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RAAKKU!
Freshwater pearl mussel in northern Fennoscandia

Metsähallituksen luonnonsuojelujulkaisuja. Sarja A 214
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The freshwater pearl mussel is protected in Finland and Sweden by the Nature Conservation Act and in Norway by the Act on freshwater fish and salmon, which prohibits the collecting of mussels from rivers touching them and disturbing them by any means. The act also refers to empty shells. In this study, the mussels were collected for measurements or to other purposes with the special permissions given by the environmental authorities in each country. After the measurements, the mussels were immediately returned to their original habitats in the river.

To prevent the possibility of illegal pearl fishing, the public version of this report does not give the exact locations of the freshwater pearl mussel populations. Also, the maps showing the distribution of the pearl mussel have been drawn in such a way that the exact location of the mussel populations cannot be determined. In Sweden and Norway, the publishing of the freshwater pearl mussel sites is not prohibited. However, we have tried to adhere to Finnish principles, also with regard to Swedish and Norwegian rivers, as closely as possible.

It is worth noting that less than one mussel out of 1000 carries a pearl. Moreover, great majority of the pearls are worthless and since the trade with freshwater pearl mussel pearls is illegal, there is neither markets for them. In Finland, the confiscation value for the freshwater pearl mussel is 589 €/ mussel.

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RAAKKU!
Freshwater pearl mussel in northern Fennoscandia

Raakku is a spoken Finnish word for the freshwater pearl mussel

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AUTHOR(S)	Panu Oulasvirta (ed.), Paul Aspholm, Marko Kangas, Björn Mejdell Larsen, Pirkko-Liisa Luhta, Eero Moilanen, Patrik Olofsson, Jouni Salonen, Santtu Välilä, Aune Veersalu and Jouni Taskinen
TITLE	Raakku! - Freshwater pearl mussel in northern Fennoscandia
ABSTRACT	The freshwater pearl mussel (*Margaritifera margaritifera*) is a species classified as endangered (EN), and protected under Annexes II and V of the Habitats Directive, and under the Nature Conservation Act. It is an indicator species, that tells about the natural state of the river ecosystem. It is also an umbrella species that provides a beneficial, clean habitat for a number of other species, including the salmon and brown trout that are the hosts of its larvae, known as glochidia. Freshwater pearl mussel populations in Fennoscandia were mapped in two previous EU-funded Interreg projects in the 2000s. This Finnish-Norwegian-Swedish project expanded and deepened the co-operation and expert network created in the previous projects by extending the measures not only to mapping, but to concrete action to protect the populations. This was implemented by producing updated information about the status and genetic structure of freshwater mussel populations, and by charting the reasons for the decline of populations, and ways and methods for maintaining and restoring non-recruiting populations, and on the other hand develop cost-efficient means to discover previously unknown freshwater mussel populations. The project's communication activities aimed at distributing information about how the protection of freshwater pearl mussel waters should be taken into consideration e.g. in forestry or other activities that influence the river environment. Field work during the project was undertaken in a total of 187 different rivers in 15 main river basins. In the course of the project, 12 new freshwater pearl mussel populations were discovered. Moreover, it was proven that freshwater pearl mussel glochidia can be detected with the naked eye in juvenile brown trout in connection with electricfishing. This method was used as a new search tool in northern rivers. Updated information about population status was acquired from 30 rivers, 21 in Finland, 4 in Sweden and 5 in Norway. Unfortunately, the status of populations proved to be worse than expected: mussel recruitment was estimated as sustainable in only 1–3 populations in the long term. The genetic structure of populations was studied in 21 rivers. Based on the results, the population were classified according to their viability and protection status, and a proposal was made concerning the rivers that should be included in the monitoring programme of freshwater pearl mussel waters in Finland. Host fish experiments revealed the segregation of freshwater pearl mussel populations into those dependent on salmon or brown trout in previous salmon rivers vs. brown trout brooks. Cultivation experiments proved that it is possible to cultivate freshwater pearl mussel glochidia in laboratory conditions, while co-operation with a fish farm proved that it is possible to infest glochidia to large numbers of host fish for potential planting purposes. In addition to this report, the project produced a booklet on the protection of freshwater pearl mussel rivers. The booklet is intended for forestry operators in particular, but is a useful tool also for the authorities responsible for freshwater pearl mussel protection, Nature Inventory Officers and hikers.
