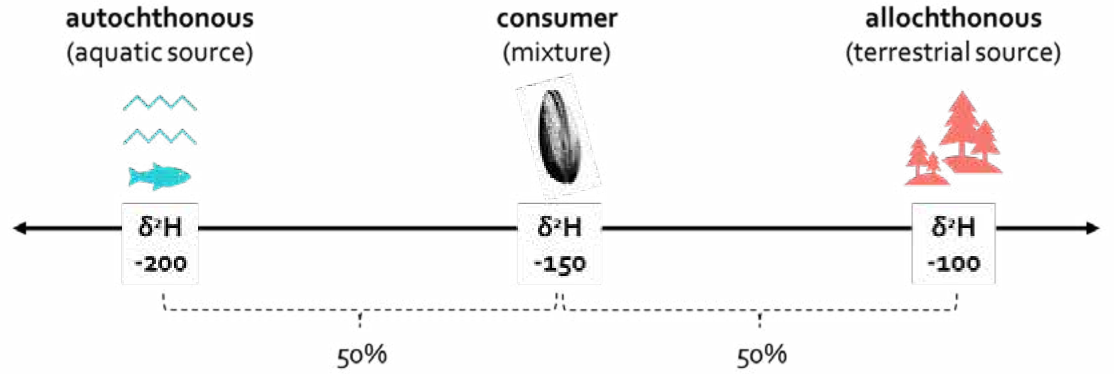

Figure 240. In this fictive example the aquatic and terrestrial food sources contribute equally to the diet of the freshwater pearl mussel consumer as it fits exactly in the middle of the two sources. Illustration: Sabrina Nykänen.

As in some cases a substantial part of the lake FPOM is of terrestrial origin, we used filamentous algae and aquatic mosses collected from the lake and the river sampling sites to correct the lake FPOM isotopic values towards more aquatic one and to increase the aquatic source's sample size (*n*) from 1 to 2–5 per river. The terrestrial food source consisted of dissolved organic matter (DOM, < 0.22 µm) collected from all the sampling sites. It is well known that DOM consists by 90–100% of organic matter of terrestrial origin (Kritzberg et al. 2004, Wilkinson et al. 2013), and therefore it can be considered good in representing of terrestrial origin in aquatic systems. We used needles and leaves collected from terrestrial plants next to the river sites to increase the *n* from 3 up to 4, and to correct the DOM signal towards more terrestrial one.

To study the contribution of the aquatic and terrestrial food sources to the diet of FPM the stable isotope ratios of carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$) and hydrogen ($\delta^{2}H$) were analyzed from all the tissue, water, and plant samples at the Department of Biological and Environmental Sciences of University of Jyväskylä.

In this study the mean SOR (*n* = 30 mussels per population) was used as one of the indicators of the condition of the populations. The SOR is an indirect measurement of the condition of the mussels via the strength of their adductor muscle, which can be lost over time as a response to poor feeding conditions (see chapter "Shell-opening resistance – a measure of condition of individual mussels" for description of the method). The other population indicator, FPM density in the nearest transect (used in the population viability assessments, see the related SALMUS subreport "Status of the freshwater pearl mussel populations" by Oulasvirta et al.) to the river sampling sites, was calculated by dividing the number of alive mussels in the transect with the area (m^2) of the mussel bed (mussel bed width * transect length).

7.3.3 Results

Based on the first Bayesian mixing model with the river as a fixed effect, which was fitted to study the contribution of the aquatic and terrestrial sources to the diet of FPM, it seems that the aquatic source was mostly preferred by FPMs in the rivers studied here (Fig. 242). However, if we look at the posterior probability estimates for the medians and the 95% Bayesian credible intervals in the Figure 243, we can see that there is variation between the rivers, and sometimes the within-river variation is vast. The Bayesian credible intervals tell us that "*given the observed data, the effect has 95% probability of falling within this range*" (Makowski et al. 2019). Therefore, our results can be interpreted for example in the following way: In Nuottijoki the posterior probability that FPM derive more than half of their energy from aquatic resource is 95%. Or: the posterior probability that FPM in Suomujoki prefer food of aquatic origin, but in Torkojoki they prefer food of terrestrial origin is 95%. The model could not converge with Sätsijoki, so it was excluded.

The mean SOR varied between 3.30–4.95 (*n* = 14) in the studied rivers (Table 24). Based on the mean SOR our study rivers were in general in good condition, especially if compared to Mustionjoki in Southern Finland where the mean SOR was 2.97 in 2019 (unpublished data). The FPM densities in the closest transects to the sampling sites varied between 0.02–64.2 individuals per m^2 (*n* = 13) (Table 24). The results suggested that the FPM populations are on average in slightly better condition in the most northern parts of our study area, but the mussel beds are less dense in the north (Table 24). In addition, the latitude was the only environmental variable to explain the variation in the mean SOR and the FPM density (Figure 241). The other variables were the river length (km), distance from lake (m), latitude, water temperature (°C), Chlorophyll-a concentration (Chl-a,

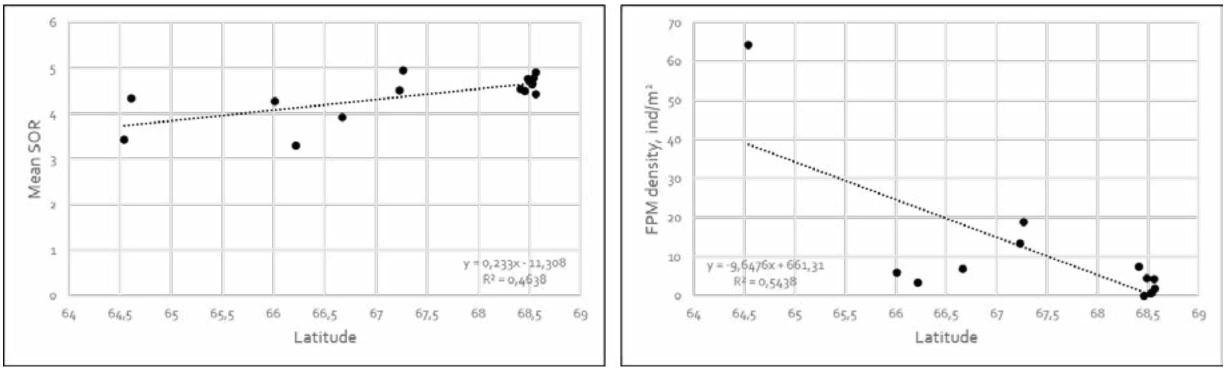

Figure 241. Effect of latitude on the mean SOR and the FPM density. Spearman's correlation coefficients (ρ) between mean SOR and latitude = 0.71 (*n* = 14, p = 0.006), and between FPM density and latitude = -0.62 (*n* = 13, p = 0.03).

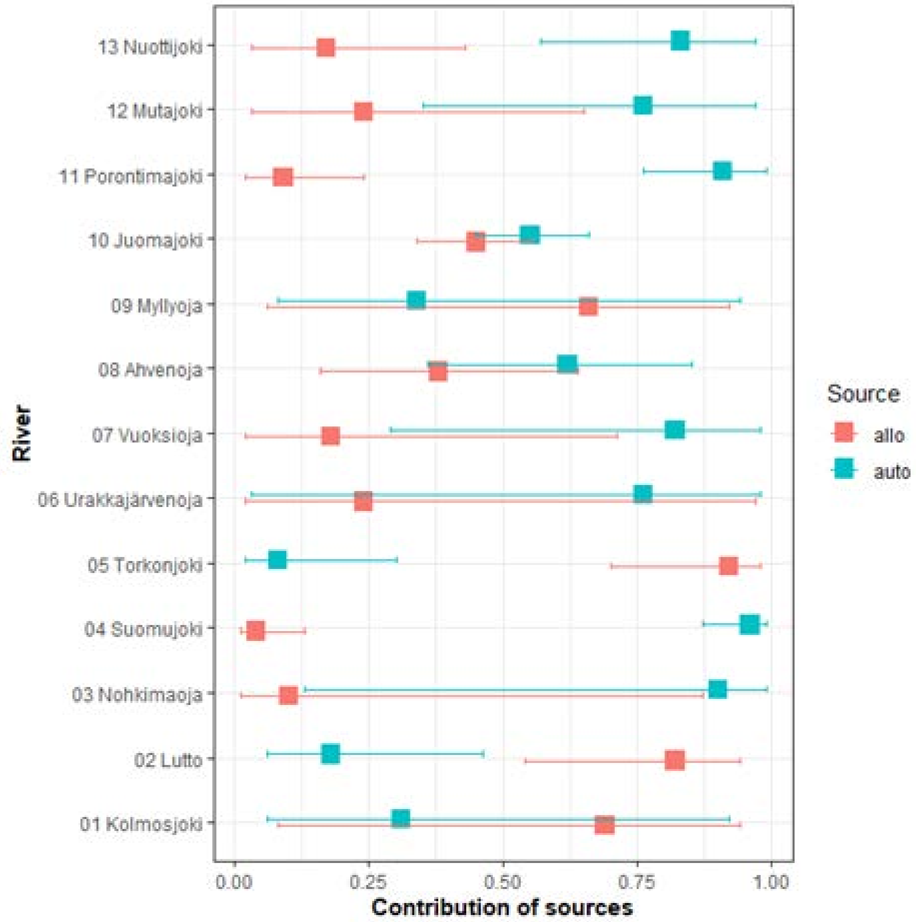

Figure 242. Contribution of allochthonous (red) and autochthonous (blue) sources in the diet of freshwater pearl mussels in the study rivers. Medians and 95% Bayesian credible intervals. Rivers are in order from north (down) to south (up).

µg/l), dissolved organic carbon concentration (DOC, mg/l), and total nitrogen concentration (TN, mg/l), pH, and dissolved oxygen concentration (DO, %) (see chapter "Water quality parameters" for additional information).

Based on the second Bayesian mixing model with the river as a random effect, which was fitted to study the effect of the diet on the condition of the FPM populations, it seems that there is a positive correlation between the mean SOR and the terrestrial source proportion in the diet of the (Figure 242). In other words, the terrestrial source seems to increase the condition of the mussels, when the mean SOR is used as proxy. This could mean that higher terrestrial detritus in the diet results in better condition. However, the 95% Bayesian credible intervals produced by the model are large, and therefore we can consider this result as indicative. The model with FPM density as a covariate did not converge so the results are not shown here.

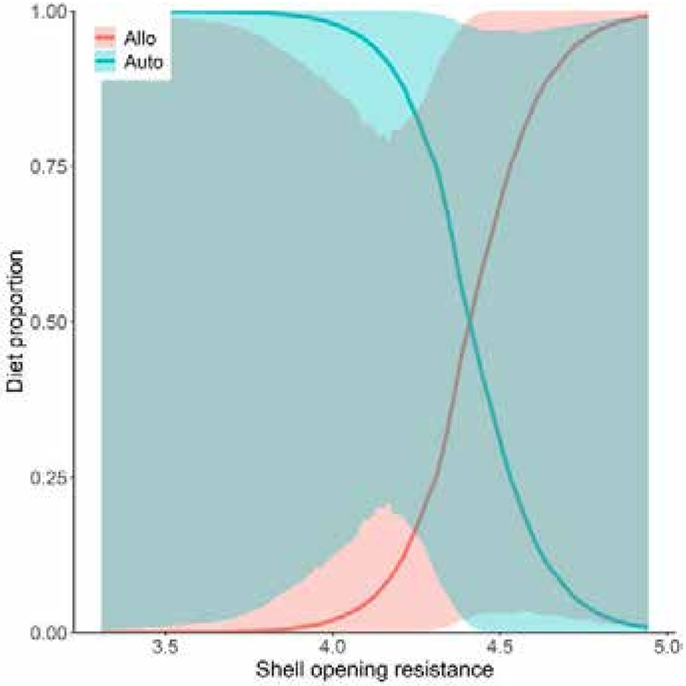

Figure 243. Posterior estimate of the diet proportions as a function of the mean shell opening resistance (SOR). Solid lines indicate the medians, shadings represent the 95% Bayesian credible intervals.

Table 24. Population variables of the studied freshwater pearl mussel rivers. Mean shell opening resistance (SOR) and length (mm) and the standard deviations (SD) in each river (n = 30 in both parameters), population size and viability assessment in each river, and the freshwater pearl mussel (FPM) density in the closest transect to the SOR sampling site within each river. Kainuu, Kuusamo, Salla and Inari regions correspond to "South/Kainuu", "Kuusamo–North Ostrobothnia", "South Lapland" and "North Lapland" in Table 21 of the chapter "Water quality parameters", respectively.

River	SOR (mean ± SD)	Length (mean ± SD)	Pop. size	Viability	FPM density (ind/m^2)
Inari region Kolmosjoki	4.43±0.86	102±10	36,500	Non-viable	4.18
Inari region Lutto	4.48±0.70	122±8	41,100	Dying-out	0.02
Inari region Nohkimaoja	4.77±0.61	87±10	13,400	Non-viable	0.63
Inari region Suomujoki	4.53±0.81	108±8	134,000	Non-viable	7.42
Inari region Torkojoki	4.75±0.47	90±8	7,200	Non-viable	4.35
Inari region Urakkajärvenoja	4.90±0.24	92±9	7,600	Viable	1.77
Inari region Vuoksioja	4.63±0.71	96±6	10,700	Maybe viable	0.54
Salla region Ahvenoja	4.95±0.20	100±11	3,100	Maybe viable	18.96
Salla region Myllyoja	3.92±0.73	96±6	1,100	Non-viable	6.90
Salla region Sätsijoki	4.50±0.72	93±5	10,000	Viable	13.29
Kuusamo region Juomajoki	4.27±0.78	100±10	7,650	Dying-out	5.97
Kuusamo region Porontimajoki	3.30±1.07	77±9	1,200	Non-viable	3.35
Kainuu region Mutajoki	3.42±1.20	75±4	14,500	Maybe viable	64.18
Kainuu region Nuottijoki	4.33±0.75	91±10	-	-	-

7.3.4 Discussion and prospects

In this study the aquatic food source seemed to dominate in the diet of FPM, but the terrestrial food source was also always used in different proportions by the studied mussel populations. This result supports those studies addressing the importance of aquatic food sources for aquatic organisms, but it is not in accordance with the previous studies concerning the diet of FPM (Geist et al. 2005, Brauns et al. 2021). This could be related to the differences in the study designs. For example, the selection and the definition of the sources was different in the previous studies, and previously the lake FPOM was not included in the possible food sources consumed by FPM. In addition, Brauns et al. (2021) used FPM juveniles and semi-adults in their study, and they may have different feeding mode (pedal-feeding vs. filter-feeding) and diet preference when compared to adult FPMs. Also, in our study δ^2H was used in addition to δ^{13}C and δ^{15}N. Geist et al. (2005) and Brauns et al. (2021) used only δ^{13}C and δ^{15}N in their studies, which do not separate as efficiently as δ^2H aquatic and terrestrial food sources (Doucett et al. 2007).

The latitude seemed to affect the condition of the FPM populations when the mean SOR and FPM density were used as indicators, so that the FPM populations are on average in slightly better condition but less dense in the most northern parts of our study area. There seemed also to be an indication that the origin of the food source used by the mussels may affect their condition in a way that the terrestrial source may be important for the performance of the individuals. So, in the north, where the mussels are slightly in better condition, the terrestrial source proportion should be in average higher in the diet than in south. However, regardless of these findings, it is interesting that no other environmental variable used here did explain the variation in the condition of the FPM populations. What mechanisms are causing these connections between the mentioned variables remains thus still an open question.

The results presented here are preliminary as new data has been collected during 2021 from 15 rivers in the Northern Finland. This data will double our river number in the future analysis. In the future analysis we will be also using the results presented by Hajisafarali et al. (2023) instead of the equation presented by Kiljunen et al. (2006) to correct the isotope ratios of the ethanol preserved samples. A preliminary examination showed that with the latter method for correcting the foot tissue's stable isotope ratios resulted more enriched than with the method of Hajisafarali et al. (2023). The increased sample size and the new method for correcting the foot tissue's stable isotope ratios are likely to affect the results.

It is important also to note that our sample size per river was relatively low, while when using Bayesian mixing models, the amount of data collected can substantially affect the precision of the diet proportion estimates and the ability of the model to converge (Phillips et al. 2014). Therefore, our sample size may have resulted in the large variation in our results, and it may be that the Bayesian mixing models are not the best approach to study our data and that in the future analysis we may use the more traditional linear mixing model.

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7.4 Temperature, acidification, and conductivity measurements in some SALMUS rivers

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Temperature loggers were installed in the rivers of the project area by several Salmus partners to monitor temperature conditions of the project area in Finland, as well as to compare data and monitor changes in environmental conditions over time, also with respect to climate change. Monitoring will hopefully continue regularly after the end of the project by other projects (LIFE Revives) and instances (Metsähallitus).

Jyväskylä University (JYU) installed 15 Onset HOBO Pendant® Temperature/Light Data Loggers (UA-001-08) in 2020 to

- Inari municipality, Lappi district. Tuloma catchment – 6 loggers: Lutto, Nohkimaoja, Urakkajärvenoja, Vuoksioja, Kolmosjoki, Torkojoki
- Salla municipality, Lappi district. Kemijoki catchment – 3 loggers: Sätsijoki, Ahvenoja, Tammakkolammenoja. Koutajoki catchment, 1 logger – Myllyoja
- Kuusamo municipality, Pohjois-Pohjanmaa district. Kem (Vienan Kemi) catchment – 3 loggers: Juomajoki, Meskusjoki, Välijoki. Koutajoki catchment – 1 logger: Porontimajoki
- Paltamo municipality, Kainuu district. Oulujoki catchment – 1 logger, Mutajoki

Metsähallitus (MH) installed 9 Onset HOBO Pendant® Temperature/Light Data Loggers (UA-002-64) in 2020 to

- Inari municipality, Lappi district. Tuloma catchment – 4 loggers: Ristinmorostonjärvenoja, Hanhioja (2 loggers), Takkireuhkaoja
- Utsjoki municipality, Lappi district. Deatnu/Teno/Tana catchment – 5 loggers: Lovttajohka, Gálddašjohka, Námmájohka, Vuohččojohka, Utsjoki
- Salla municipality, Lappi district. Kemijoki catchment – 10 loggers: Saukko-oja, Purkaoja, Sätsijoki (3 loggers), Käärmeoja, Tammakkolamminoja, Hangasjoki, Hevosoja, Myllyjoki

All loggers were installed during the field season 2020, between June and October (Fig. 244a). First offload of the data was performed during field season 2021 using Hobo the Universal Optic USB Base Station/couplers and Onset Hoboware for Windows free software (Fig. 244b).

Data offload from Metsähallitus (MH) loggers in Kemijoki catchment was not performed in 2021 due to technical problems and it will take place later. During the field season 2021, additional 15 temperature loggers were installed by Jyväskylä University. First data offload from them will take place also later, in 2022 or 2023 as part of the LIFE Revives project.

Figure 244a. The loggers were attached into the riverbed with a metal rod. Logger locations were marked. In the picture logger attaching system used by MH. **b.** Jonna Kuha (JyU) offloading data from a logger in the field in August 2021. Photos: Aune Veersalu.

7.4.1 Results

Temperature data was obtained from 24 loggers (Fig. 245). Data for one-year-long period was analyzed from 22 loggers. In addition, logging data from shorter periods was used when possible.

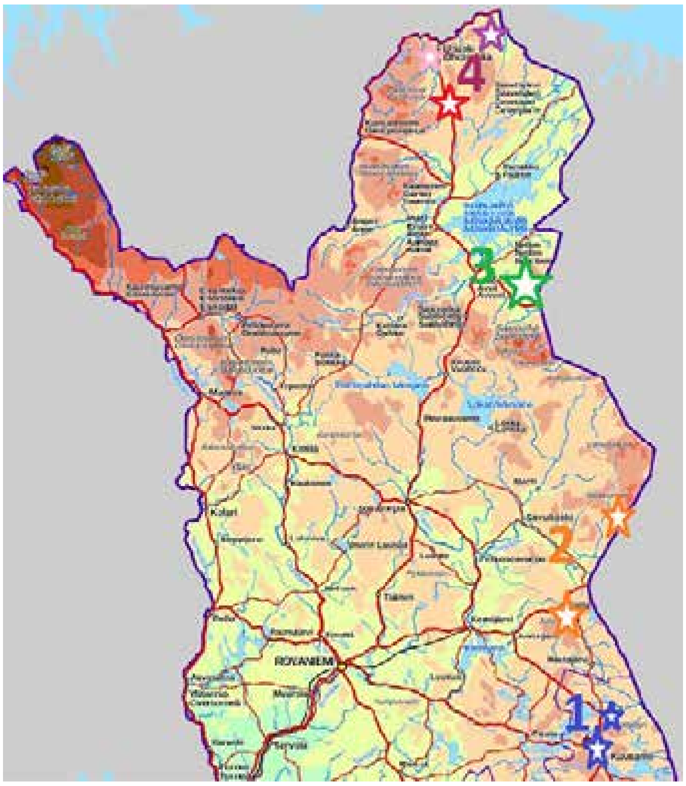

Figure 245. Logger locations and the number of analysed logger data sets in each region (in brackets). 1. Kuusamo municipality (4 loggers) 2. Salla municipality (4) 3. Inari municipality (10) 4. Utsjoki municipality (5).

Summarized temperature data for 2020/2021 is presented in Fig. 246. One river, Mutajoki in Kainuu region, situates about 150 km more south from Kuusamo. The yearly average (6.77 °C) and median (2.94 °C) temperatures were there highest of all rivers logged. As it was the only river in that region and logging period was not a full year (22.9.2020–10.9.2021), the data of Mutajoki is not included in further analyses.

The yearly average temperatures varied from 4 °C to 6 °C and were generally a bit higher in Kuusamo, a region more south, but the average varied a lot also between rivers of the same region. Average temperatures by region were: Kuusamo 5.87 °C, Inari 5.20 °C, Salla 5.0 °C, and Utsjoki 4.48 °C. The highest average temperatures (about 6 °C) were measured in rivers Porontima-, Meskus- ja Välijoki; and the lowest in the river Gálddašjohka (4.03 °C). Median temperatures of the year were also very low due to a long cold winter prevailing in the climate zone of project regions. The lowest median was in Utsjoki region (0.6 °C), and the other regions levelled also quite uniformly: Kuusamo 1.28 °C, Inari 1.33 °C, Salla 1.2 °C. However, winter temperatures 2020/2021 did not go under 0°C anywhere in the rivers studied, the lowest minimum temperatures (0.01 °C) were observed in riv-

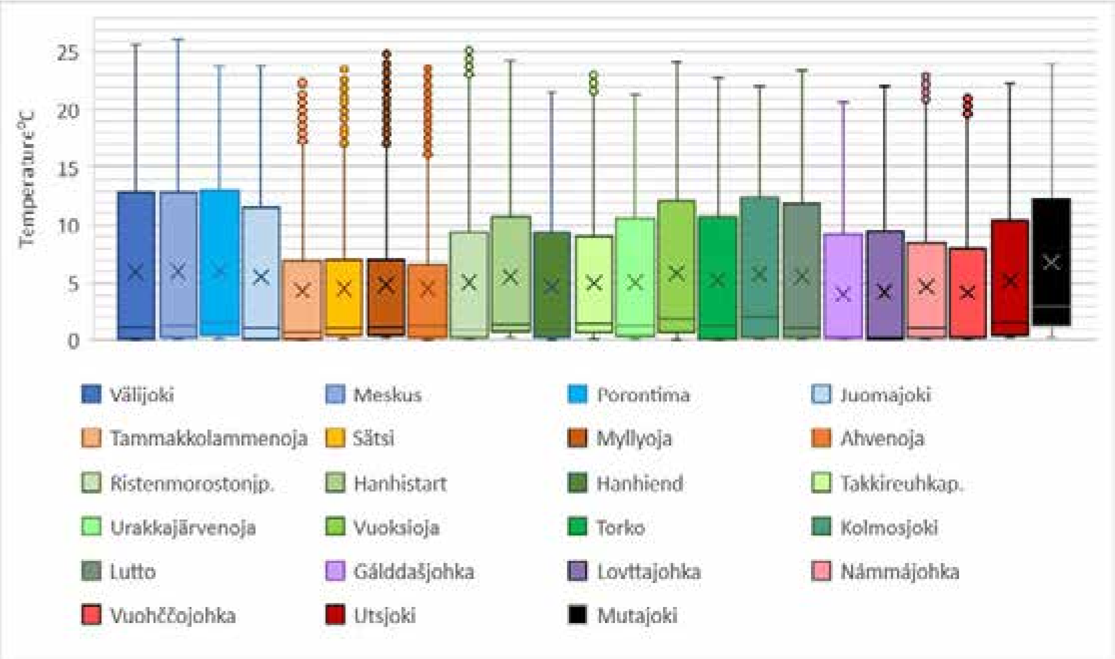

Figure 246. Temperatures in some FPM rivers during a one-year-period, yearly average and medium temperatures with maximum and minimum temperatures indicated. Rivers are shown geographically from south to north: blue shades – Kuusamo, yellow shades – Salla, green shades – Inari, red/violet shades – Utsjoki region.

ers Välijoki, Tammakkolammenoja, Ahvenoja, Vuoksioja, Torkojoki and Nohkimaoja (Fig. 247).

Length of the winter period (from November 2020 to April 2021), given in Figure 247, was determined based on the average and maximum monthly temperatures (Fig. 248b). Temperatures in FPM rivers dropped during Sept.-Oct. 2020 and rose quickly in May–June 2021 (Fig. 248a). Average monthly temperatures in October 2020 were already ≤ 5 °C (except for 5.02 °C in Kuusamo region), lowest average (3.3 °C) was reached in Utsjoki region (Fig. 248b), but maximum temperatures were still over 8 °C at that time (highest maximum temperature 9.3 °C in Inari region, and the lowest maximum temperature in Utsjoki region 8.1 °C). Median temperatures in October were below 5 °C in all regions (Fig. 248a). From November 2020 to April 2021 temperatures remained mostly around or under 1 °C – in practice, during the whole wintertime. Some higher peaks, over 3 °C, were logged in Kuusamo region in November 2020 and in other regions in April 2021 (Fig. 248a). In May 2021, minimum winter temperatures were still observed in several rivers (Ahvenoja, Tammakkolammenoja, Nohkimaoja, all 0.01 °C; Juomajoki, Urakkajärvenoja, Gálddašjohka and Lovttajohka, 0.121 °C), but average temperatures were already over 2 °C in all rivers, and maximum monthly temperatures were already much higher (from 8.58 °C in Utsjoki region to 11.92 °C in Kuusamo region).

Median temperatures for most productive summer months (June-August) were 12.54 °C in Utsjoki region and 15.08 °C in Inari region. Higher median summer temperatures were observed more south in Kuusamo and Salla region. However, logging period in Kuusamo was approximately from 9.6.2020 to 9.8.2021, so it did not cover the whole summer period in either of the study years. In Salla, the logger data offload took place on 6.8.2021, so it did not cover the whole summer period either. Accordingly, only the data of full months logged are included in Figure 250. The highest temperatures during the monitoring period occurred in all regions in July 2021. The highest temperature (26.1 °C) was logged in Meskusjoki, Kuusamo district on 5.7.2021. Average temperature of Kuusamo rivers in July 2021 was 19.01 °C and median 19.64 °C. Average temperature at Salla rivers in July was 17.64 °C (median 17.69 °C, max 24.84 °C in Myllyoja on 7.7.2021). Average July temperature in Inari region rivers was 16.76 °C (median 17.47 °C, max 25.61 °C in Ristinmorostonjärvenoja on 7.7.2021). Average temperature of Utsjoki region rivers in July 2021 was 14.89 °C (median 14.28 °C, maximum 23.39 °C in Námmájohka on 7.7.2021).

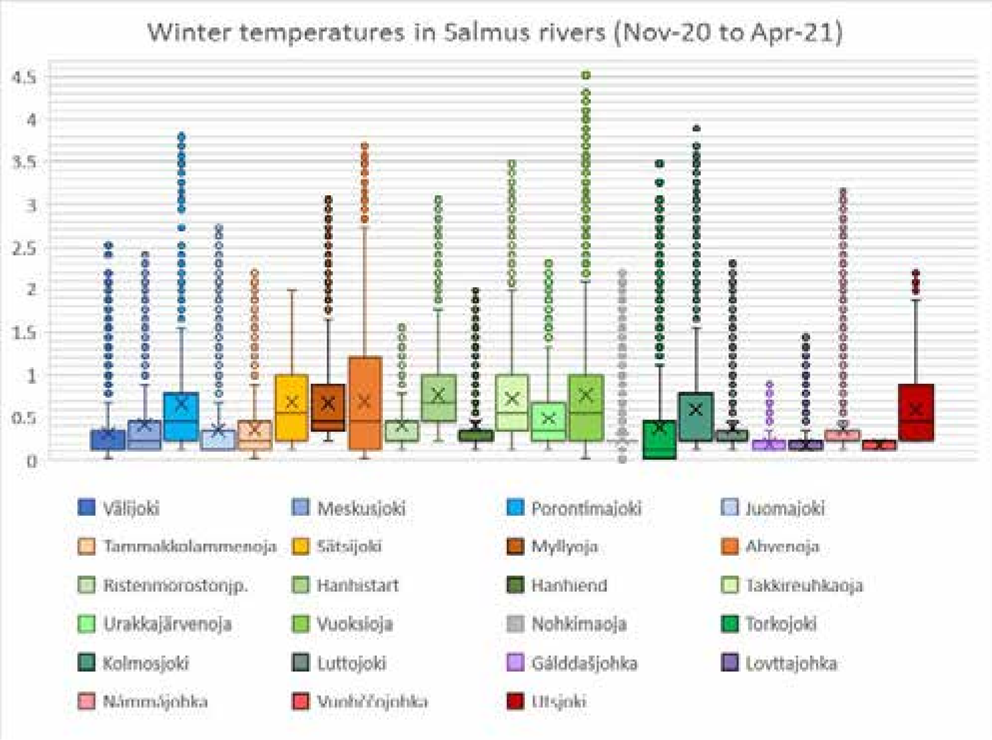

Figure 247. Temperatures during the winter period in FPM rivers according to logger data 2020/2021. Rivers are shown geographically from south to north: blue shades – Kuusamo, yellow shades – Salla, green shades – Inari, red/violet shades – Utsjoki region.

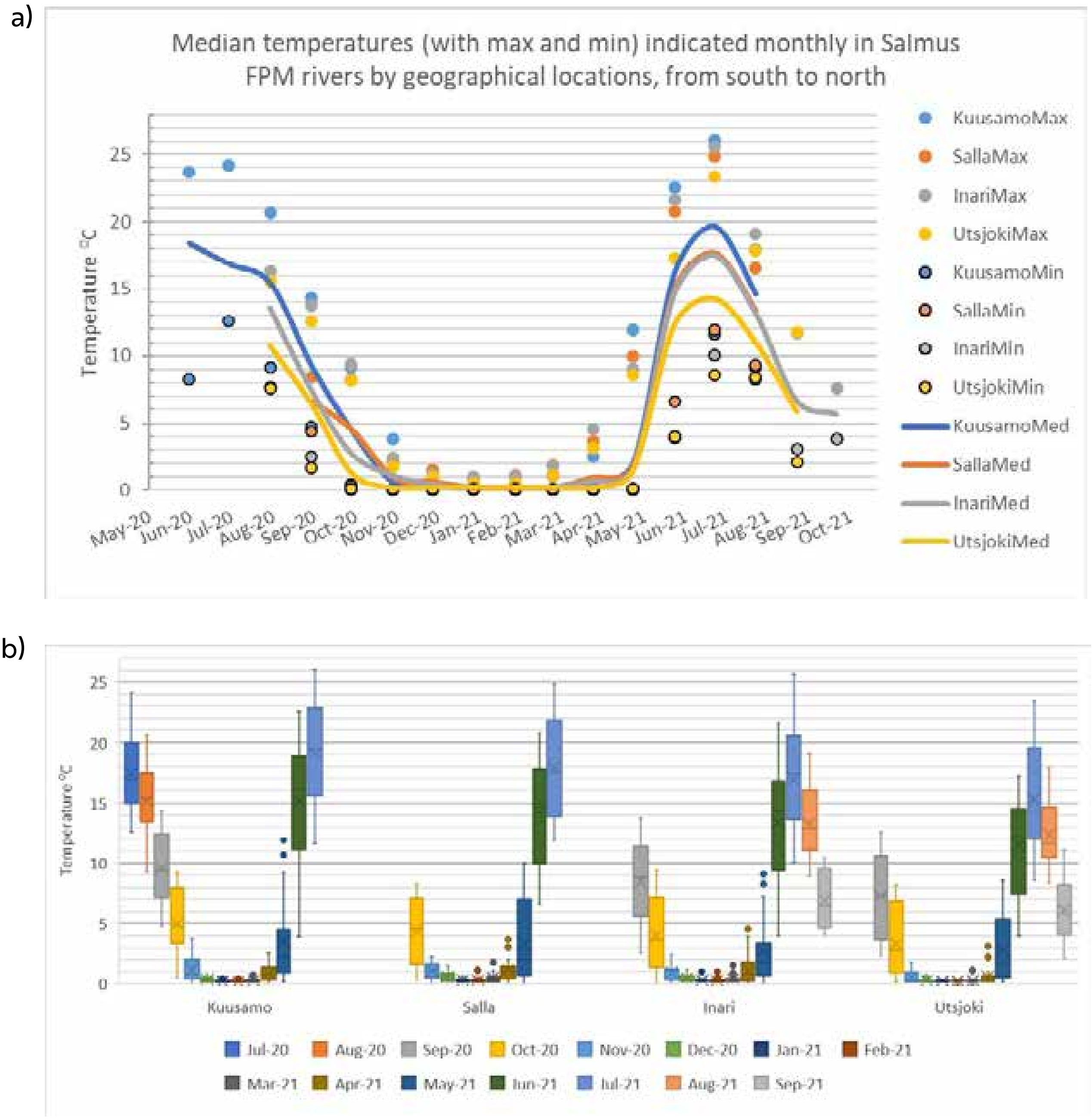

Figure 248. Project river temperatures by region and month. **a.** Water temperature medians (with max and min indicated) during logging period 2020/2021, including all data **b.** Monthly temperature fluctuations by region, full logging months indicated only. In Kuusamo and Salla region n = 4 (number of rivers logged full month). In Inari region n = 9, except Sep-20 n = 5; Oct-20, Jun-21, Jul-21 n = 8; Aug-21 n = 4; Sep-21 n = 1. In Utsjoki region n = 5, except Sep-20 n = 2; Sep-21 n = 3. Rivers logged in Inari district belong to Tuloma catchment and rivers in Utsjoki district belong to Teno catchment. Rivers in Kuusamo and Salla district belong to either Kemijoki or Koutajoki catchments.

7.4.1.1 Kuusamo region

Temperature logger data from Kuusamo region is given in Figure 249. Meskus–Väli-Juomajoki river system belongs to Kem catchment river system and shares a freshwater pearl mussel (FPM) population classified as *dying soon/non-viable/dying*, respectively. The estimated size of the population was 13,050 individuals, see the attached report "Status of the freshwater pearl mussel populations". Porontimajoki belongs to the Koutajoki catchment (with a *non-viable* FPM population, estimated population size 1,230 ind., see the report "Status of the freshwater pearl mussel populations"). Temperature loggers were installed 9.–13.6.2020 and offloaded 7.–9.8.2021. For the comparative temperature analyses only the data from August 2020 to July 2021 was used. Porontimajoki seems to cool down a bit slower in October (median temperature 5.91 °C), compared to Välijoki-Meskus-Juomajoki system (medians in October 4.0 °C, 4.1 °C, 4.8 °C, respectively), but it warms up slower in May (average 1.95 °C; Välijoki-Meskus-Juomajoki system in May 2021 3.0 °C, 3.4 °C, 2.3 °C, respectively). The highest temperature 26 °C was observed in river Meskusjoki in July 2021 and the lowest in river Välijoki from November 2020 to April 2021 with only 0.01 °C. Recorded temperature data of Mutajoki, a river 150 km more south in Kainuu region with a recruiting FPM population, is given for comparison in Figure 250. It warms up earlier in spring than Kuusamo rivers (median 9.37 °C in May 2021) but had similar temperature conditions in October 2020 (median temperature 5.4 °C).

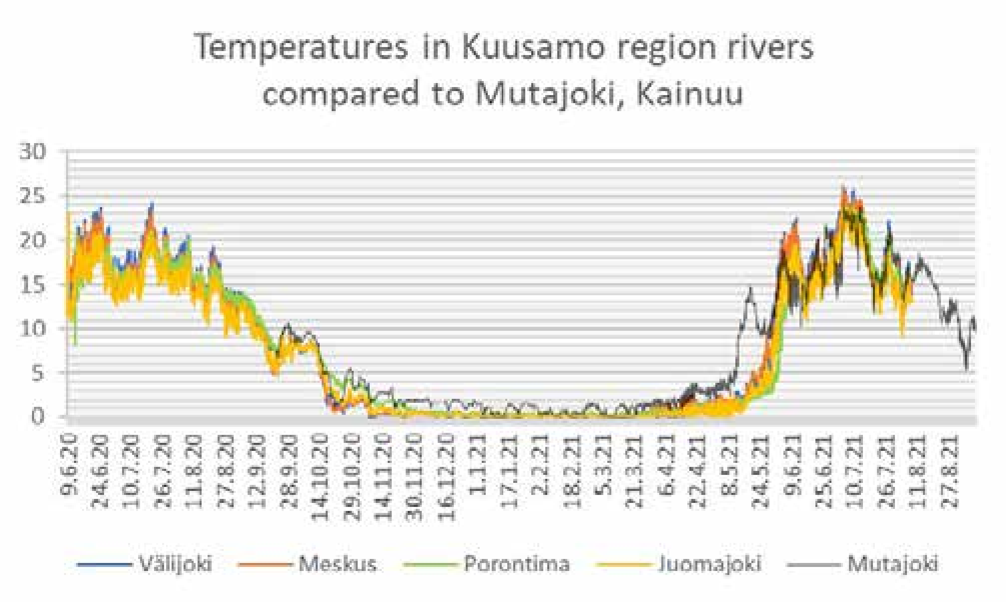

Figure 249. Temperatures in Kuusamo region rivers from logging period Jun-2020 to Aug-2021, compared to Mutajoki, a river more south in Kainuu region (logging period Sep-2020 to Sep-2021).

7.4.1.2 Salla region

Temperature logger data from Salla region is given in Figure 250. Temperature loggers were installed 18.–21.9.2020, the first data offload took place 7.–9.8.2021, so the monitoring period was slightly less than one year. Therefore, the data for this region is not fully comparable with other regions due to the incomplete annual monitoring period achieved. Myllyoja (Fig. 251) belongs to Koutajoki catchment, the other three rivers to Kemijoki catchment. Maximum temperature was observed in July 2021 in Myllyoja (24.84 °C), also July's median temperature was highest in Myllyoja (18.85 °C). In other rivers of this area median temperatures in July 2021 remained between 17–18 °C. Minimum temperatures during the wintertime were observed in Tammakkolammenoja and Ahvenoja (0.01 °C). FPM populations with recruiting FPM populations are found in Sätsijoki (*viable*, also the biggest population of these rivers, with an estimated size of 9944 FPM individuals) and Ahvenoja (*maybe viable*). Myllyoja and Tammakkolammenoja host *non-viable* FPM populations (see the annexed report "Status of the freshwater pearl mussel populations").

Figure 251. FPM area in Myllyoja. Of all the rivers monitored in the Kuusamo region, the highest temperatures were measured in Myllyoja in July 2021. Photo: Aune Veersalu.

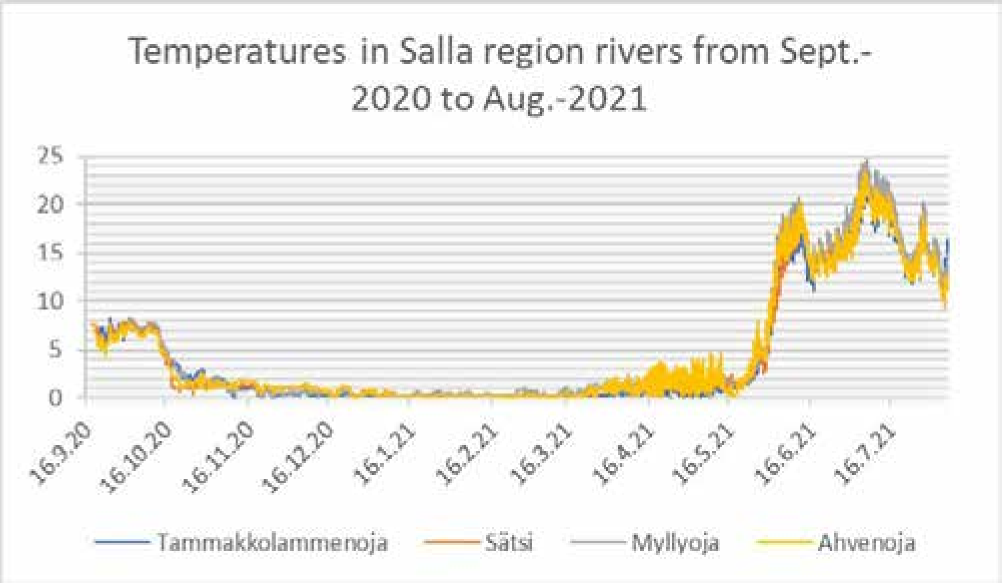

Figure 250. Temperature logger data from Salla region rivers 2020/2021.

7.4.1.3 Inari region

Rivers in Inari municipality belong to Tuloma/Lutto catchment. Altogether 10 loggers were installed to this area, 14.–19.8.2020 six loggers and 24.9.–8.10.2020 four loggers. Data was offloaded 29.–31.8.2021 and 24.9.13.10.21, respectively. One logger stopped working in May (Nohkimaoja), so whole-year data was not obtained there. Logger data from some rivers is given in Figure 252. Urakkajärvenoja is a narrow (0,5–1 m in width) brook, smallest of all streams shown in Figure 253. On the contrary, Lutto river is the biggest one in this data set, about 20–30 m wide. Nevertheless, no big differences between those two streams were detected in this data. Average temperatures of this one-year-long period were 5.86 °C in Lutto and 5.35 °C in Urakkajärvenoja, also summer temperature was a bit higher in Lutto (July median 17 °C and 15 °C, respectively).

A viable FPM population is found in Urakkajärvenoja. Maybe this brook remains cooler in the summertime due to many of its springs. It is also warmer during the winter (minimum 0.121 °C) than Vuoksioja, which partly shares the same FPM population, even though the population there is only *possibly viable* (Fig. 255). Highest summer temperatures in this area were logged in another very small creek Ristinmorostonjärvenoja (Figs 246 and 254) – 25.61 °C in July 2021 (July median being 17.44 °C). High summer temperatures occurred also in Vuoksioja – 24.26 °C in July 2021 (July median 17.66 °C). Lowest temperatures (0.01 °C) are logged in Torkojoki, Nohkimaoja and Vuoksioja (Fig. 247), nonetheless some FMP recruitment was documented in all those rivers. Large maximum temperature fluctuations in the winter were also found in Vuoksioja (see Fig. 247) and hundreds of empty shells were found there during the FPM survey in 2019. So, it is highly possible that freezing problems on the channel bottom may occur in this river (Fig. 253b).

Hanhioja is one of the best FPM rivers in Finland with a *viable* population – in fact the only one known in the *viable* category before the current SALMUS project (Oulasvirta et al. 2015). For this reason, temperature loggers were installed at the upper and the lower end of the population to detect temperature differences along the stream course. One logger was also placed in its headwater stream Ristenmorostonjärvenpuro, where an FPM population (considered though as a part of Hanhioja population) was found in 2019 and

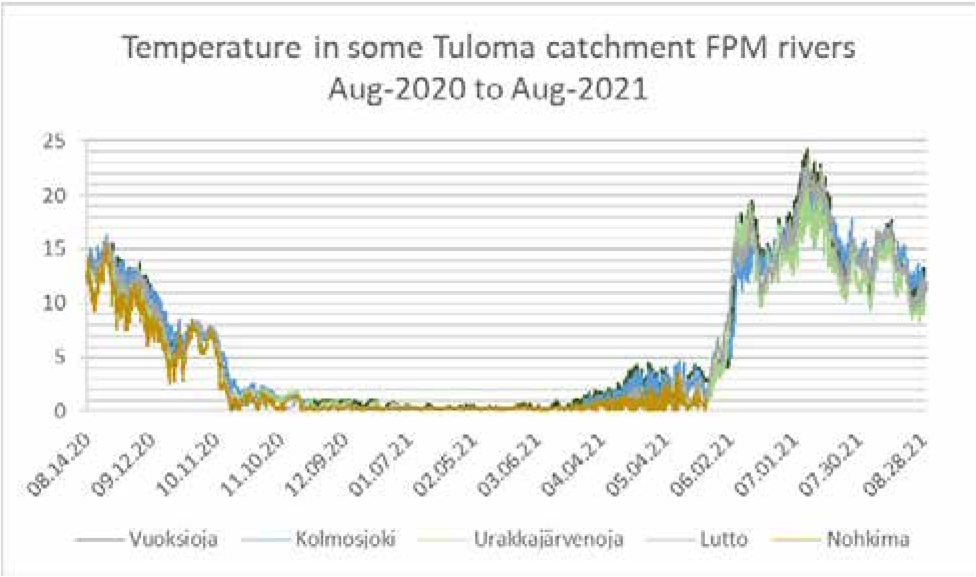

Figure 252. Temperature logger data from some Inari region rivers 2020/2021.