KEYWORDS	freshwater pearl mussel, *Margaritifera margaritifera*, glochidia, river environment, status of stream waters, salmon, brown trout, host fish, genetic diversity, electric fishing, forestry, catchment areas, drainage basins
OTHER INFORMATION	Interreg IV A Nord Programme project ‘Restoration of freshwater pearl mussel populations with new methods’.

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TEKIJÄ(T)	Panu Oulasvirta (toim.), Paul Aspholm, Marko Kangas, Björn Mejdell Larsen, Pirkko-Liisa Luhta, Eero Moilanen, Patrik Olofsson, Jouni Salonen, Santtu Välilä, Aune Veersalu ja Jouni Taskinen
JULKAISUN NIMI	Raakku! – Jokihelmisimpukka pohjoisessa Fennoskandiassa
TIIVISTELMÄ	Jokihelmisimpukka eli raakku (*Margaritifera margaritifera*) on erittäin uhanalaiseksi (EN) luokiteltu, luontodirektiivin II ja V liitteen sekä luonnonsuojelulailla rauhoitettu laji. Raakku on jokiluonnon luonnontilaisuudesta kertova indikaattorilaji ja sateenvarjolaji, joka muodostaa hyvän ja puhtaan elinympäristön monelle muulle lajille kuten sen toukkien isäntänään käyttämille lohelle ja taimenelle. Raakkukantoja on pohjoisen Fennoskandian alueella kartoitettu 2000-luvulla kahdessa aiemmassa EU:n rahoittamassa Interreg-hankkeessa. Tässä suomalais-norjalais-ruotsalaisessa hankkeessa laajennettiin ja syvennettiin edellisten hankkeiden aikana luotua yhteistyö- ja asiantuntijaverkostoa ulottamalla toimenpiteet kartoituksen lisäksi konkreettisiin toimiin populaatioiden suojelemiseksi. Tätä päämäärää toteutettiin tuottamalla päivitettyä tietoa raakkupopulaatioiden tilasta ja geneettisestä rakenteesta sekä kartoittamalla populaatioiden taantumisen syitä ja kehittämällä keinoja ja menetelmiä, joilla ei-lisääntyviä populaatioita voidaan ylläpitää ja elvyttää sekä toisaalta kustannustehokkaasti löytää uusia vielä tuntemattomia raakkuesiintymiä. Tiedotuksen kautta pyrittiin levittämään tietoa, miten raakkuvesien suojelu huomioidaan esim. metsätaloustoimissa tai muissa jokiluontoon vaikuttavissa toimissa. Kenttätöitä hankkeen aikana tehtiin yhteensä 187 eri joella 15 eri päävesistöalueella. Hankkeen aikana löydettiin 12 uutta raakkupopulaatiota. Lisäksi osoitettiin, että raakun toukat voidaan havaita sähkökalastuksen yhteydessä taimenen poikasista paljain silmin, mitä sovellettiin uutena etsintämenetelmänä pohjoisilla joilla. Päivitettyä tietoa populaatioiden tilasta hankittiin 30 joelta, joista 21 sijaitsi Suomessa, 4 Ruotsissa ja 5 Norjassa. Populaatioiden tila osoittautui odotettua huonommaksi: vain 1–3 populaatiossa simpukoiden lisääntymisen taso arvioitiin kestäväksi pitkällä tähtäimellä. Populaatioiden geneettistä rakennetta tutkittiin 21 joella. Tulosten perusteella luokiteltiin populaatioiden elinkykyisyys ja suojelustatus sekä tehtiin ehdotus raakkuvesien seurantaohjelman kohdejoista Suomessa. Isäntäkalakokeiden perusteella paljastui raakkupopulaatioiden eriytyminen lohi- tai taimenriippuvaisiksi vanhoilla lohijoilla vs. tammukkapuroilla. Kasvatuskokeet osoittivat, että raakun nuoruusvaiheita voidaan kasvattaa laboratoriossa. Yhteistyö kalanviljelylaitoksen kanssa osoitti, että kalanviljelylaitoksilla voidaan tartuttaa suuria määriä raakun isäntäkaloja glokidioilla mahdollista istuttamista varten. Tämän raportin lisäksi hankkeen aikana tuotettiin opasvihkonen raakkuvesien suojelusta. Vihkonen on suunnattu erityisesti metsätalouden toimijoille, mutta sitä voivat hyödyntää työssään myös raakun suojelusta vastaavat viranomaiset, luontokartoittajat ja tavalliset retkeilijät.