Figure 253. Urakkajärvenoja (**a**) and Vuoksioja (**b**) on 30.10.2019, after a period when air temperature had suddenly dropped to -20 ºC in some days. In Urakkajärvenoja water temperature was at this moment 0.1 ºC. Due to many springs, Urakkajärvenoja stays cooler during summer and warmer during winter than Vuoksioja. Mussels in Urakkajärvenoja dug deep even in summer, maybe due to the interstitial spring water (see picture a). In a bit bigger Vuoksioja with a larger headwater lake water temperature was still 0.3 ºC. A phenomenon where water flows over the newly formed ice, building up ice layers and causing bottom ice, was observed in Vuoksioja on that day (b). Photos: Aune Veersalu.

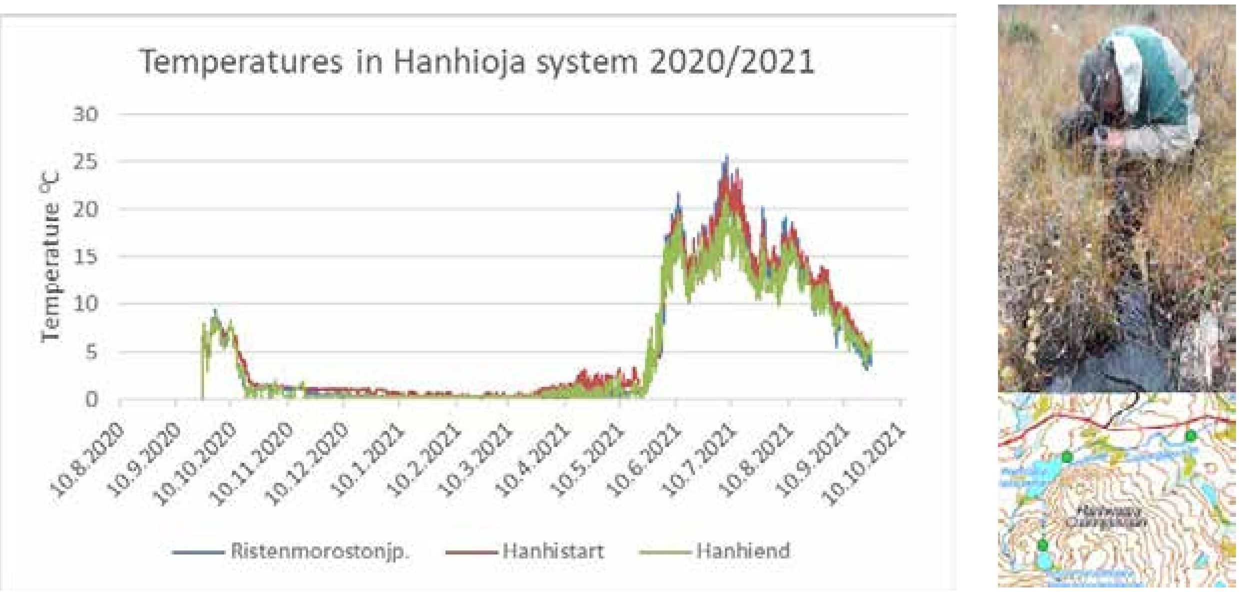

Figure 254a. Temperatures during a one-year period in Hanhioja (at the start and end points of the FPM population) and its headstream, Ristenmorostonjärvenpuro, Inari municipality. **b**. Map with loggers location (from right to left – Ristenmorostonjärvenpuro, Hanhioja start, Hanhioja end) and a picture of S.Kankaanpää (MH) trying to fit an aquascope into tiny Ristenmorostonjärvenpuro. Photo: Aune Veersalu.

the population size was assessed during current project. Results are given in Figure 254a. The upper logger of Hanhioja is situated close to the Hanhijärvi lake, where Hanhioja (and the FPM population in it) starts (Fig. 254b). Temperatures are higher there, cooling down more slowly in autumn (Oct. 2020 median at the upper end of FPM population was 4.0 °C and at lower end 2.7 °C). In spring, upper end also warms up earlier (May 2020 average at the upper end was 2.18 °C and 1.82 °C at the lower end). Median temperatures in July 2021 were accordingly 18 °C and 15 °C, maximum temperature 21.57 °C was logged in both ends. Minimum winter temperature 0.121 °C occurred at the lower end (Fig. 247). Ristinmorostonjärvenpuro is a very small stream, on average only 0,5 m wide (Fig. 254b). Even though it also has a headwater lake, it heats up in summer more than Hanhioja (see above) and cools down quicker in autumn. Nevertheless, its minimum temperatures (0.121 °C) didn't go in the winter lower compared to those observed at the Hanhioja population end point (Hanhiend, Figs 247 and 254a).

7.4.1.4 Utsjoki region

On the Finnish side of Deatnu/Teno/Tana catchment altogether five FPM rivers are known – Pulmankijoki side rivers Lovttajohka and Gálddašjohka, Utsjoki mainstem and its tributaries Námmájohka and Vuohččojohka. Temperature loggers were placed to all of them in August–September 2020. Data was offloaded in September and October 2021. The one-year data from September 2020 to August 2021 was used in comparisons (Figs 246 and 247). Temperatures from August 2020 to October 2021 are given in Figure 255. Highest temperature was logged in Námmájohka (23.38 °C in July, median 16.0 °C). July's median was anyhow higher in Utsjoki – 16.3 °C and the lowest value was recorded in Gálddašjohka (13.6 °C). Winter minimum (0.121 °C) was logged in all Utsjoki region rivers except for Utsjoki, where it was 0.232 °C. Utsjoki is the largest of FPM rivers compared in this connection, and the logger is situated next to a quite big Mierasjärvi lake so that cooling in autumn and warming in spring are much smoother than in smaller rivers.

The best FPM population of these rivers is by far found in Lovttajohka with some recruitment taking place. This river has also some headwater lakes. More downstream, Lovttajohka joins the Gálddášjohka river – a river with no lake upstream and altogether only few mussels found. Comparison of logger data from those two rivers is given in Figure 256a. No big differences were detected, probably because logger in Lovttajohka is situated also far from the head lake, almost at the lower limit of the population, due to logistic problems (Fig. 256b).

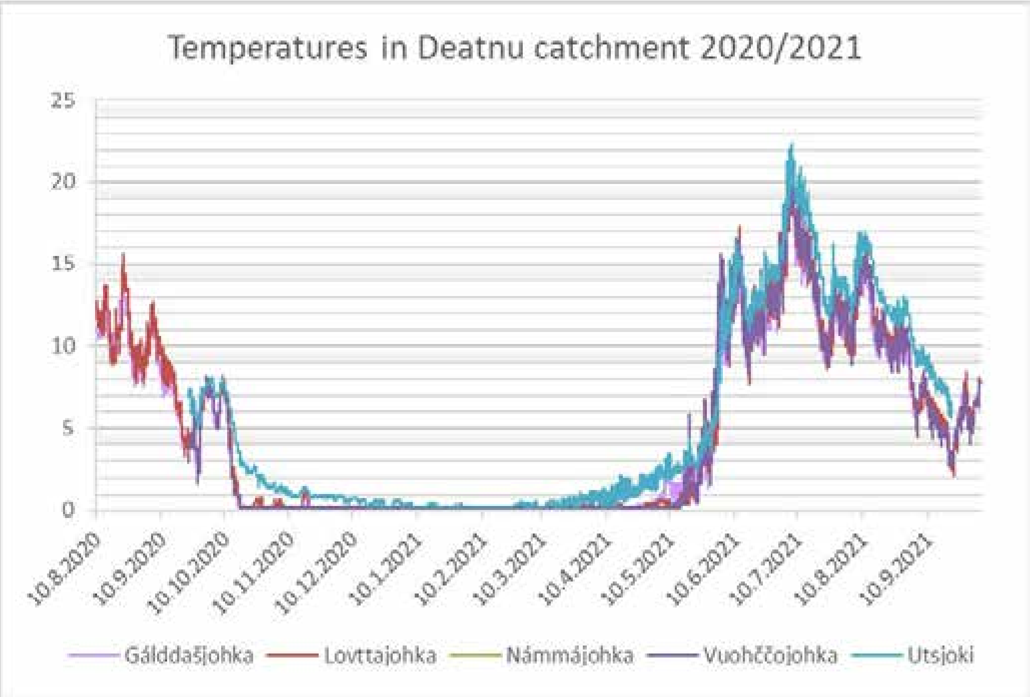

Figure 255. Temperatures in FPM rivers of Utsjoki region from August 2020 to October 2021.

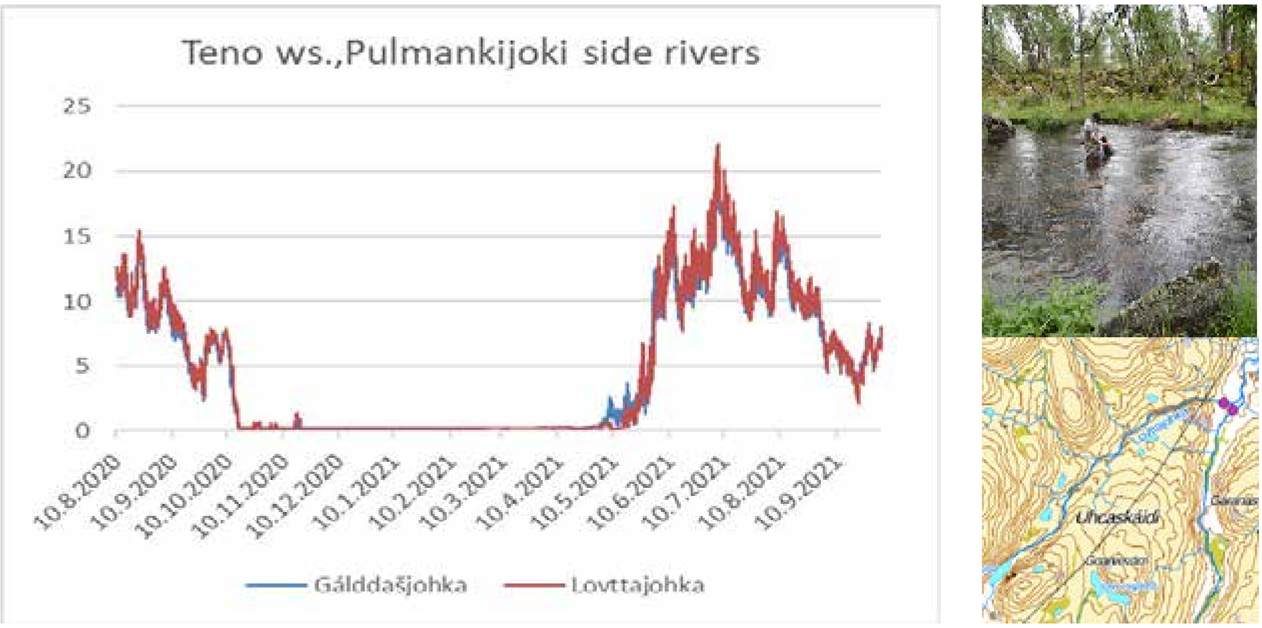

Figure 256a. Comparison of temperatures in two FPM rivers of Teno watershed. **b.** Logger locations are indicated in the map and logger place in Lovttajohka is checked by M.Hynninen (MH) in the picture. Photo: Aune Veersalu.

7.4.2 Conclusions

Freshwater pearl mussel *Margaritifera margaritifera* prefers cool oligotrophic rivers, optimal temperature limit < 25 °C is suggested by Degerman et al. (2009). Some maximum temperature peaks exceeded this limit in July 2021 (Meskusjoki 26.097 °C, Välijoki 25.71 °C, Ristinmorostonjärvenoja 25.6 °C) but average and medium monthly temperatures remained below 20 °C (highest 19 °C was met in Kuusamo region) in spite of the extremely hot summer 2021.

The overall average temperature of year 2020/2021 was in this logger data (all rivers) 5.2 °C and the median only 1.13 °C. These numbers are strongly affected by the very long-lasting low temperature period in the winter. In spring, maximum temperatures generally rose over 5 °C in May. In June, median temperatures exceeded 12 °C in Utsjoki and 16 °C in Kuusamo. In July, median temperatures ranged from 14.3 °C to 19 °C (from north to south), in August between 11 °C and 14.6 °C, and in September 5 °C and 9 °C, respectively. In October, temperatures can still exceed 5 °C but median temperatures were already lower (the highest median was recorded in Kuusamo 4.55 °C), and it was already the time when hibernation period of FPM started. According to Schmidt & Vandre (2010), some FPM growth can be observed when temperature is > 5 °C but the actual growth starts at temperatures > 8 °C (Scheder et al. 2014). So, according to this one-year data we can suggest that some FPM growth starts in May and some growth can still occur in October, but most of the important feeding and growing season in those regions takes place from June to August, slowing already down in September.

Logging period was far too short to make any well-grounded comparisons, as years can be very different and logging periods' starting and ending times also differed among different rivers, which all affected annual logging data. Much longer logging period would also be needed for conclusions about human influence or changing environmental conditions. All loggers installed to the rivers during SALMUS project continue logging and will be offloaded next time in the summers 2022 and 2023.

7.4.3 pH and conductivity measurements

Many of the rivers in the SALMUS project area are low in conductivity and hence susceptible to acidification due to local geology (Aspholm et al. 2015). Acidification of rivers takes place mostly during floods of snow-melting season in spring or in connection of heavy rain periods in summer. For FPM, pH values 6.2–7.5 are supposed to be optimal (Degerman et al. 2009). A good environment for FPM usually has low electrical conductivity. The maximum 200 µS/cm is supposed for this species, but many researchers do not allow conditions with more than 50–90 µS/cm for a reproducing FPM population (Bauer 1988, Absolon & Hruska 1999).

Conductivity and pH measurements were carried out in spring 2021 in Teno watershed (Utsjoki region) by Metsähallitus:

- 3 stations in Teno watershed FPM rivers during snow-melt acid peak (altogether 13.4.–18.6. and daily between 11.5. and 2.6.2021, Fig. 257).
- Occasional pH measurements in Teno watershed rivers during the spring flood 2021
- Altogether 114 pH measurements in 43 rivers during spring 2021.

For conductivity and pH measurements, a WTW Portable Conductivity Meter and a JBL colorimetric test (for pH 6.0–7.6) were used, as the hand-held pH meter was broken. This means that pH values less than 6 are here only suggestive and they are based solely on visual colorimetric test approximation.

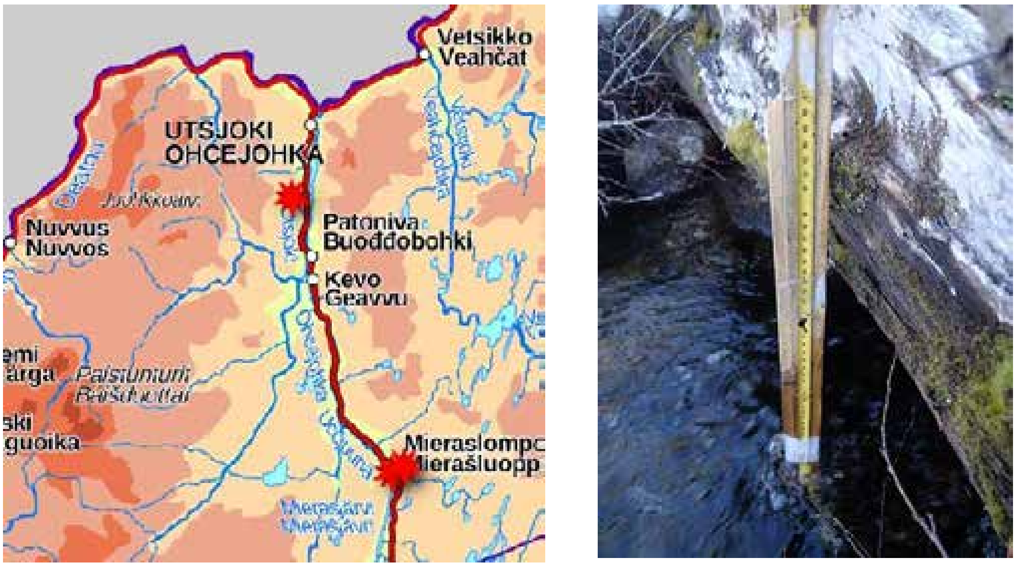

Figure 257. pH stations in Utsjoki and its tributaries Námmájohka and Vuohččojohka in spring 2021 and the water level station in Korretoja for general flood indication for the Utsjoki region. Photo: Aune Veersalu.

7.4.3.1 Results

Decreasing pH during snow-melt season in 2021 was observed in all stations (Fig. 258). In Utsjoki, pH remained above 6.2, decreasing from normal 6.8 (measured during low water seasons in previous years) to 6.25. Conductivity in Utsjoki was slightly higher compared to its tributaries, varying from 47.9 to 62.2 µS/cm. Acid peak and pH<6.0 was observed in both side rivers during the snow-melting period, but it was more serious in Námmájohka, where also lowest values for conductivity were met (29.9–41.2 µS/cm).

For comparison and for mapping the general situation in Teno watershed regarding acid peak during snow-melt season, occasional pH measurements in Teno watershed rivers were performed 18.5., 26.5. and 1.6.2021.

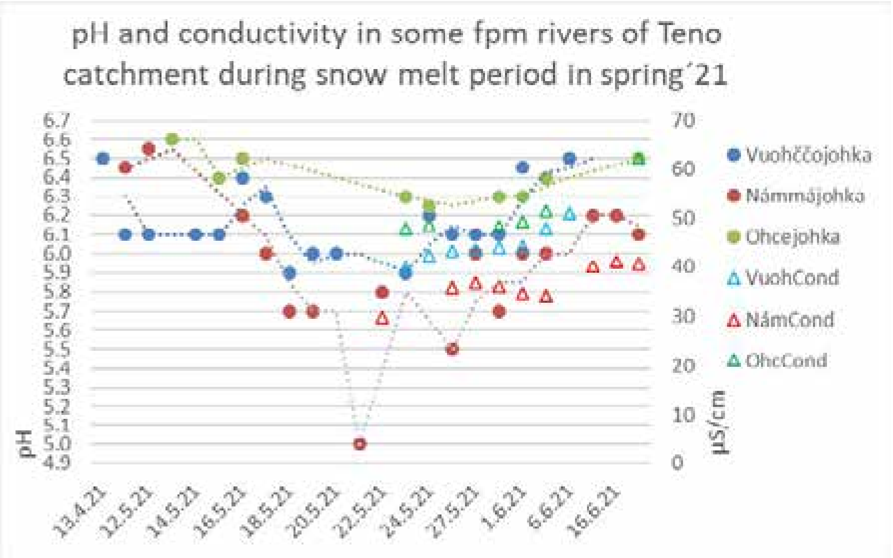

Figure 258. Conductivity and pH fluctuations in Utsjoki and its tributaries. The pH values < 6 are indicative and only for reference here.

The results indicated decreased pH in all rivers measured (Figs 259a and 259b), but these measurements did not necessarily catch the lowest acid peak nor show the actual acid peak values in those rivers. The spring of 2021 was also exceptional due to the lack of real spring flood, so the period of acidic conditions was prolonged in rivers. More detailed studies should be made to determine the current springtime acidification situation in the rivers of this region.

Acid peaks can also take place during heavy rains in summer. In Oulujoki catchment, pH < 6 was detected in some SALMUS project FPM rivers during the flood 22.–23.8.2021 (Fig. 260). Measurements during the normal water level conditions were made in only one of those rivers (Varisjoki) by JyU in 12.9.2021 showing pH value of 6.42, which is well inside the optimum range for FPM.

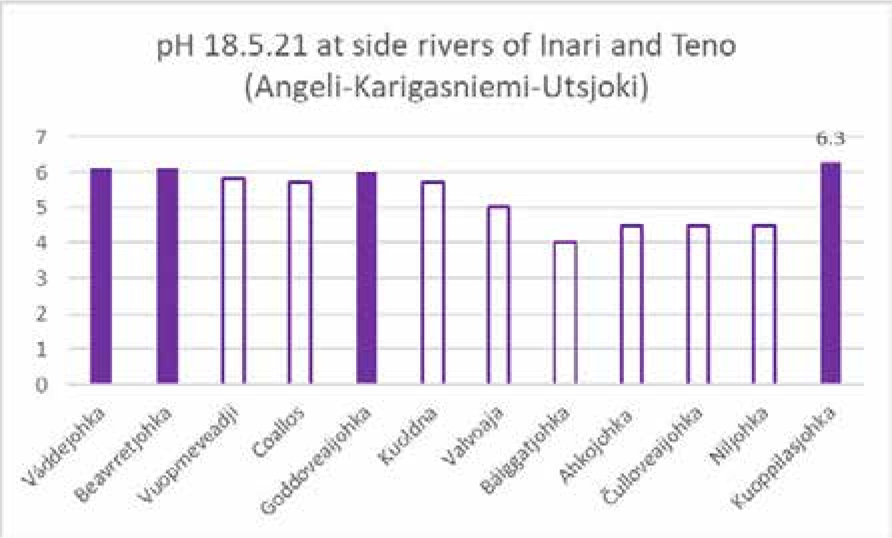

Figure 259a. Results of occasional pH measurement during snow-melting period 2021. In Áhkojohka, Čulloveaijohka and Kuoppilasjohka additional measurements were done 26.5.2021, when pH was 6.0 in all studied rivers and an additional measurement showed pH value 6.2 for Bađđá.