AVAINSANAT	jokihelmisimpukka, raakku, *Margaritifera margaritifera*, glokidiot, jokiluonto, virtavesien tila, lohi, taimen, isäntäkala, geneettinen monimuotoisuus, sähkökoekalastus, metsätalous, valuma-alueet
MUUT TIEDOT	Interreg IV A Nord -ohjelman hanke Jokihelmisimpukkakantojen elvyttäminen uusilla menetelmillä (Restoration of freshwater pearl mussel populations with new methods).
SARJAN NIMI JA NUMERO	Metsähallituksen luonnonsuojelujulkaisuja. Sarja A 214

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FÖRFATTARE	Panu Oulasvirta (red.), Paul Aspholm, Marko Kangas, Björn Mejdell Larsen, Pirkko-Liisa Luhta, Eero Moilanen, Patrik Olofsson, Jouni Salonen, Santtu Välilä, Aune Veersalu och Jouni Taskinen
PUBLIKATION	Raakku! – Flodpärlmusslan i norra Fennoskandien
SAMMANDRAG	Flodpärlmusslan (*Margaritifera margaritifera*) klassas som en starkt hotad art (EN) och den ingår i habitatdirektivets bilagor II och V och är fridlyst enligt naturvårdslagen. Flodpärlmusslan är en indikatorart, som berättar om ett vattendrags naturtillstånd. Den är också en paraplyart, som bildar en god och ren livsmiljö för många andra arter, såsom lax och öring som också fungerar som värddjur för flodpärlmusslans larvstadier. Bestånden av flodpärlmussla kartlades i norra Fennoskandien på 2000-talet i två tidigare Interreg-projekt, som finansierades av EU. Inom detta finsk-svensk-norska projekt utvidgade och fördjupade man det samarbets- och sakkunnignätverk som bildades under de föregående projekten genom att inte enbart göra inventeringar utan också genom att vidta konkreta åtgärder för att skydda populationerna. Detta mål verkställdes genom att man producerade uppdaterad information om flodpärlmusselpopulationernas tillstånd och genetiska struktur samt utredde orsakerna till att populationerna gått tillbaka. Man tog också fram metoder med vilka icke-reproduktiva populationer kan upprätthållas och återupplivas och metoder för att kostnadseffektivt hitta nya, hittills okända förekomster av flodpärlmussla. Man spred också information om hur skyddet av vattendrag med flodpärlmussla kan tas i beaktande exempelvis vid skogsbruksåtgärder och andra åtgärder som inverkar på vattendragens natur. Fältarbete utfördes vid sammanlagt 187 vattendrag och 15 huvudavrinningsområden. Under projektet fann man 12 nya flodpärlmusselpopulationer. Därtill påvisades att man vid elfiske kan observera flodpärlmusslans larver på öringsyngel med blotta ögat, vilket tillämpades som en ny sökmetod vid åar i norr. Uppdaterad information om populationernas tillstånd fick man från 30 åar, av vilka 21 låg i Finland, 4 i Sverige och 5 i Norge. Populationernas tillstånd visade sig vara sämre än väntat: endast i 1–3 populationer uppskattades nivån på musslornas reproduktion vara hållbar på lång sikt. Populationernas genetiska struktur undersöktes vid 21 åar. Utgående från resultaten klassade man populationerna