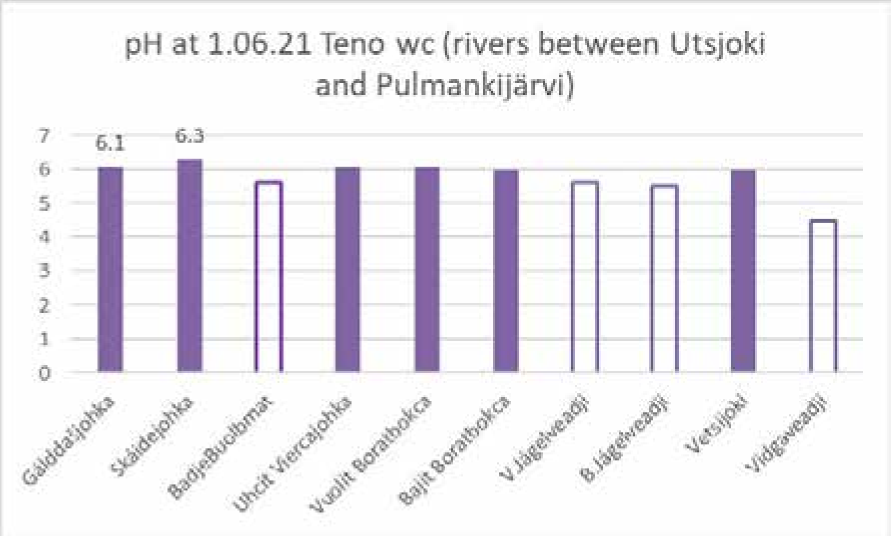

Figure 259b. Results of occasional pH measurement during snow-melting period 2021. Empty columns (values pH <6.0) are not exact due to the method used.

Figure 260. During a flood period after heavy rains in 22.-23.8.2021, pH value < 6.0 was measured in Lahnajoki, Korpijoki, Leväjoki and Varisjoki in the Oulujoki river catchment, Kainuu region.

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8 Ecosystem services and values of freshwater ecosystems and species living in them

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8.1 Background

Freshwater ecosystems have undergone severe global declines and are therefore widely considered to be among the most threatened environments (IPBES 2018, Gozlan et al. 2019). While freshwater ecosystems cover only about 2% of the Earth's surface, biological and phylogenetic diversity is comparatively high (Román-Palacios et al. 2022) and inland capture and aquaculture provide > 40% of world's reported finfish production (Lynch et al. 2016). In addition, freshwater ecosystems deliver many ecosystem services (ES) to humans, but research on them remains limited (Hanna et al. 2018, Kaval 2019) and these habitats are neglected in international policies, like the United Nations Sustainable Development Goals (SDGs; Lynch et al. 2020, Elliott et al. 2022). Thus, research on freshwater ecosystems in general and in particular ecosystem services and values, is highly warranted to close knowledge gaps and provide policy makers and natural resource managers with a better understanding of the various ecosystem services provided by freshwater ecosystems that are in congruence with the SDGs in order to ensure sustainable use of freshwater resources and avoid further negligence in freshwater conservation (Vári et al. 2022). Exploration of ecosystem services and values may clarify connections to social-economic conditions as well as personal motivations for inland watercourse preservation. Recent systematic assessments showed that studies focussed on freshwater ecosystem services and values are relatively rare and more extensive projects on freshwater ecosystems were just recently implemented (Hanna et al. 2018, Kaval 2019, Langhans et al. 2019, Podschun et al. 2018).

The ecosystem service concept was originally introduced to demonstrate the benefits provided directly or indirectly by natural habitats to humans and to increase awareness of the importance of biodiversity and its conservation (Daily et al. 1997, Birkhofer et al. 2015). Through the years, the concept has undergone a transition from valuing ecosystem services primarily in monetary terms of economically important species (Martín-López et al. 2014) towards more function-related assessments that distinguished between three main types of ecosystem services (Millennium Ecosystem Assessment 2005). For freshwater ecosystems, up to 32 ecosystem services have been found through systemic reviews (Hanna et al. 2018, Kaval 2019), for example:

1. Provisioning services: food, wood, water;
2. Regulating services: flood regulation, climate regulation;
3. Cultural services: spiritual and recreational ecosystem services.

Nonmonetary ecosystem services and services that have no material benefit to humans (e.g., existence value of biodiversity, sentimental value of a place or memories, and educational value) have been studied even less in freshwater ecosystems. There has been a call for better integration and emphasis on non-monetary values in ecosystem assessments to achieve more holistic freshwater assessments (Vári et al. 2022). This may also involve the inclusion of different stakeholder groups and socio-cultural preferences (e.g., indigenous communities; Martín-López et al. 2012, Vári et al. 2022). Questionnaires have been increasingly used for this purpose as they allow surveying different societal and interest groups (Ebner et al. 2022, Getzner 2020, Schmidt et al. 2017). Here, we decided to use a questionnaire to ask different stakeholders in the community of the Fennoscandian Greenbelt, where 90% of viable freshwater pearl mussels (*Margaritifera margaritifera*) are found, about their perceptions, attitudes, and values towards this and their salmonid host species, the Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*). We were especially interested in characterizing non-monetary and non-use ecosystem service values as these have been traditionally understudied. In connection to this, we decided to develop the online questionnaire because the project was significantly impacted by the coronavirus pandemic and this way, we were able to reach a comparatively high number of people that we could otherwise have not reached under the circumstances. This was also done because spatial scaling has been identified as another key issue for freshwater ecosystem service assessment and multiple-scale assessments, including transboundary work, have been suggested to retrieve meaningful ecological results (Kaval 2019, Vári et al. 2022). The use of a questionnaire approach may allow for statistical analysis across and within jurisdictional boundaries if enough persons can be reached.

Formal and informal education and nature-based, cognitive recreational activities like nature viewing, walking, and swimming, are barely considered in ecosystem service assessments (Mocior & Kruse 2016). These experiences are important because they may contribute to knowledge transfer from scientific to popular knowledge as well as raising awareness on environmental issues among the general public (Mocior & Kruse 2016). Education and recreational activities can therefore contribute to sustainable use of river ecosystems and preservation of nature and educational ecosystem services. Indirectly, they may also contribute to human well-being and health. However, often the educational value is assessed by teachers and researchers (Mocior & Kruse 2016). Here, we were interested to study whether different societal groups attribute an educational value to rivers and species that live in them.

Another issue with ecosystem service assessments is that they often focus on one economically relevant key species or species complexes, especially, if a monetary evaluation is conducted (Blicharska & Rönnbäck 2018, Butler et al. 2009). However, this neglects the importance of biodiversity and species interactions in the ecosystem that are significant for ecosystem health and leads to one-sided conservation and management strategies (e.g., stocking of fish species may be relevant to anglers without consideration of impacts on other species). Understanding and knowledge of ecosystem services of certain species may vary widely between stakeholders, resulting in biased perceptions of valid management options. This also leads to conservation and management strategies focussed on specific species rather than protection of the ecosystem as whole. The ecological value of non-economically exploited species is often ignored (however, see Doyle et al. (2014) for an example on jellyfish). Further, assessments often focus on single, direct use values, which ignore the complexities of ecosystems (Scholte et al. 2015). Here, we attempted to address some of the abovementioned issues to gain deeper insight in the valuation of ecosystem services in freshwater ecosystems.

8.2 Material and Methods

8.2.1 Questionnaire development

We developed an online survey on the SurveyXact platform (https://www.surveyxact.no/) to assess the perceptions and attitudes of people of different societal backgrounds towards freshwater ecosystems and some species that live in them. We included questions and statements that covered a wide range of ecosystem services that encompassed the three abovementioned types of ecosystem services but put an emphasis on generally neglected and understudied socio-cultural ecosystem services.

The questionnaire consisted of several 10-point Likert scale statements regarding freshwater species like Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*), the two main host species of freshwater pearl mussels (*Margaritifera margaritifera*). For the latter, some questions were included as well. A few statements were adjusted from previously published questionnaires for our purposes (Liu et al. 2019 – on sea trout; here some statements used for brown trout and Atlantic salmon to be comparable in the same study). This was done because we aimed to assess different stakeholder groups and demographics and therefore, some of these statements have not been assessed previously for these groups. Statements concerning management were developed to capture potentially competing interests and preferences among respondents from different social backgrounds and work sectors. We also expected that demographics could influence the answers and therefore, we collected information on gender, age, geographical location in relation to the nearest river and town/village as well as whether respondents live in a rural area or urban area. This may also allow for the assessment of spatial differences in perceptions and attitudes across spatial scales.

Several questions/statements were included in the questionnaire that asked about potential educational and learning benefits of different freshwater species and biodiversity in general as well as educational aspects of angling. Also, other aspects like whether people would attend outdoor excursions in form of guided tours and if they would recommend such events to others, were asked to assess the educational potential and value of freshwater systems and some species that live in them.

Although a stronger emphasis was placed on exploration of socio-cultural ecosystem services and their values to stakeholders, we also included a contingent valuation method (CVM, Whitehead & Haab 2013) in form of willingness-to-pay (WTP) to evaluate economic values of freshwater ecosystem services. It is typically used to estimate demand for services that are not economically traded. Here, we included two WTP questions that a) asked participants to value a guided tour to learn more about freshwater ecosystems and some species that live in them (ES: educational value), and b) inquired how much respondents would be willing to pay/donate for river restoration in their residence area to increase the occurrence of freshwater pearl mussels (ES: biodiversity). The choice to ask about the freshwater pearl mussel in this context was made because less is known about potential economic values for this species than, for example, fish species.

The questionnaire was first developed in the SALMUS working group and then sent to affiliated parties for additional input and as a pilot study. The survey was translated into eight languages: English, Norwegian, Finnish, Swedish, Russian, northern Sami, Skolte Sami, and Lule Sami. The language selection was based on the main languages spoken in the study area (i.e., Greenbelt of Fennoscandia), including some of the larger indigenous languages in the area. Northern Sami is spoken by approx. 90% of the Sami people and Skolte Sami is comparatively widespread in northern Finland. The questionnaire was first written in English and then translated into the different languages by either native speakers from the research team or professional translators.

8.2.2 Distribution of questionnaire

Distribution of the survey was achieved by various channels to reach different (Table 26). For distribution of the online version, a project internet site was created on NIBIO's website, which included an online link to the survey. This link was also distributed by email to potential interest groups like Angler associations and others (for details, see Table 26). Additionally, the link was distributed on social media like LinkedIn and Twitter.

We anticipated that local communities with an on average older population will have less access to these channels and therefore, we also prepared > 2,500 print copies of the survey which were distributed to local schools, mailboxes in Sami villages, library busses in north-eastern Finnmark (Norway) and northern Finland, and supermarkets and libraries in Kirkenes (Finnmark, Norway). The questionnaires were distributed in envelopes with stamps on them so that participants could easily send the questionnaires to NIBIO Svanhovd. The first page of the document included instructions and contact details.

8.3 Results and Discussion

The collection of answers is ongoing because we are still continuously receiving filled-in questionnaires from the distribution of printed copies to local communities. Therefore, the here presented results are preliminary and an update of this report will be published as a scientific article later. The here presented data are based on the online answers received as of May 2022. We currently have an additional > 150 printed (partially) filled-in questionnaires from the Fennoscandian Green Belt that will be added to the final analysis.

Table 26. Distribution of the survey.

Distribution channel	Link/website
NIBIO website	www.nibio.no/ecosystem-services-survey
European Greenbelt website	https://europeangreenbelt.org/news/news/we-need-your-help/
INTERACT	https://eu-interact.org/share-your-knowledge-on-freshwater-pearl-mussels-and-salmonids/
Approx. 2,500 printout copies distributed to library busses in north-eastern Norway and Finland and local Sami villages as well as local social meeting points	http://bibliotekbussen.no/
Approx. 200 printout copies given to library in Kirkenes and local supermarket	-
Email newsletters: ECO-LOG CONFREMUS network	https://www.cost.eu/cost-action/conservation-of-freshwater-mussels-a-pan-european-approach/
LinkedIn – posted twice (by NIBIO and by Cornelya Klütsch)	https://www.linkedin.com/in/cornelya-fc-kl%C3%BCtsch-3443491a/recent-activity/shares/
Twitter: Swedish Infrastructure for Ecosystem Services NIBIO Svanhovd Twitter account IUCN European Regional Office	-
School visits in northern Norway	-
Email to Hunting and Angler Associations in Finland, Norway, and Sweden	-

In total, 283 responses were obtained through the online website (www.nibio.no/ecosystem-services-survey; Fig. 261). Of those, 167 person (59%) completed the survey, 66 persons (23%) partially completed the survey, and 50 persons (18%) received the survey, but did not answer any questions.

8.3.1 Demographics, educational and occupational background, geographical background of participants

The pool of respondents consisted of 96 men (56%; Fig. 262), 67 (39%) women, 5 (3%) preferred not to answer this question, and 2 (1%) identified as a different gender.

The age distribution of respondents indicated that about 2/3 (66%) of the respondents were between 30–59 years old with fewer respondents being younger or older (Fig. 263).

Concerning the geographical distribution of participants, roughly 1/3 each lived in rural, rural-urban, or urban areas (Fig. 264). Future analyses will look at whether there is a connection of the geographical origin of respondents to their perceptions, attitudes, and values.

Regarding the country of origin, most respondents came from the primary target region of the Fennoscandian Green Belt (i.e., Norway 37%, Finland 29%, Sweden 9%, and Russia 1%; Fig. 265). Unfortunately, due to the geopolitical situation with Russia, no more answers could be collected from there. Future analyses will focus on the question whether answers differed between countries in this region and outside of the target region.

The majority of respondents also provided additional information on their proximity to the closest river and village/town they are living, which may give further insight into regional patterns.

We also asked participants about their highest educational degree (Fig. 266) and their occupational field (Fig. 267). Regarding the former, many respondents held an

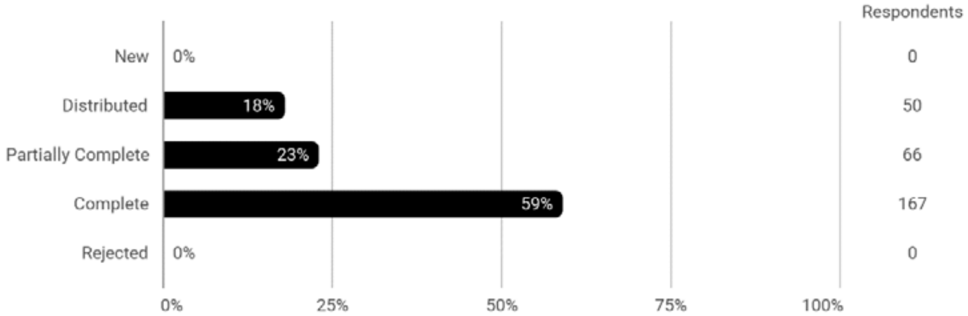

Figure 261. Statistics of reply rate for the online version of the survey.

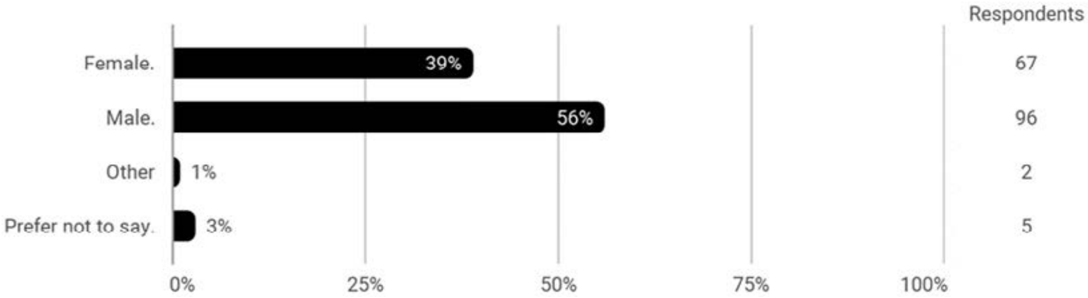

Figure 262. Gender statistics.

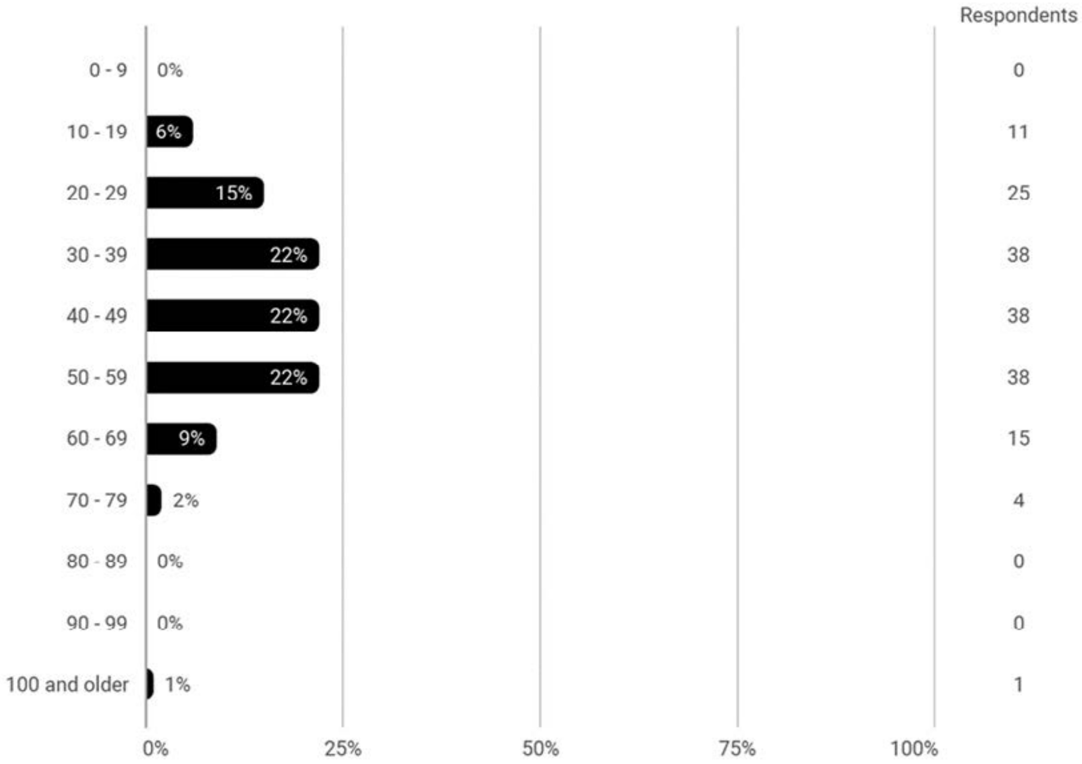

Figure 263. Age statistics of respondents.

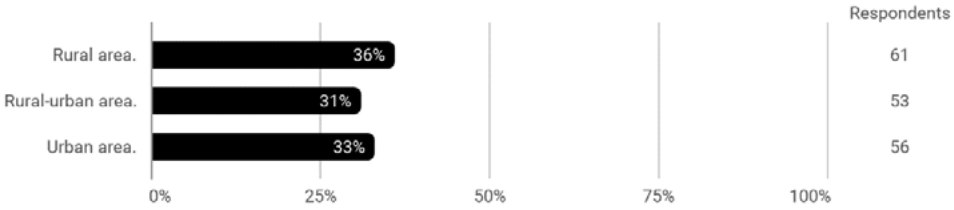

Figure 264. Geographical distribution of respondents in relation to proximity to urban areas.

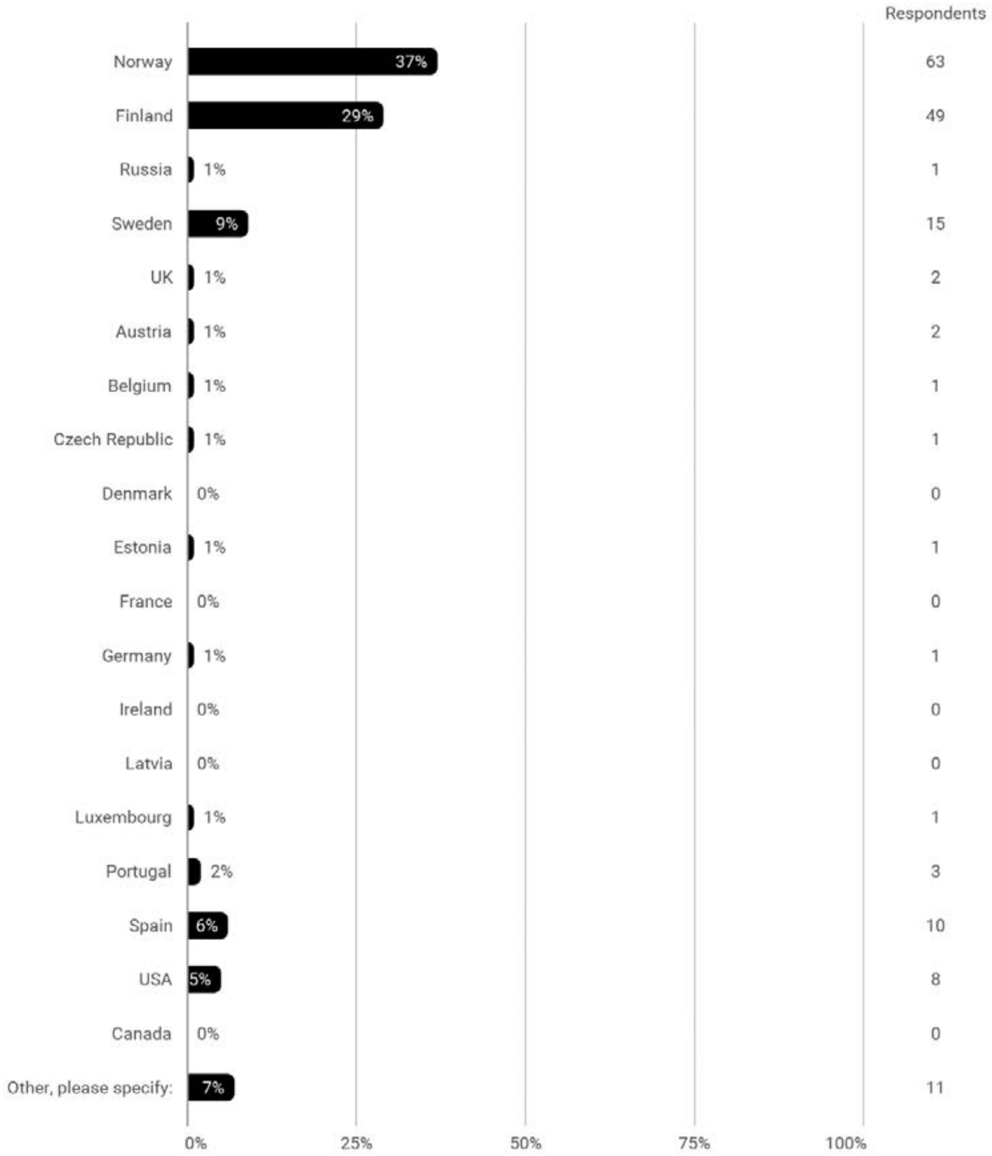

Figure 265. Geographical origin of participants based on country.

advanced university degree (i.e., Master's 38% or PhD 27%). This reflects on one hand the fact that northern European countries have a high percentage of people pursuing a college/university degree (e.g. approx. 35% of Norwegians have a college/university degree; https://www.cost.eu/cost-action/conservation-of-freshwater-mussels-a-pan-european-approach/). In addition, we expected a bias towards higher educational degrees in the online version because this was distributed to professional freshwater networks like the CONFREMUS COST action network. Again, the distribution of print copies to local communities is anticipated to reach other demographics with additional occupational backgrounds. The local distribution of questionnaires will also increase the proportion of respondents from the Sami community. Nevertheless, already now the results show that different stakeholder groups (academics, natural resource managers, public) were covered by the questionnaire, which will be used in future analyses to test whether perceptions and attitudes towards freshwater ecosystems and species as well as if preferred management recommendations differ among stakeholder groups.

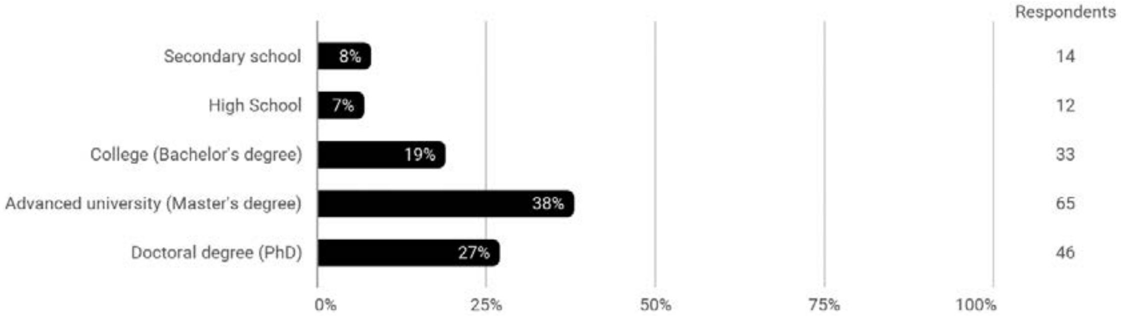

Figure 266. Highest educational degree among respondents.

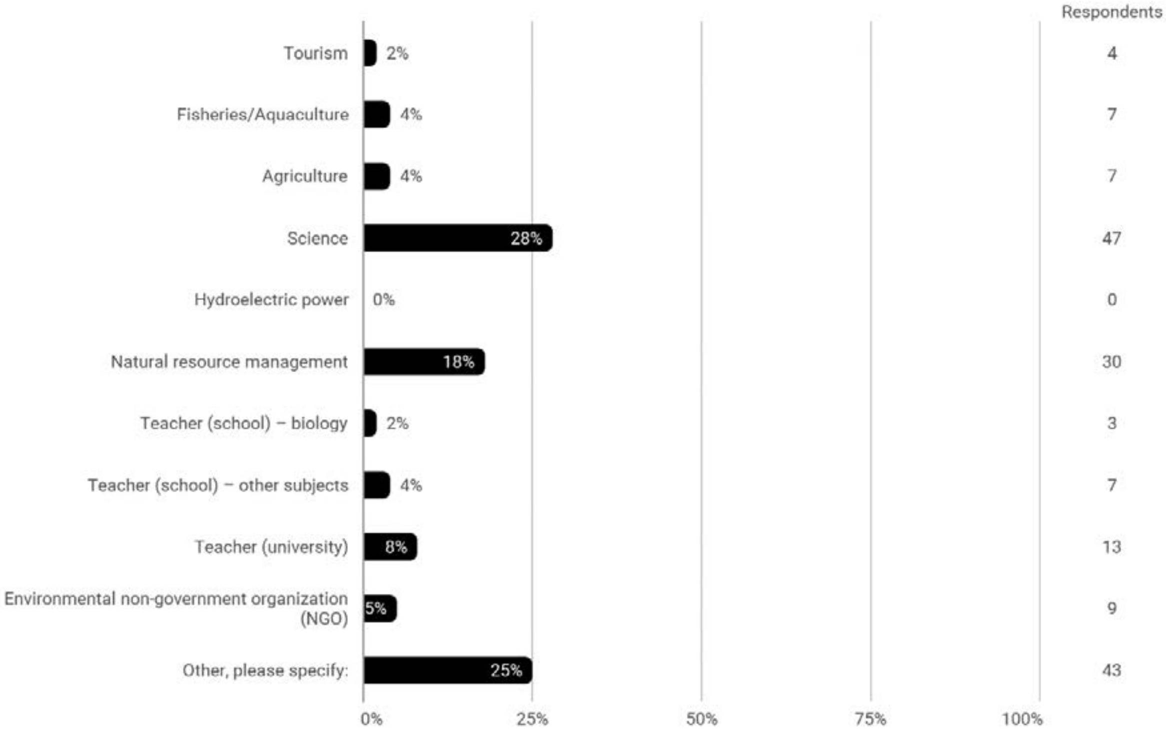

Figure 267. Professional work sectors and occupations by questionnaire participants.

8.3.2 Freshwater fish and ecosystem services

The second part of the questionnaire was dedicated to people's perceptions, attitudes, and use of two freshwater fish species, Atlantic salmon, and brown trout, commonly found in (northern) freshwater systems. At the same time, these species are very important for the life cycle of the freshwater pearl mussel, the third surveyed freshwater species.

Most respondents did go fishing/angling (73%; Fig. 268), while only about a quarter (27%) of participants did not. Of those that go out fishing/angling, the majority (50%) go one or a few times per year.

In the following, we present the results of Likert scale statements for the two fish species studied. On each Likert scale, the value 1 corresponded to 'Strongly disagree/Not true' while 10 corresponded to 'Strongly agree/True'.

For both fish species, participants agreed strongly or somewhat with the statement that these fish species (Atlantic salmon: 78%, brown trout: 72%, respectively) are an important part of our cultural history and traditions (Fig. 269a and b).

Regarding the importance of the different fish species as regular food items, the results were similar for both fish species, with Atlantic salmon (40% strongly or somewhat agreed with the statement) slightly preferred and/

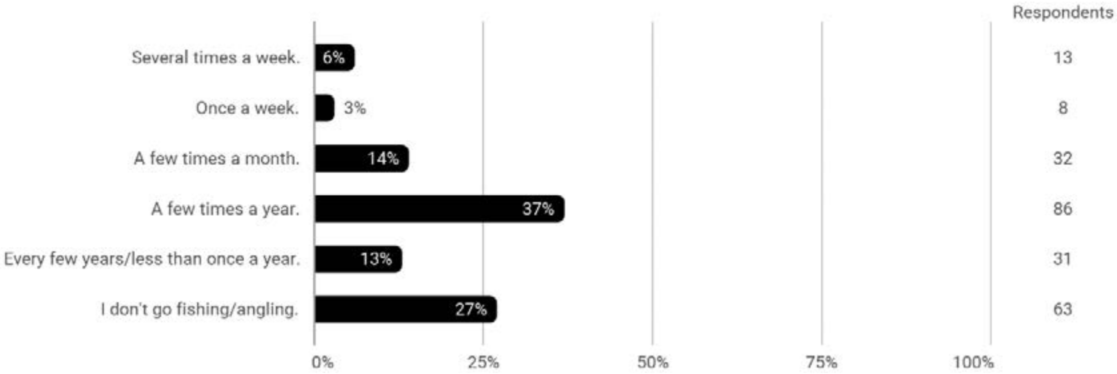

Figure 268. Overview of how often participants go fishing/angling.

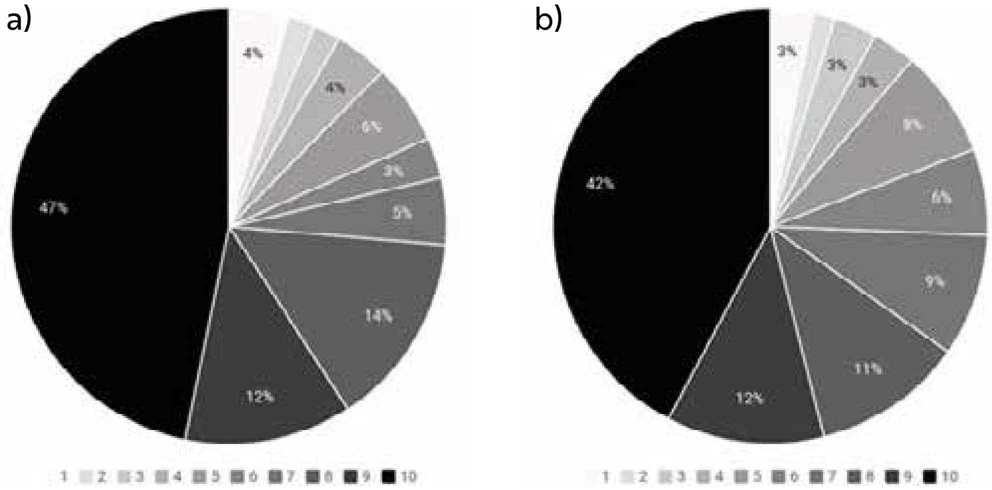

Figure 269. Evaluation of the statement a) Atlantic salmon is an important part of our cultural history and traditions, and b) Brown trout is an important part of our cultural history and traditions.

or more commonly considered as a daily food item than brown trout (27% strongly or somewhat agreed with the statement) (Fig. 270). Future analyses will focus on assessing whether there are regional and demographic differences among respondents in their regular fish intake.

However, for most respondents, the two fish species had no spiritual or religious meaning (Fig. 271a and b) with about 74% (Atlantic salmon) and 72% (brown trout) of respondents replying that they only agreed weakly or not at all with the statement.

Concerning the importance of recreational fishing for the local tourism industry, there were similar results for both fish species, with 60% of respondents replying that Atlantic salmon contributes somewhat or very strongly to the local tourism industry (Fig. 272a). Similarly, for brown trout, 54% of respondents answered that recreational fishing contributes to local tourism industry somewhat or strongly (Fig. 272b). In Finland, the northern region of Lapland has been identified as a preferrable recreational angling region where active anglers spent

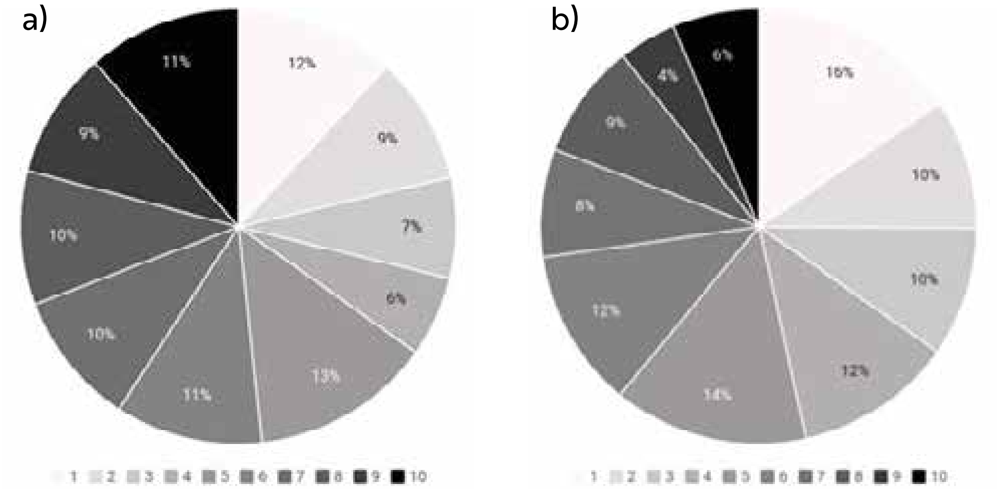

Figure 270. Evaluation of the statement a) Atlantic salmon is an important daily food item, and b) brown trout is an important daily food item.

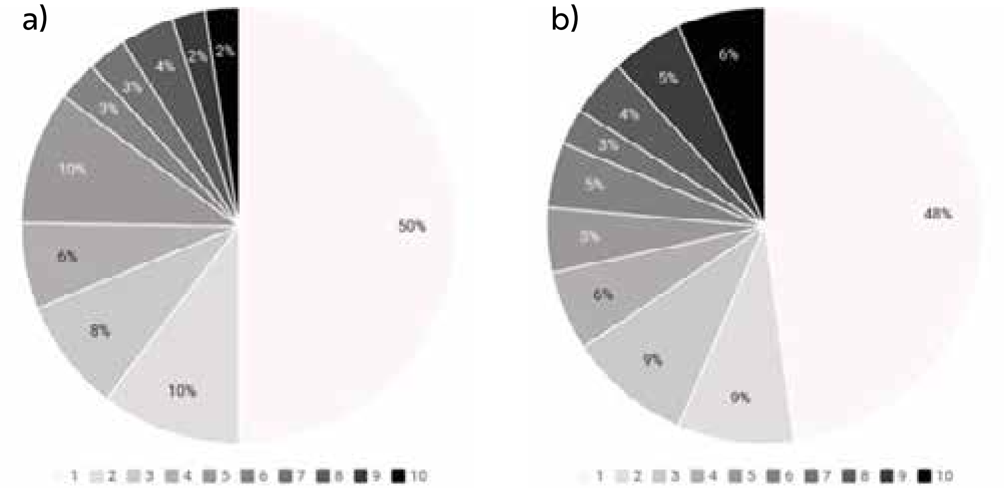

Figure 271. Evaluation of the statement a) Atlantic salmon has spiritual and/or religious meaning for me, and b) brown trout has spiritual and/or religious meaning for me.

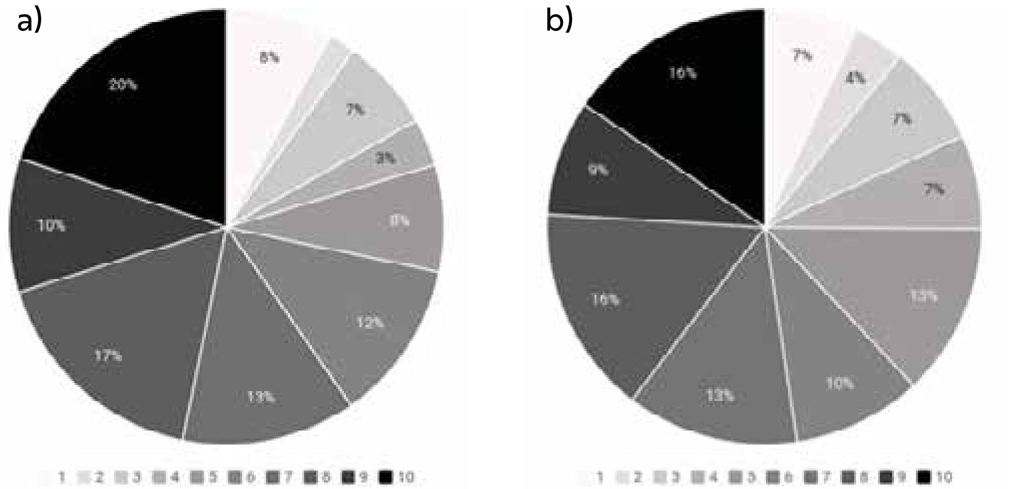

Figure 272. Evaluation of the statement a) Recreational fishing of Atlantic salmon contributes to the local tourism industry, and b) Recreational fishing of brown trout contributes to the local tourism industry.

more fishing days than in southern regions in Finland. This may be partially reflected in the obtained results because the core region of the survey was in northern Norway and northern Finland. However, relatively speaking, fewer fishing days are spent on Atlantic salmon and brown trout in (northern) Finland (Pokki et al. 2021). In Norway, the consumption of goods and services related to recreational angling has been estimated to be 129 million Euro (Andersen & Dervo 2019).

However, when looking at wealth creation of commercial fishing, only about 34% of respondents thought that Atlantic salmon (Fig. 273a) and 21% that brown trout (Fig. 273b), respectively, contribute to this somewhat or strongly. These results probably reflect the recent decline of commercial fishing in Norway and Finland. Here, the number of licensed fishery instruments (i.e., net and traps) declined by one-third from 2007 to 2017 (Myrvold et al. 2019). The number of active salmon fishermen at sea dropped by approx. 75% from 3,600 in 1993 to 900 in 2013 (NASCO 2014). Nevertheless, 290 tons of Atlantic salmon were reportedly caught in 2018 (ICES 2018). In Finland, local fishermen (mainly Sami people) catch about 7,000 kg in the border rivers Teno and Näätämöjoki with net and traps (Myrvold et al. 2019). Similarly, rod fishing days declined by approx. 19% (900,000 to 730,000). Due to new fishery agreement between Finland and Norway, the number of fishing days in the river Teno (Finland) decreasing from 32,000 in 2016 to 10,000 in 2017 (ICES 2018). With additional incoming data, we hope to gain further insight into this matter concerning perceptions of specific societal and geographical groups.

When asked if the two fish species are important for the health of the river ecosystems, more than 80% (Atlantic salmon: 86%; brown trout: 84%, respectively) of respondents agreed somewhat or strongly with this statement, indicating that there is a recognition of the importance of freshwater fish species for ecological functions in aquatic ecosystems (Fig. 274).

Concerning the educational value of Atlantic salmon and brown trout (Figs 275a and 275b), similar results emerged from the questionnaire answers. More than two-third of contributors (Atlantic salmon: 71%; Fig. 274a; and brown trout: 72%, respectively, Fig. 275b) thought that humans can learn a lot or something from these fish species. About 15% of respondents remained neutral towards

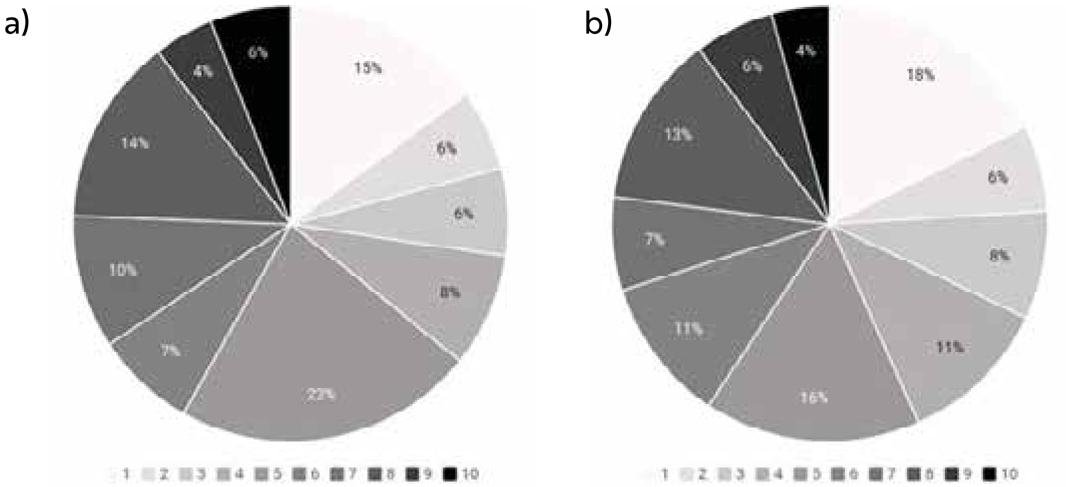

Figure 273. Evaluation of the statement a) Commercial fishing of Atlantic salmon contributes to wealth creation, and b) Commercial fishing of brown trout contributes to wealth creation.

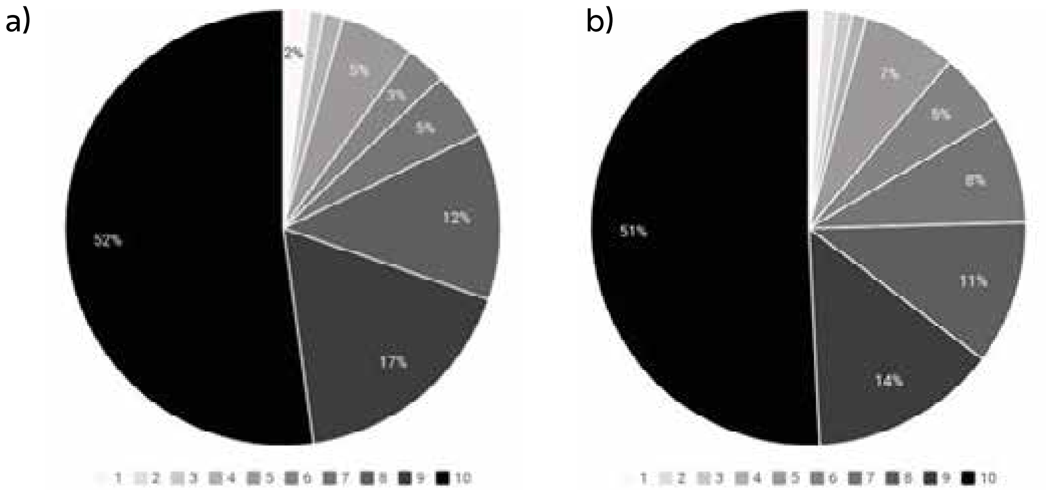

Figure 274. Evaluation of the statement a) Atlantic salmon is important for the health of rivers, and b) brown trout is important for the health of rivers.