enligt livskraftighet och skyddsstatus samt gav förslag på åar till uppföljningsprogrammet för åar med flodpärlmussla i Finland. Proven med värdfiskar visade att populationerna i gamla laxåar och öringsbäckar utvecklas på olika sätt och blir sålunda lax- eller öringsberoende. Fiskuppfödningsproven visade att flodpärlmusslans ungdomsstadier kan födas upp i laboratorieförhållanden. Samarbetet med en fiskodlingsanstalt visade att man vid fiskodlingsanstalter kan få glochidier att infektera ett stort antal värdfiskar med tanke på potentiell utplantering. Inom detta projekt togs fram förutom denna rapport också en guide om skyddet av vattendrag med flodpärlmussla. Guiden riktar sig främst till aktörer inom skogsbruket, men också myndigheter som ansvarar för skyddet av flodpärlmusslan, naturinventerare och friluftsmänniskor kan ha nytta av den.
NYCKELORD	flodpärlmussla, glochidier, *Margaritifera margaritifera*, ånatur, vattendragens tillstånd, lax, öring, värdfisk, genetisk mångfald, elprovfiske, skogsbruk, avrinningsområden
ÖVRIGA UPPGIFTER	Projektet Återställning av flodpärlmusslans populationer med nya metoder (Restoration of freshwater pearl mussel populations with new methods) inom programmet Interreg IV A Nord.
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ALMMUSTUHTTIMA NAMMA	Raakku! Johkaskálžu davvin Fennoskandias		
ČOAHKKÁIGEASSU	Johkaskálžu (*Margaritifera margaritifera*) lea hui áitatvuložin (EN) meroštallojuvvon, luoddudirektiivva II ja V čuvvosa sihke luonddusuodjalanlágain ráfáidahtton šládja. Johkaskálžu lea johkaluonddu luondduviđa indikáhtoršládja ja arvesuodješládja, mii ráhkada buori ja ráinnas eallinbirrasa máŋgga eará šládjii dego dan suovssaid isiđinnis atnin lussii ja dápmohii. Johkaskálžošlájat leat Fennoskandia davviguovlluin gártejuvvon 2000-logus guovtti ovddit EU:a ruhtadan Interreg-fidnus. Dán suopmelaš-norgalaš-ruoŧŧelaš fidnus viiddiduvvui ja čiekŋudahttui ovddit fidnuid áigge ráhkaduvvon ovttasbargo- ja áššedovdifierpmádat nu ahte doaibmabijut olahuvvoje gártema lassin konkrehtalaš doaimmaide populašuvnnaid suodjaleami várás. Dát mihttomearri ollašuhttui nu ahte buvttaduvvui ođđa áiggedási diehtu johkaskálžopopulašuvnnaid dilis ja genehtalaš ráhkadusas sihke gártemiin populašuvnnaid maŋosmannama ákkaid ja gárgehemiin hutkkiid ja vugiid, maiguin ii-lassáneaddji populašuvnnat sáhttet doalahuvvot ja ealáskahttot sihke nuppe dáfus goluid dáfus beaktilit gávdnat vel dovdameahttun johkaskálžogávdnosiid. Dieđáhusa bakte viggojuvvui viiddiduvvot diehtu, mot johkaskálžočáziid suodjaleapmi váldojuvvo vuhtii omd. vuovdedoallodoaimmain dehe eará doaimmain, mat váikkuhit johkalundui. Fidnu áigge bargojuvvoje gieddebarggut oktiibuot 187 sierra jogas 15 sierra váldočázádatviidodagas. Fidnu áigge gávdnoje 12 ođđa johkaskálžopopulašuvnna. Dasa lassin čujuhuvvui, ahte johkaskálžžu suovssat sáhttet áicojuvvot šleađgaguolástusa olis