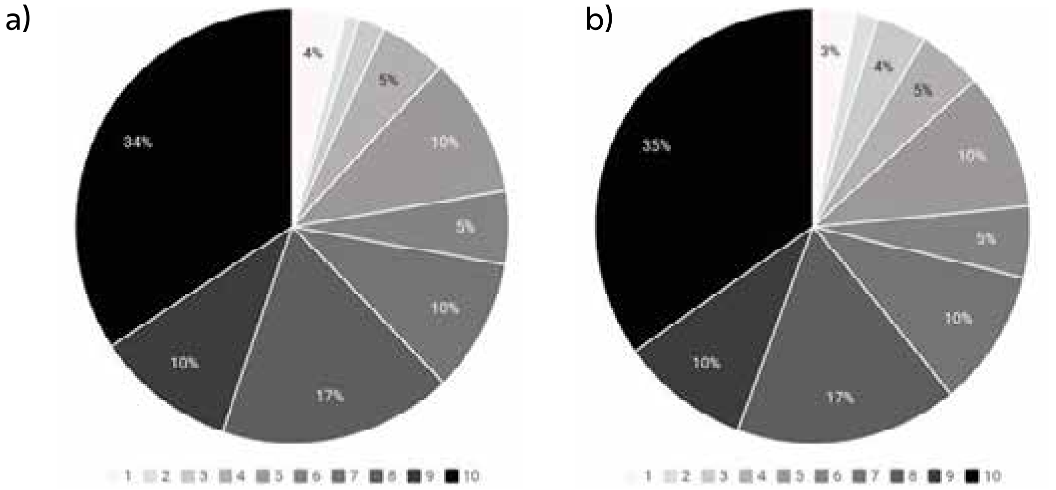

Figure 275. Evaluation of the statement a) We can learn a lot from Atlantic salmon, and b) We can learn a lot from brown trout.

this statement, and the remaining 13–14% disagreed strongly or somewhat with the statement and thought that these fish species do not provide an educational value.

Regarding the existence value, a large majority of participants strongly or somewhat agreed that both fish species have an intrinsic value as species (Atlantic salmon: 83%; Fig. 276a; brown trout: 83%; Fig. 276b). About 12–13% of respondents neither agreed nor disagreed with the statement while only a small minority (Atlantic salmon: 5%; Fig. 276a; brown trout: 4%; Fig. 276b) strongly or somewhat disagreeing with the statement.

We also offered a comment field prompting contributors to elaborate on why some of the abovementioned statements are important or not important to them. Here, we present a few of the replies as they give further insight into people's perceptions and attitudes.

One person replied:

> *'Many freshwater fish populations are struggling, and they are a key part of the ecosystems. I wish more attention was placed on restoration for restoration's sake rather than just game fishing. But usually, you need public engagement to fund restoration, so it is a complex balance.'*

This participant points out the importance of restoration to achieve a more natural state of the ecosystem rather than with the goal of furthering human interests, like game fishing. This suggests that the respondent appreciates the value of the ecosystem and its species themselves without the need of being beneficial for humans. However, the person also recognizes the importance of public engagement to advance restoration initiatives and that there are difficulties to keep engagement without there being benefits for certain interest groups. This is certainly connected to aspects being later asked about in the questionnaire, like different stakeholder engagement (e.g., Should all voices be heard in the development of management plans).

Another replied:

> *'Anadromous fish show the condition of our waterways. As has unfortunately been shown over a long period of time, we are losing our watercourse affiliated species due to poor management in combination with an uncontrolled aquaculture industry. Our watercourses and their species are important for me and us because it gives a natural pleasure to experience.'*

This person mentions two potential factors for degradation of natural watercourses:

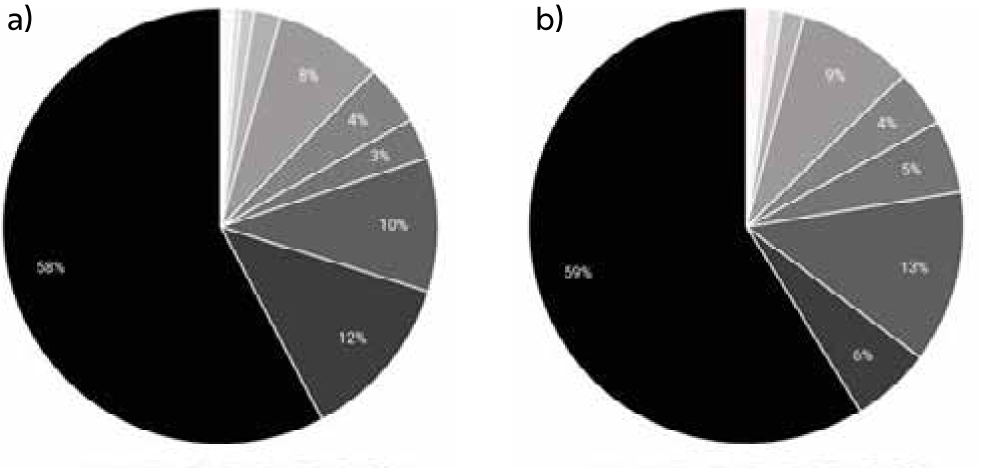

Figure 276. Evaluation of the statement a) Atlantic salmon is important in and of itself for its existence, and b) brown trout is important in and of itself for its existence.

inadequate management and lack of control of the aquaculture sector. This statement contains therefore two aspects that have not been explicitly asked about in the questionnaire and thus, provide further insight. Like the first person, this person also emphasizes nature itself to be pleasurable and therefore, valuable.

A third person commented:

> *'Tourism destroys the coziness and tradition of fishing.'*

This respondent perceives tourism as a disturbance for local traditions of fishing and the feeling they connect with those traditions. Research indeed shows that tourism can have negative effects on local traditions and cultural values (e.g., Sroypetch 2016, Zhuang et al. 2019). Thus, a careful balance needs to be achieved between tourism (even ecotourism that may include guided tours as an educational value as elaborated on below).

A fourth and final statement:

> *'We Finns could hardly exist without salmon and trout. For millennia, our most important industries and our food sources were fish, and the most important of these were migratory fish salmon and trout.'*

Here, the participant elaborates on the historical ecosystem services of salmonid fishes and emphasizes their paramount importance for the Finnish people as a nation.

Asked about the underlying interests and benefits of fishing/angling, participants (Fig. 277) replied that *spending time in nature* (i.e., engagement and interaction with nature value; 75%), *relaxation* (i.e., therapeutic value; 60%), followed by *memorable experiences while fishing* (i.e., memory, transformative value; 40%), *spending time with friends or family* (i.e., social bonds; 54%) are the most important aspects of this activity. Other benefits, like *being alone* (i.e., therapeutic value; 43%), *clearing one's head* (i.e., therapeutic value; 32%), *learning more about fishing* (i.e., educational value; 34%), *teaching fishing to children* (i.e., educational value and social bonds; 32%) were commonly identified as

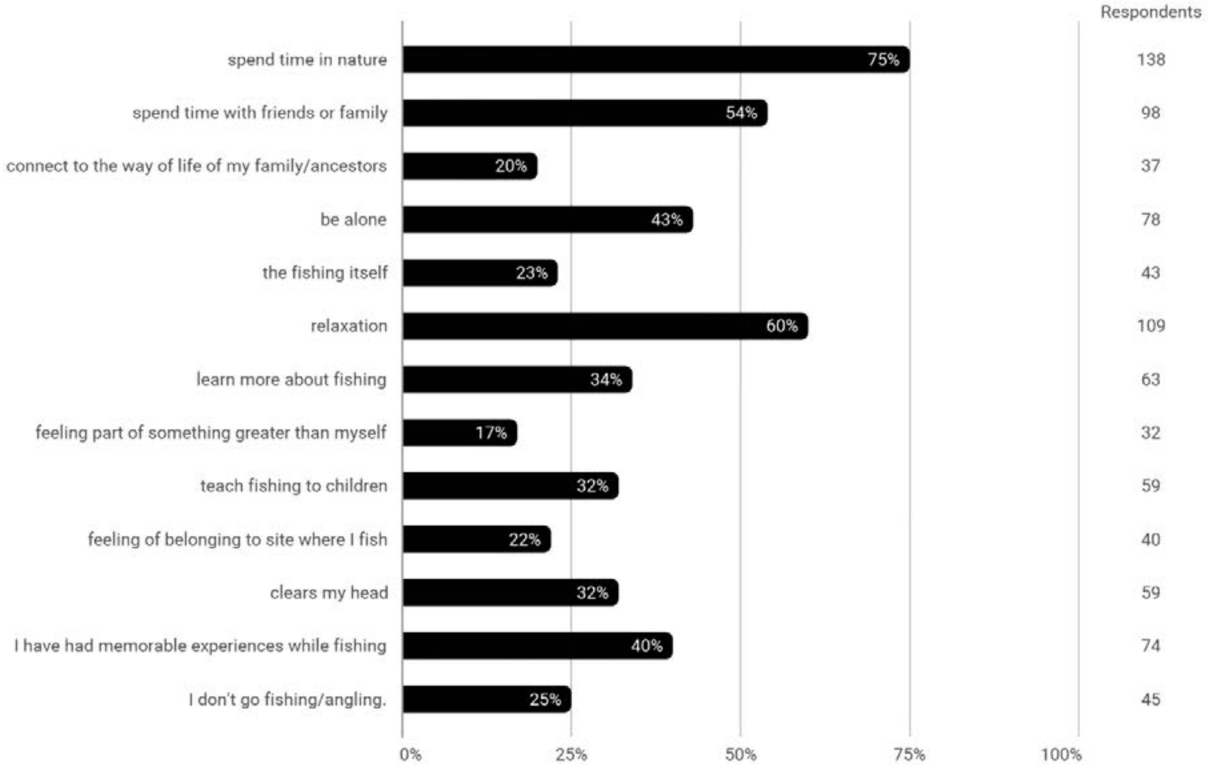

Figure 277. Cultural ecosystem services of fishing/angling.

well. Less popular benefits included *connecting to the way of life of my family/ancestors* (social bonds, traditional value; 20%), *the fishing itself* (i.e., excitement; 23%), *feeling of belonging to the site where I fish* (i.e., place of identity; 22%), and *feeling part of something greater than myself* (i.e., spiritual value; 17%).

8.3.3 Ecosystem services of freshwater pearl mussels

The first question in this questionnaire part inquired whether participants know freshwater pearl mussels. Most respondents answered with 'yes', indicating that most have had some type of previous knowledge on the species (Fig. 278).

Asked whether freshwater pearl mussels are part of people's cultural heritage (i.e., cultural value; Fig. 279), approx. 2/3 (65%) of participants answered that they consider this species to be part of their cultural heritage somewhat or strongly while 1/3 (35%) did not consider the species to be part of their cultural heritage at all or only weakly.

Historically, freshwater pearl mussels were harvested to use their pearls and shells for pottery, jewellery, and art and hence, were culturally and economically important in the past (Vaughn 2018). We wanted to know whether people were aware of this historical ecosystem service as ecosystem services can change over time and asked whether freshwater pearl mussels were responsible for wealth creation in the past (i.e., historical value, Fig. 280). About 47% of respondents thought that freshwater pearl mussels were somewhat or strongly economically important in the past. Future statistical analyses need to show whether this result can be further analysed, including demographics and socio-cultural information.

Participants clearly rejected the statement that freshwater pearl mussels have spiritual and/or religious meaning (i.e., spiritual value) to them with 68% replying that they totally or somewhat disagreed with the statement (Fig. 281). Spiritual/Religious benefits of freshwater pearl mussels have been proposed previously (Vaughn 2018) but could not be confirmed as an ecosystem service in the core study area based on these results. It appears that other ecosystem services are more prominently associated with freshwater pearl mussels in the Green Belt of Fennoscandia.

Participants clearly supported the statement that freshwater pearl mussels as a species are important for the health of rivers (i.e., ecological value; Fig. 282; 90% of participants supported the statement strongly or somewhat). This indicated that there was appreciation of the species itself (ecosystem service: biodiversity and value: existence value) and potentially some knowledge about the ecological function of freshwater pearl mussels.

Overall, participants valued all three species as important for the health of rivers, suggesting appreciation of single species but also total biodiversity in river ecosystems as an important factor. This was also confirmed by the fact that participants were more likely to use a river for recreational activities, for example, like nature-viewing and walks, if high biodiversity, as a river health indicator, was present (Fig. 283). Thus, the ecological value and recreational use of a river are increased if high biodiversity levels are present. This instance touches on the complex

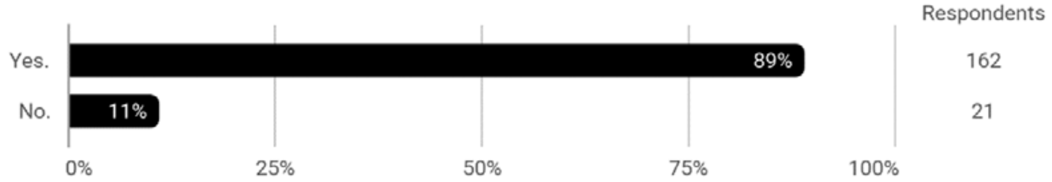

Figure 278. Answers for question whether participants know freshwater pearl mussels.

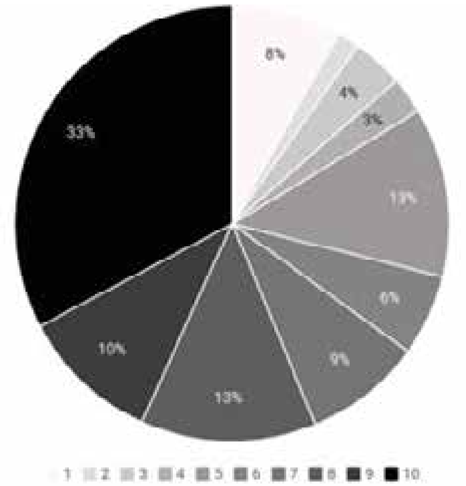

Figure 279. Freshwater pearl mussels are part of our cultural heritage.

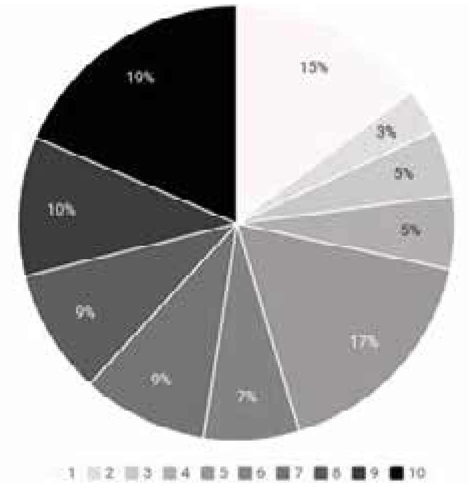

Figure 280. Freshwater pearl mussels created wealth in the past, but not now.

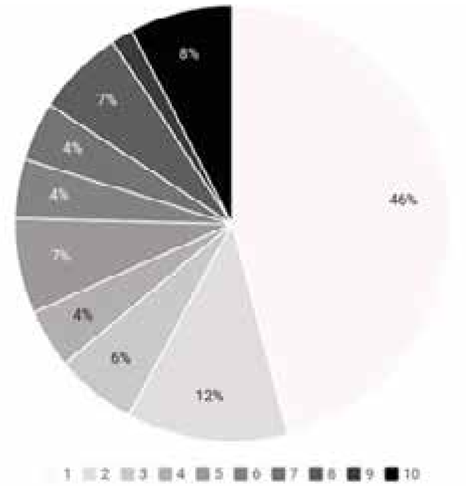

Figure 281. Freshwater pearl mussels have spiritual and/or religious meaning for me.

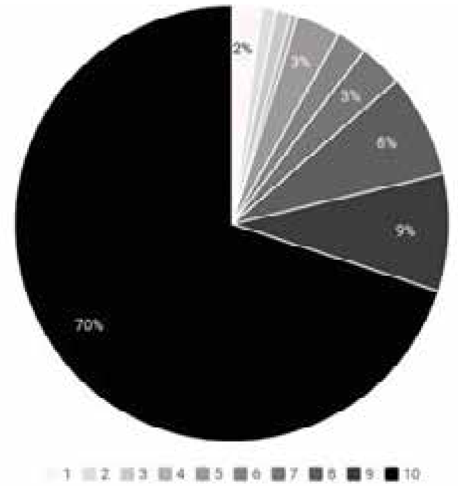

Figure 282. Freshwater pearl mussels are important for the health of rivers.

relationship of biodiversity and ecosystem services (Mace et al. 2012), which we will discuss also further below. Biodiversity has multiple interactions with the ecosystem service concept as it can either directly influence an ecosystem service (i.e., different recreational uses of watersheds), be a good itself (i.e., valuation of single or multiple species), or be support for ecological processes and functions (Mace et al. 2012). Hence, protection of biodiversity in river ecosystems also contributes to preservation of these ecosystem services for human well-being now and in the future.

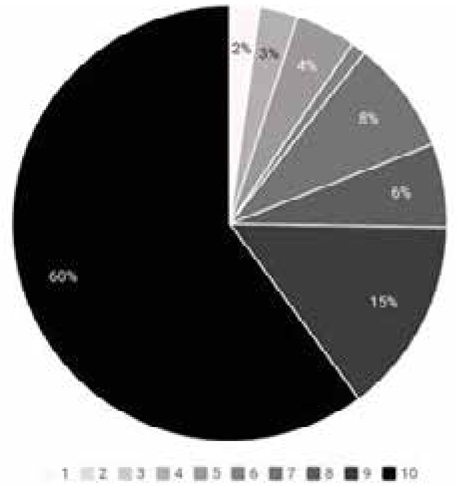

Figure 283. High biodiversity in a river means that I am more likely to use that river for recreational activities (e.g., swimming, angling, walks, nature viewing).

Respondents also agreed strongly or somewhat that freshwater pearl mussels have an educational value (76%; Fig. 284). There was strong agreement among respondents that all three species have a high educational value (Fig. 284). Since high diversity was considered an important factor for participants to use a river for recreational activities, the informal educational value of rivers is also improved by elevated biodiversity levels. There is a close relationship between recreational activities, (informal) education, and freshwater habitats with their intrinsic biodiversity. Recreational activities can be environmentally educative and outdoor recreationists themselves connect environments and learning and consider learning as a motivational factor for outdoor activities (Kil et al. 2014). Outdoor environmental education can contribute to a holistic learning experience including all senses, which enhances memorizing and the learning process (i.e., learning by doing; Mirrahimi et al. 2011). In addition, outdoor learning promotes social emotional intelligence by being exposed to different environments and people (e.g., intercultural awareness, teamwork, and communication skills; Mirrahimi et al. 2011).

Because of the interactions of education, recreation, and nature and biodiversity, it has been suggested to enrich visitor experience, particularly in protected areas with high ecological value, with targeted educational-recreational activities (Stenseke & Hansen 2014). Hence, we asked participants also whether they would be willing to pay for guided tours (by an environmental educator or scientist) and if yes, how much (Fig. 285) and whether they would recommend guided tours to others based on their knowledge of freshwater pearl mussels (Fig. 286).

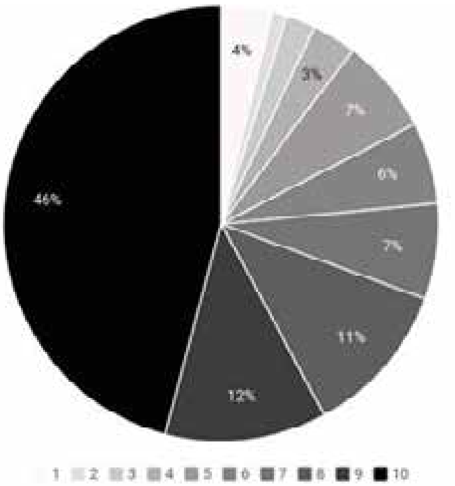

Figure 284. We can learn a lot from freshwater pearl mussels.

Regarding the willingness-to-pay for a guided tour (Fig. 285), only 16% did not want to pay. Most people were willing to pay in the middle range (16–20 Euros: 18%; 11–15 Euros: 15%, and 6–10 Euros: 16%, respectively). A smaller proportion was willing to pay over 20 Euros; 21–25 Euros: 7%, 26–30 Euros: 10%, > 30 Euros: 12%, respectively).

The vast majority of respondents were positive to recommend educational guided tours on freshwater species to others (81%; Fig. 286).

There was one comment in the comment section that elaborated on the financial strain of such educational events for families. Thus, exclusion of certain groups (e.g., low-income families) from such events may not be lowering the economic ecosystem service value of educational guided tours. However, the non-monetary value of education will decrease if fewer families attend in total. Hence, a careful evaluation which value is more important, needs to be made. In terms of public education and participation to facilitate long-term sustainable use of freshwater ecosystems, the non-monetary value of education should probably receive a higher weight in the discussion.

Participants also strongly or somewhat agreed that freshwater pearl mussels have an existence value (84%; Fig. 287), meaning that people receive a benefit from just knowing that the species exists (Bartkowski 2017). This was further confirmed by other questions asking about motivations to pay for restoration of freshwater systems to support freshwater pearl mussels (Fig. 288) to retrieve

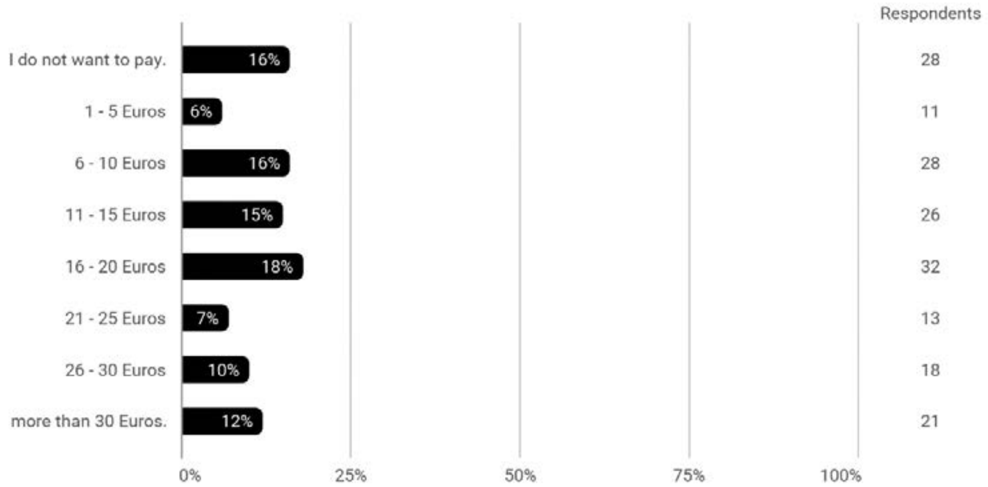

Figure 285. If yes, how much would you be willing to pay for a fee for a guided tour (i.e., a scientist/park manager would explain river ecosystems and talk about some of the species that you can find in them)?

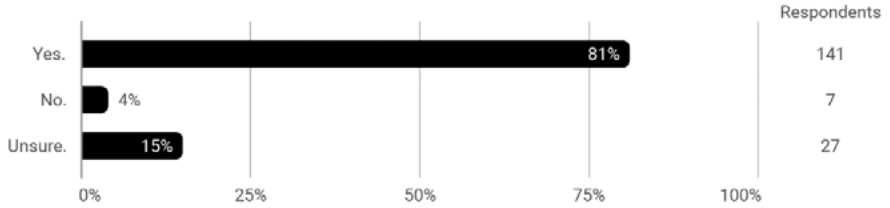

Figure 286. With what you have learned about freshwater pearl mussels and their host fish species, would you recommend others to attend workshops and guided tours to nearby rivers to learn more about the biology of these species?

an indirect monetary evaluation of the existence value of freshwater pearl mussels (Bartkowski 2017). In addition, we also asked if participants would miss any of the species if it were to disappear, introducing a scenario of change to further assess the existence value of the three species (Fig. 289).

Almost one-third of respondents (31%) were willing to pay/donate between 31–50 Euros (Fig. 288) while between 12–13% of respondents were willing to pay either 1–10 Euro, 11–20, and 21–30 Euro (Fig. 288). About 30% of participants were willing to pay above 50 Euro for restoration purposes.

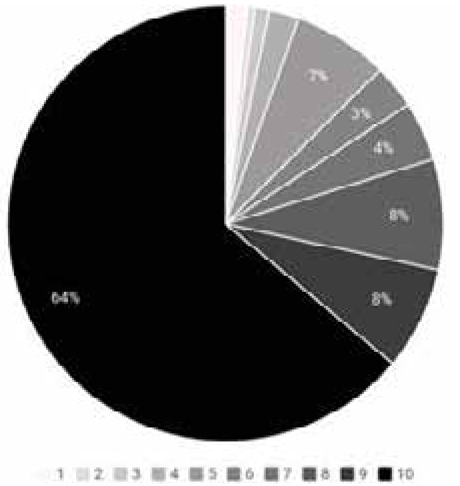

Figure 287. Freshwater pearl mussels are important in and of themselves for its existence.

The existence value as a non-use value has been debated in economic ecosystem service evaluations because a species as such, for example, can only exist or not exist in economic terms while the most used economic ecosystem service assessments measure change and/or trade-offs in goods or services (e.g., water supply, annual fish catch; Bartkowski 2017). However, with the here introduced willingness-to-pay scenario questions, an indirect monetary value can be derived.

Most respondents replied that they would miss all three species (freshwater pearl mussel: 87%, Atlantic salmon: 90%, and brown trout: 91%, respectively; Fig. 289).

Follow-up questions, dealing with the respondents' motivation to pay that included other non-use values, were also analysed (Kenter et al. 2016).

Asked about the option for future visits (i.e., option value) as a motivation to pay/donate for restoration to increase the occurrence of freshwater pearl mussels, more than half (56%) of respondents considered this to be an important or somewhat important motivation for their willingness to pay (Fig. 290).

Protecting freshwater pearl mussels for other users' benefit (i.e., altruistic value) was another option and 61% of respondents answered that this is a very or somewhat

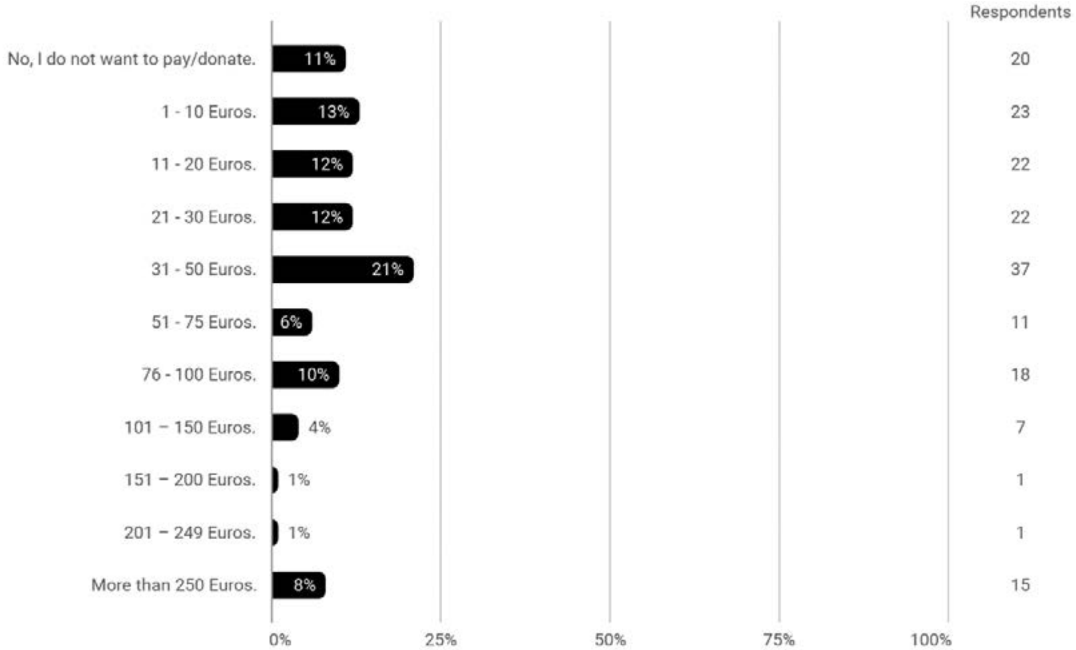

Figure 288. Would you be prepared to pay/donate anything for river restoration in your area to increase the occurrence of freshwater pearl mussels? If yes, how much money per year would you be willing to pay?

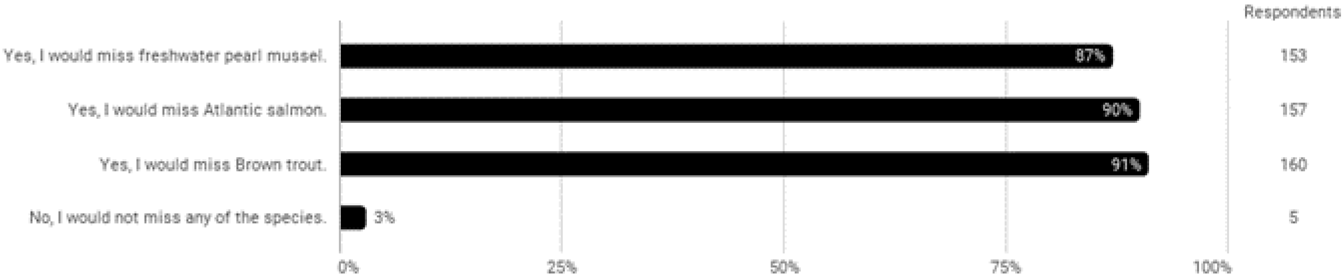

Figure 289. Would you miss any of the species if they would disappear? Multiple answers are possible.

important motivation to pay for restoration (Fig. 291).

Most participants (88%) replied that a strong or somewhat strong motivation for their willingness to pay was to protect freshwater pearl mussels for future generations (i.e., bequest value, Fig. 292). This suggests that the bequest value was more important to respondents than the altruistic and option values.

Finally, 91% of participants thought that they had a very high or somewhat high motivation to pay for restorations to increase the occurrence of freshwater pearl mussels to protect other species (i.e., existence value, biodiversity value; Fig. 293). This is in accordance with earlier questions and confirms that participants assess the existence value of species as very important.

Taken together, respondents rated the bequest and existence values as more important than the option and altruistic values, although all non-use values were rated as important.

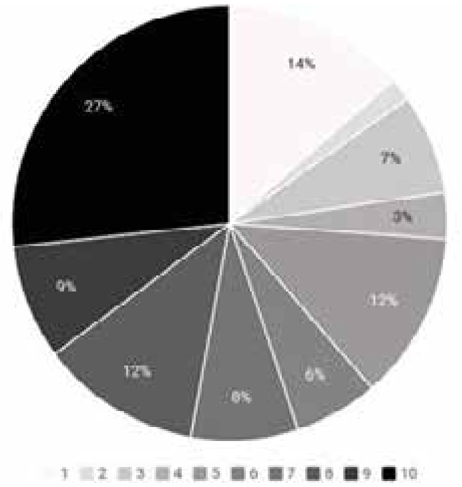

Figure 290. What is your main motivation for your willingness to pay? For each of the statements below, you can choose a value of 1 (untrue/I do not agree at all) to 10 (true/I fully agree). – Protect for the option of future visits.

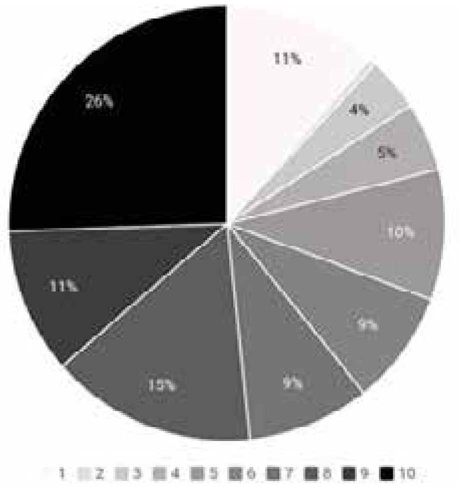

Figure 291. What is your main motivation for your willingness to pay? For each of the statements below, you can choose a value of 1 (untrue/I do not agree at all) to 10 (true/I fully agree). – Protect for other users' benefit.

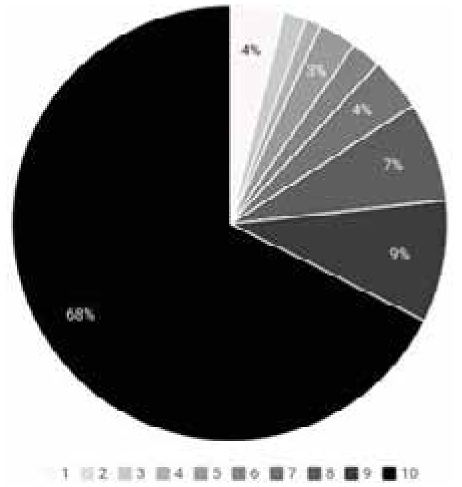

Figure 292. What is your main motivation for your willingness to pay? For each of the statements below, you can choose a value of 1 (untrue/I do not agree at all) to 10 (true/I fully agree). – Protect for future generations.

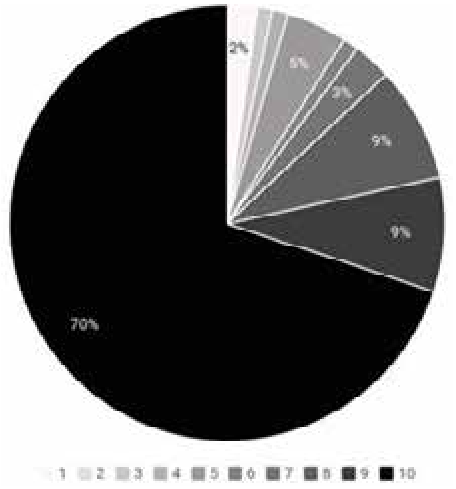

Figure 293. What is your main motivation for your willingness to pay? For each of the statements below, you can choose a value of 1 (untrue/I do not agree at all) to 10 (true/I fully agree). – Protection for the sake of other species, irrespective of personal benefits.

8.3.4 Ecosystem services of rivers

Clean water is probably one of the most prominent and easy-to-understand measures of health for river ecosystems. Water-quality related ecosystem services have been in the past neglected, because of an existing misconception that water quality is a final ecosystem service (Keeler et al. 2012). Instead, water quality contributes to numerous ecosystem services, ranging from provision of drinking water to recreational activities, like safe-contact water for swimming or angling. Therefore, we added a set of questions to inquire about the value of clean water (i.e., high water quality) in river ecosystems, particularly for provisioning and cultural ecosystem services (Böck et al. 2018).

First, we asked whether clean water has relevance to participants when it comes to use of a river ecosystem for recreational activities (Fig. 294). Most respondents thought that clean water is very or somewhat important for their decision to use the river for recreational activities (91%). In turn, this suggests that worsening water quality would affect recreational ecosystem services negatively.

Similarly, participants valued water quality for food/fish quality highly or somewhat (93%; Fig. 295).

Clean water was considered very or somewhat important for the ecosystem drinking water by 96% of the respondents, indicating that this was probably the most important ecosystem service of high-water quality for participants (Fig. 296).

Finally, we asked participants to evaluate the importance of clean water for commercial fishing as an ecosystem service. This was less important to participants; 73% deemed clean water to be important for commercial fishing (Fig. 297). This reflects, to some extent, the lesser importance given to commercial fishing for wealth creation (Figs 273a and 273b) and could be mean that for northern Fennoscandian rivers (not sea!), importance of commercial fishing is not a primary use of rivers.

Overall, respondents regarded ecosystem services, which are based on high water quality, as very valuable.

Biodiversity, like water quality, can be considered a final ecosystem service. However, biodiversity is often also the basis for other ecosystem services, and as a good itself (Mace

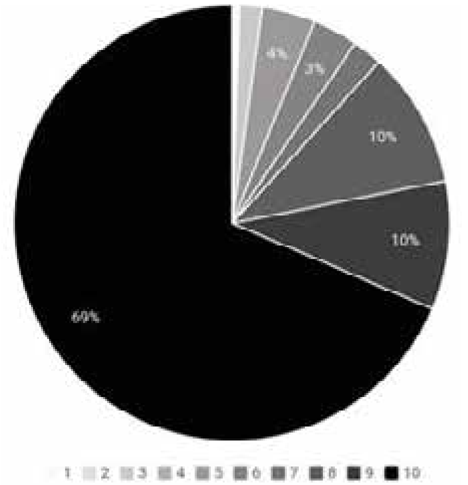

Figure 294. Clean river water in a river means that I am more likely to use that river for recreational activities (e.g., swimming, angling, walks, nature viewing).

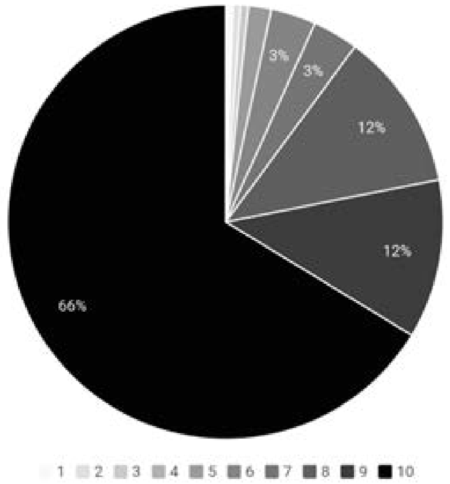

Figure 295. Clean river water means that quality of food (e.g., fish) from the river is better.

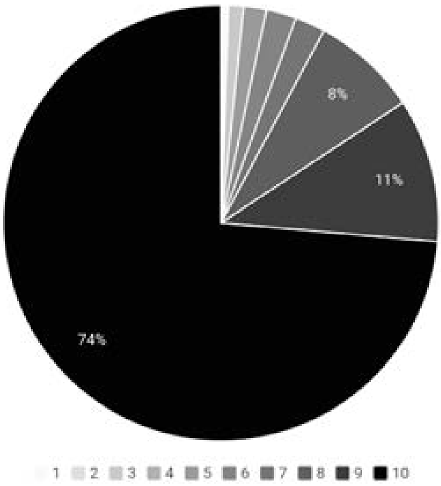

Figure 296. Clean river water means that quality of drinking water is better.

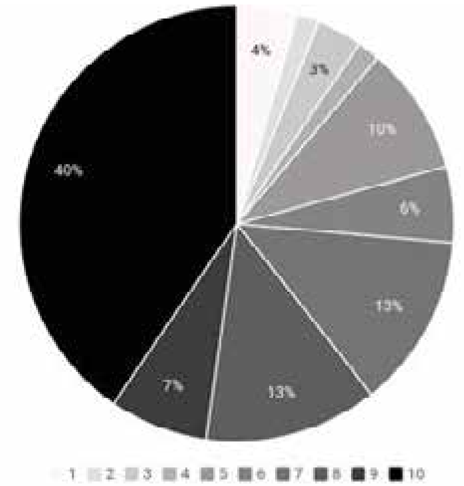

Figure 297. Clean river water contributes to success of commercial fishing.

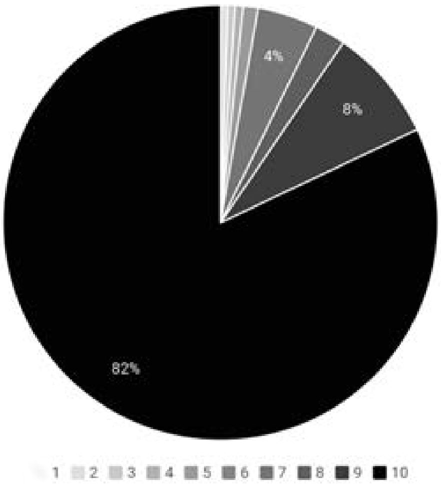

Figure 298. High biodiversity is important for river health.

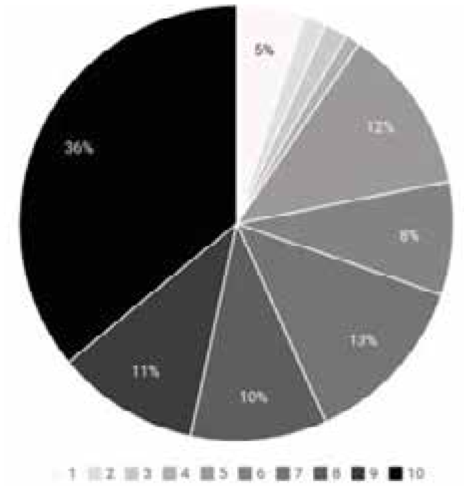

Figure 299. High biodiversity contributes to success of commercial fishing.

et al. 2012). Consequently, the multiple interactions of biodiversity and ecosystem services should ideally be considered in ecosystem service assessments (Mace et al. 2012). Therefore, an additional set of questions was added to the questionnaire looking at biodiversity as a regulator and indicator for ecosystem services in rivers.

Most respondents considered high biodiversity as very or somewhat important for river health (96%; Fig. 298). We used the expression *river health* as an umbrella term to avoid jargon for the maintenance of biological processes in the ecosystem as well as ecosystem functioning. Thus, biodiversity as a regulator for key ecological processes was highly valued by participants.

About 70% of respondents thought that high biodiversity is very or somewhat important for commercial fishing (Fig. 299). This again confirms that commercial fishing was an outlier compared to other questions in the set (Figs 273a and 273b).

In congruence with previous results, 83% of participants would be also more inclined to visit a geographical area with rivers that have higher biodiversity and cleaner water due to freshwater pearl mussels (Fig. 300).

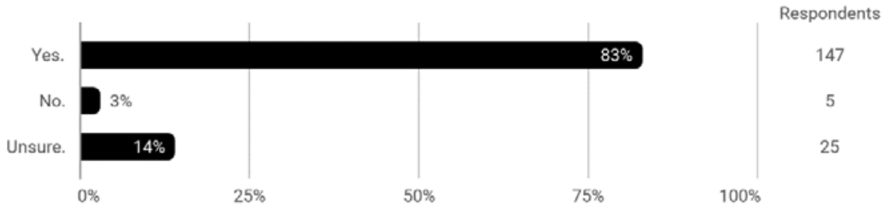

Figure 300. Would cleaner water and increased biodiversity due to freshwater pearl mussels make you visit an area?

Freshwater pearl mussel is a species that filtrates water (up to 50 l/day per adult specimen) and therefore, it contributes to clean water in rivers where it is present. Hence, it is a key species for the provision of clean water that benefits other species (i.e., biodiversity value) as well as human well-being in numerous ways.

8.3.5 Conservation and natural resource management options for freshwater ecosystems

A last set of statements dealt with potential conservation and natural resource management options as well as public participation in conservation and management for participants to evaluate. In addition, a comment field was offered to participants for further suggestions and elaborations.

Asked whether fishing and other activities should be limited to areas without freshwater pearl mussels to avoid damage of existing colonies, 59% of respondents considered this a very good or somewhat good option while 19% of respondents did strongly or somewhat reject this option, and 23% of respondents remained neutral (Fig. 301). Future statistical analyses will show whether different socio-economic and stakeholder groups answered differently.

Many participants (59%) were strongly or somewhat in favour of reducing fishing of the species mentioned earlier in the questionnaire (i.e., Atlantic salmon and brown trout; Fig. 302). Almost a quarter (23%) of participants had no specific preference and the remaining participants (18%) strongly or somewhat rejected the statement.

Less than half of respondents (42%) favoured a length reduction of the fishing season as a protective measure while more than one-third (35%) had no specific preference, and 23% rejected this option strongly or somewhat (Fig. 303).

Respondents were generally very or somewhat willing to pay/increase the fishing license fee if the money would benefit restoration efforts (59%; Fig. 304). Only 18% rejected this statement strongly or somewhat while 24% of respondents did not have a preference (Fig. 304). Taken together with the previous statement (Fig. 303), this suggested that participants were rather willing to pay more for fishing licenses rather than shorten the fishing season.

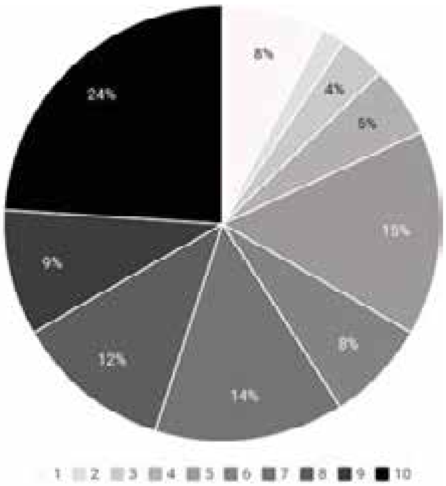

Figure 301. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Fishing and other activities should be limited to areas without freshwater pearl mussels (FPM) to avoid disturbance and damage to FPM colonies.

Most participants strongly or somewhat supported the introduction of a special protection status for the remaining freshwater pearl mussel populations in Fennoscandia (84%; Fig. 305) with the remaining 16% of respondents wither having no preference or not supporting this potential conservation measure.

More than half of respondents (62%; Fig. 306) strongly or somewhat agreed that all voices in society should be heard to build a management plan to preserve species. One-

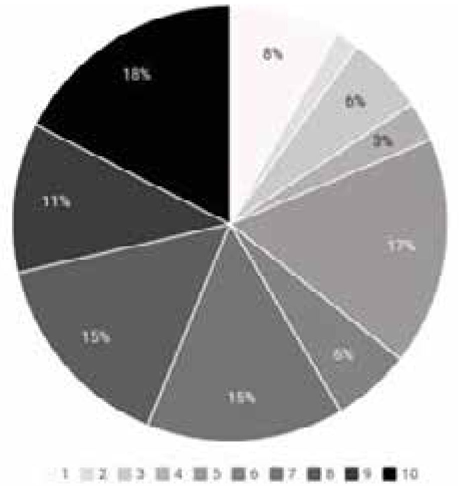

Figure 302. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Should fishing of these fish species be reduced in rivers where freshwater pearl mussels are present?

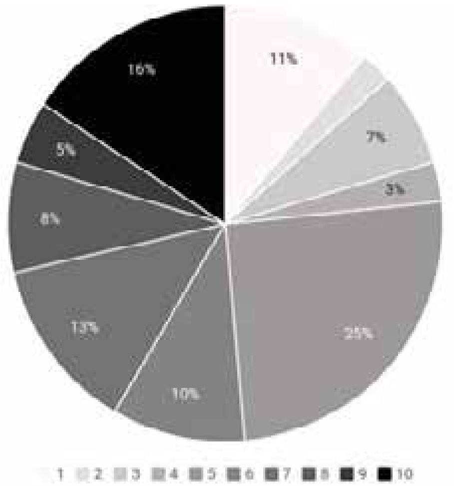

Figure 303. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Should length of the fishing season be reduced to 50% (e.g., only odd weeks)?

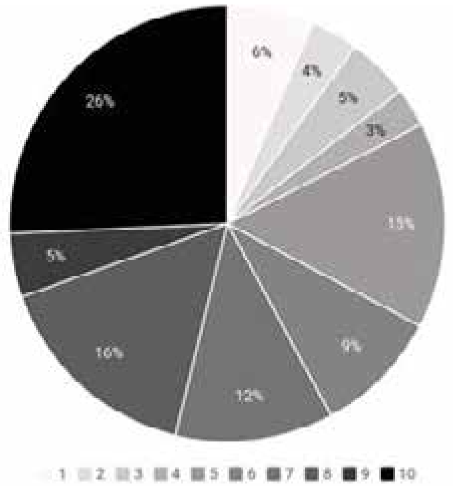

Figure 304. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Introduce and/or increase fish licence fee to cover restoration efforts for salmonid fishes and other species (e.g., freshwater pearl mussel) in rivers.

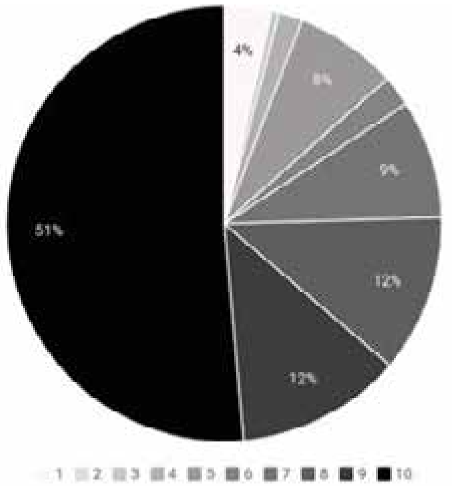

Figure 305. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? About 90% of remaining European freshwater pearl mussel populations are found in northern Fennoscandia and north-western Russia. Should a special protection status be introduced for rivers with freshwater pearl mussels in them in this region?

fifth of participants strongly or somewhat rejected this option while the remaining 18% did not have a preference.

There was strong agreement with the statement that residents are knowledge holders that can contribute to preservation of local freshwater ecosystems (87%; Fig. 307) while the remaining 13% of respondents did not agree or remained neutral.

When asked whether indigenous traditional knowledge is valuable for the local protection of freshwater ecosystems and species living in them, 78% of respondents strongly or somewhat agreed with this statement, while 13% of participants were neutral and the remaining 9% of participants disagreed strongly or somewhat with this statement (Fig. 308).

Then we asked whether certain stakeholder groups (e.g., scientists, residents, or indigenous communities) have greater knowledge than others regarding the protection of rivers and freshwater species. Concerning scientists, 79% of the respondents strongly or somewhat agreed that researchers have the best knowledge for freshwater preservation (Fig. 309) while 18% of participants remained neutral concerning the statement. Only 3 % of respondents thought that scientists do not have substantial knowledge to protect freshwater ecosystems. Trust in scientists transcended across respondent groups since about only one-third of respondents were researchers. Also, the agreement for this statement was much stronger than when participants were asked about knowledge of other stakeholder groups (see details below).

In contrast, only about one-third (33%; Fig. 310) of respondents strongly or somewhat agreed that residents are the most import-

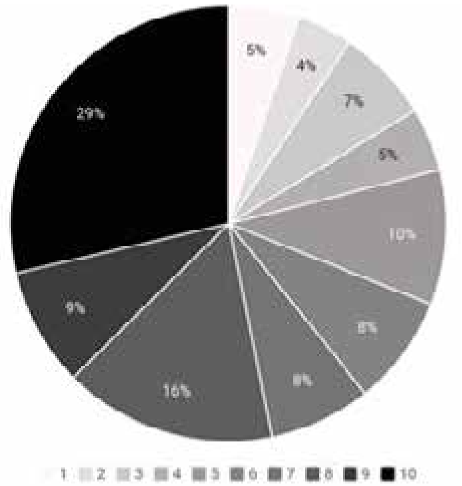

Figure 306. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? All voices in society should be heard to develop a management plan to protect species.

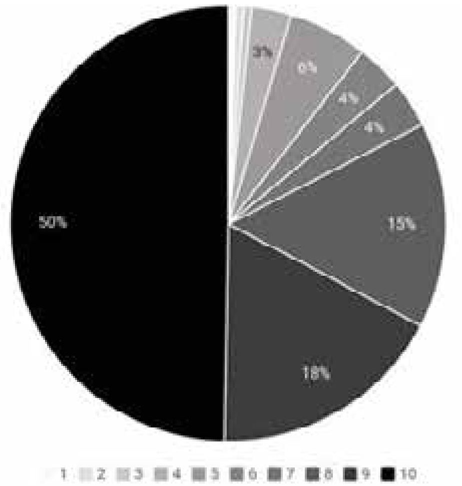

Figure 307. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Local knowledge by residents is valuable to protect local freshwater species and rivers.

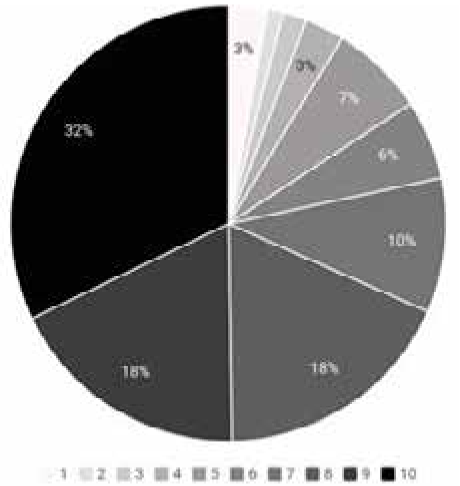

Figure 308. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Indigenous traditional knowledge is valuable to protect local freshwater species and rivers.

ant knowledge holders when it comes to freshwater ecosystem protection. Another third (34%) were neutral and the remainder (33%) disagreed with this statement to various degrees.

A similar picture emerged when participants were asked whether indigenous knowledge holders have the best knowledge to protect rivers and species residing in them. One quarter (25%; Fig. 311) disagreed with this statement strongly or somewhat while one third (33%) had no preference regarding this statement. The remaining 42% of respondents strongly or somewhat agreed that indigenous peoples know best to conserve freshwater ecosystems.

To release fishing pressure from salmonid fish, one possibility would be to advertise fishing/angling of other species to shift attention to less threatened species (e.g., Ignatius et al. 2019). Many of the respondents (58%; Fig. 312) strongly or somewhat supported this

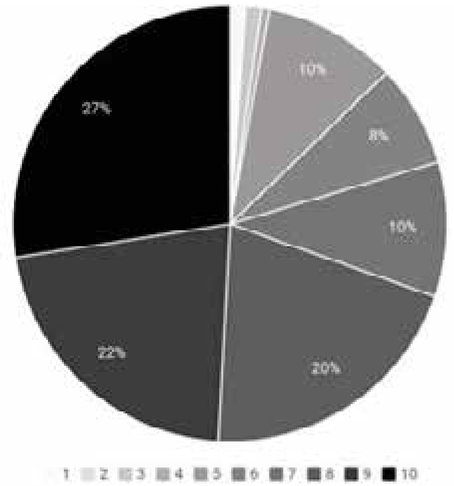

Figure 309. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Scientists know best to protect rivers and freshwater species.

Figure 310. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Locals know best to protect rivers and freshwater species.

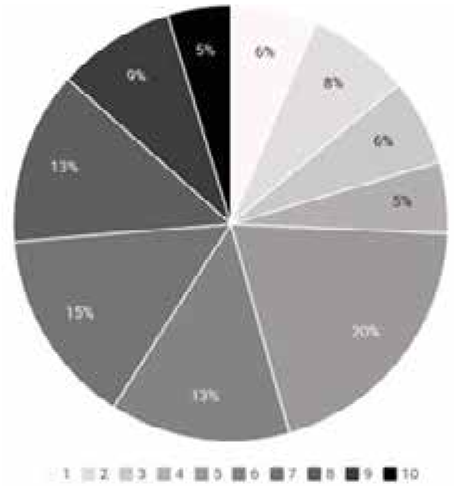

Figure 311. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Indigenous people know best to protect rivers and freshwater species.

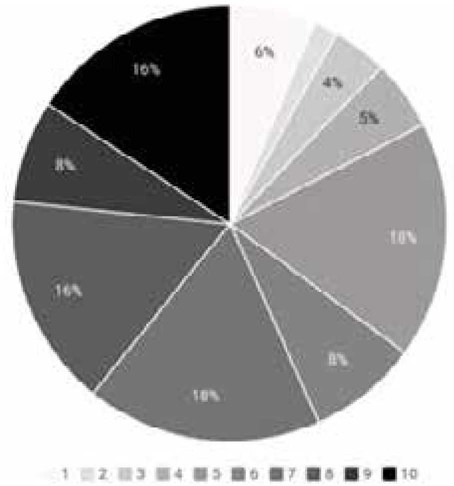

Figure 312. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Fishing of other fish species should be advertised to relieve pressure of salmonid fish stocks.

measure, indicating that many people would be open to fish other species if they would be informed that this will help to preserve stocks of salmonid fish. One possible explanation for this result may be connected to the multiple benefits of recreational fishing (Fig. 277). It is possible that for a lot of people the fishing experience and associated benefits are more important than the actual fish species they are catching. About one quarter (26%) of participants remained neutral and just 16% did strongly or somewhat disagree with this statement.

There was strong agreement (65% of respondents; Fig. 313) that recreational fishing/angling is not the main cause for declining fish stocks. One quarter (25%) of participants did not have a strong opinion on this statement and the remaining 10% of respondents disagreed strongly or somewhat with this statement.

There was also strong support for the restoration of spawning grounds for salmonid fishes (85% of contributors agreed with the statement strongly or somewhat; Fig. 314) while only 2% disagreed somewhat or strongly with this potential measure.

Concerning commercial fisheries, respondents thought that both local commercial fisheries as well as marine commercial fisheries have a responsibility to contribute to the preservation of fish and other species in rivers (Figs 315 and 316). Regarding local commercial fisheries, 88% of participants strongly or somewhat agreed with the statement that commercial fisheries have a responsibility to contribute to preservation of fish and other species in rivers (Fig. 315). Only 3% disagreed strongly or somewhat with beforementioned statement while 9% neither agreed nor disagreed.

Similar results were found for the responsibility of marine commercial fisheries towards preservation of freshwater ecosystems and species, with 85% of contributors strongly or somewhat agreeing with the statement (Fig. 316). Again, only a small minority (6 %) of respondents strongly or somewhat disagreed with the statement while again 9% of participants remained neutral.

The results clearly point to a societal expectation that commercial fisheries in this specific case and businesses/industry more generally should provide aid in biodiversity

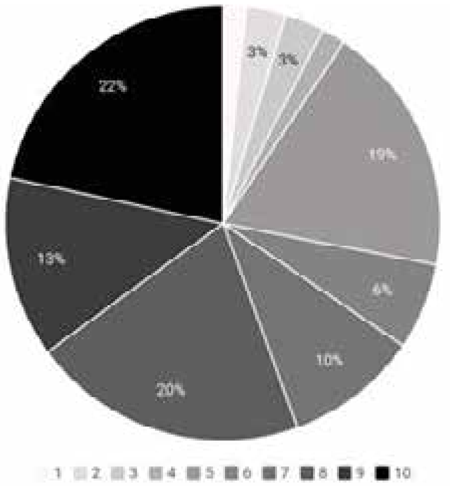

Figure 313. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Recreational fishing is not the main cause for declining fish stocks.

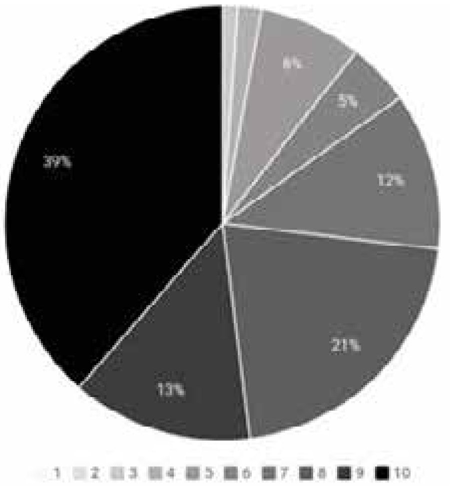

Figure 314. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Management should focus on restoration of spawning grounds and nursery habitat for salmonid fishes.

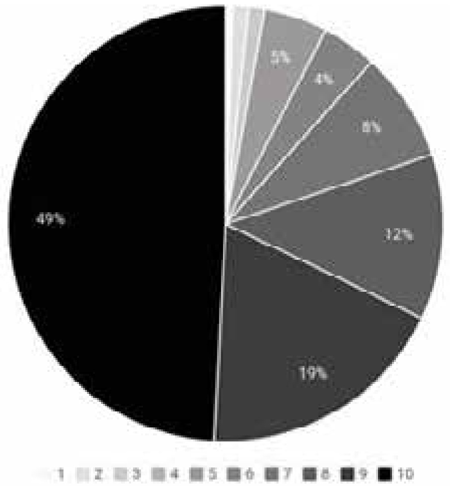

Figure 315. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Local commercial fisheries have a responsibility to contribute to preservation of fish and other species in rivers.

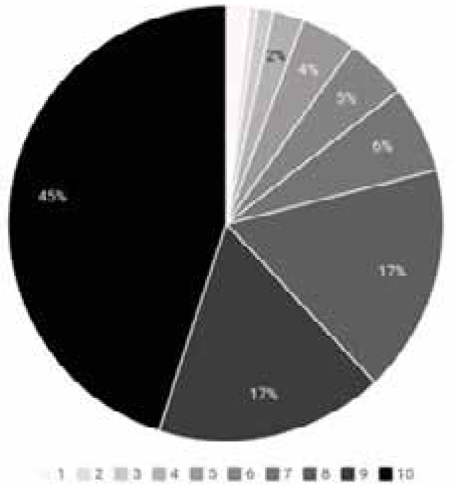

Figure 316. What measures should be taken to restore and conserve river ecosystems and protect the freshwater pearl mussels and salmonid fishes? Marine commercial fisheries have a responsibility to contribute to preservation of fish and other species in rivers.

and ecosystem conservation (Barbier et al. 2018, Salzman et al. 2018, Thompson 2021). One possible way forward is business payment for ecosystem services (PES; Salzman et al. 2018, Thompson 2021). So far, funding schemes for this type of payment have been mainly voluntarily by businesses and examples have been rare, particularly in aquatic ecosystems (Bladon et al. 2016, Chen et al. 2021, Porras et al. 2017, Salzman et al. 2018, Sorice et al. 2018). PES activities by companies have also rarely been continuous efforts but rather single events (Smith et al. 2019). Further, only between 7–21% of PES schemes are actually paid by cooperate businesses, and government involvement varies among schemes (Bennett et al. 2014, Brouwer et al. 2011, Ezzine-de-Blas et al. 2016, Hejnowicz et al. 2014). In Norway, PEA schemes include the REDD+ Readiness Payments and REDD+ Performance Payments (Salzman et al. 2018). In Finland, a few case studies on PES have been published (e.g., Sarkki 2011). However, PES schemes directly targeted at freshwater ecosystems appear even less common and future research should focus on the link of freshwater ecosystem PES schemes and how to practically implement these in the Fennoscandian Green Belt region and the European Green Belt.

Although here we asked only about commercial fishing as a business, industries could be asked to participate, like for example, the tourism sector, aquaculture companies, hydroelectric power companies, and others.

Finally, we offered participants another opportunity to comment on the second part of the questionnaire. Below, we present a few comments that mainly touch on aspects that were not picked up in the questionnaire and that therefore provide further insight into people's perceptions and attitudes.

First comment (provided twice with slightly different wording):

> *'The main cause of decline of salmonids and pearl mussels is the damming of rivers. Recovering some rivers should be a priority for conservation.'*

The issue of river damming was not inquired about in the questionnaire. This is, however, an important point because Scandinavian countries have had a lot of hydroelectric power development in the 1970s–1990s because hydroelectric power was seen as a 'green' energy source. Negative effects of river damming were either ignored or became apparent in later years. In recent years, dam removal as a restoration measure has been increasingly introduced (https://damremoval.eu/; Eloranta et al. 2019).

Second comment:

> *'Illegal fishing is something that should be used more resources on and the penal code for illegal fishing should be tightened. It is so attractive food and those who do this often get away with it.'*

Illegal, including underreported and unregulated, fishing (IUU), as a thread to river ecosystems has also not been picked up in the questionnaire itself. Illegal fishing has been on the rise in northern parts of Norway (https://thebarentsobserver.com/ru/2015/10/illegal-fishing-worst-north). In Norway, action has recently been taken to reduce illegal fishing (https://www.regjeringen.no/no/dokumenter/nou-2019-21/id2680187/?ch=7). However, the emphasis appears to be on coastal and marine fisheries rather than inland fisheries, which is congruent with the negligence of issues in rivers mentioned in the introduction. It is recommended to increase knowledge on illegal and overfishing in river ecosystems in the Fennoscandian Green Belt.

Third comment:

> *'In the large rivers of northern Finland, power companies take 100% of the water for their own use. Even 20% of the water would be given living space for ecosystems.'*

This statement elaborates on the unequal distribution of resources towards industry and economic interests at the cost of natural ecosystems. As outlined above, payment for ecosystem services (PES) schemes could be one possible mitigation measure to finance inland aquatic ecosystems.

We conclude with a final comment:

> *'There is too little emphasis on ecological perspective in the operationalized administration today. The Biodiversity Act is weak, and facilities the degradation of nature because it is not specified how natural values are to be weighed against economic interests.'*

This comment elaborates on the weak and unspecific language of international policy documents as well as (national?) implementation of those policies when it comes to the conflict of interest between non-monetary and economic valuation of natural resources. We come full circle on why we focussed on non-monetary and socio-cultural ecosystem services and values in this study and hope to have contributed to a small, but growing body of evidence that these types of ecosystem services and values deserve more attention to achieve inclusive and holistic conservation of freshwater ecosystems.

8.4 Conclusions and Outlook

Although the results presented in this report are preliminary, some interesting patterns emerged from this study. In this analysis, respondents strongly recognized non-monetary ecosystem services and values as beneficial across stakeholder groups. This suggests that non-monetary and non-use ecosystem services and values are useful components for holistic ecosystem service assessments in freshwater ecosystems, like inland watercourses. This is encouraging given the severe underutilization of these types of ecosystem services and values as well as the scarcity of studies on ecosystem services in freshwater ecosystems. However, there is more work to be done for a full integration, including the development of new indicators, of non-monetary ecosystem services and values into standardized ecosystem service assessments for freshwater ecosystems. Here, we chose two willingness-to-pay scenarios that fit in the standard ecosystem service assessment, but other indicators are possible. For example, the educational value of a species or ecosystem may be expressed as the number of teaching days at a location (Böhnke-Henrichs et al. 2013). Future work with the final dataset will be used to disentangle more specific stakeholders' perceptions and attitudes as well as assess demographic and spatial differences in preferences for ecosystem services and values.

The results clearly showed that more is expected from industrial stakeholders to protect aquatic ecosystems and species inhabiting them. This is consistent with recent research on business engagement in biodiversity conservation (e.g., Thompson 2021, Stephenson & Walls 2022). However, in practice, payment for ecosystem services schemes remain underused for various reasons (Thompson 2021). Importantly, participants clearly believed both inland and marine commercial fisheries should contribute to biodiversity conservation. Hence, future research should assess how these industries are currently contributing and where improvements need to be made (this applies also to other industries that use freshwater ecosystem services, like tourism and hydroelectric power companies, etc.). It has been pointed out by others (e.g., Thomson 2021, Stephenson & Walls 2022) that companies' internal policies for biodiversity conservation engagement can be confounding, hampering continuous contributions to payment for ecosystem services schemes or other initiatives. A second problem is that many initiatives are voluntary (Thompson 2021). Therefore, it is recommended that future research focusses on how to improve business engagement and payment schemes in the Fennoscandian Green Belt for long-term preservation of freshwater ecosystem services in this region. In addition, the role of governmental involvement in PES schemes should be reviewed for the Fennoscandian Green Belt.

Different management interventions for relieving pressure from salmonid fish species and river ecosystems have been largely accepted by respondents whereas others were only weakly supported. Although beyond the scope of this study, it would be interesting to learn more about motivations and why these differences exist. For now, we can deduce from the results that our sample showed that communication and outreach to the public on why other fish species than salmonid fishes should be targeted for fishing/angling and introduction of and/or increased fishing license fees may be possible additional measures to improve management of freshwater ecosystems in the Fennoscandian Green Belt. This section also highlighted several aspects (e.g., illegal fishing, river damming) that were not part of the questionnaire but that were brought up in the comment section and therefore, these should be part of future discussions on natural resource management strategies in this region.

Acknowledgements

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