dápmotveajehiin rabas čalmmiiguin, mii heivehuvvui ođđa ohcanvuohkin davvijogain. Áiggedássái ođaduvvon diehtu populašuvnnaid dilis háhkojuvvui 30 jogas, main 21 ledje Suomas, 4 Ruoŧas ja 5 Norggas. Populašuvnnaid dilli gávnnahuvvui ovddalgihtii vurdojuvvon heittogeabbon: duššе 1–3 populašuvnnas skálžžuid lassáneami dássi árvvoštallojuvvui girdavažžan guhkit áigge geahčastagain. Populašuvnnaid genehtalaš ráhkadus dutkojuvvui 21 jogas. Bohtosiid vuođul klassifiserejuvvui populašuvnnaid eallinnávccalašvuohta ja suodjalanstáhtus sihke dahkkojuvvui evttohus johkaskálžočáziid čuovvunprográmma čuozáhatjogain Suomas. Isitguolleiskkosiid vuođul iktui johkaskálžopopulašuvnnaid sierraneapmi luossa- dehe dápmotsorjavažžan boares luossajogain vs. dápmotjogažiin. Šaddadaniskkosat čájehe, ahte johkaskálžžu nuorravuođa muttut sáhttet šaddaduvvot laboratoriijain. Ovttasbargu guollešaddadanlágádusain čájehii, ahte guollešaddadanlágádusain sáhttet njoamuhuvvot stuora mearit johkaskálžžu isitguolit glokidioin vejolaš šaddadeami várás. Dán raportta lassin fidnu áigge buvttaduvvui ofelašgihppagaš johkaskálžočáziid suodjaleamis. Gihppagaš lea čujuhuvvon earenoamážit vuovdedoalu doaibmiide, muhto dan sáhttet atnit ávkin barggusteaset maid eiseválddit, geain lea ovddasvástádus johkaskálžžu suodjaleamis, luonddugártejeaddjit ja dábálaš vánddardeaddjit.		
ČOAVDDASÁNI	johkaskálžu, raakku, *Margaritifera margaritifera*, glokidiot, johkaluondu, rávdnječáziid dilli, luossa, dápmot, isitguolli, genehtalaš máŋggahápmásašvuohta, šleađgaiskkosguolásteapmi, vuovdedoallu, golganviidodagat		
EARÁ DIEĐUT	Interreg IV A Nord -prográmma fidnu Johkaskálžonáliid ealáskahttin ođđa vugiiguin (Restoration of freshwater pearl mussel populations with new methods).		
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FORFATTER(E)	Panu Oulasvirta (red.), Paul Aspholm, Marko Kangas, Björn Mejdell Larsen, Pirkko-Liisa Luhta, Eero Moilanen, Patrik Olofsson, Jouni Salonen, Santtu Välilä, Aune Veersalu og Jouni Taskinen
TITTEL	Raakku! - Elvemusling i nordlige Fennoskandia
SAMMENDRAG	Elvemuslingen (*Margaritifera margaritifera*) er en utryddingstruet art og er beskyttet av habitatdirektivet tillegg II og V, samt av naturvernloven. Dette er en indikatorart. En art som forteller oss om forholdene i elvens økosystem. Det er også paraplyart som gir et gunstig og rent habitat for en rekke andre arter, blant annet laks og ørret. Disse fiskeartene fungerer som verter for larvene, som kalles glochidier. Antall elvemuslinger i Fennoskandia er undersøkt i to tidligere EU-finansierte Interreg-prosjekter på 2000-tallet. Dette finsk-norsk-svenske prosjektet ble til et utvidet og dypere samarbeidsnettverk for eksperter opprettet i tidligere prosjekter, ved å utvide arbeidet til ikke bare kartlegging, men til konkrete tiltak for å beskytte bestanden. Dette ble gjennomført ved å utarbeide oppdatert informasjon om statusen og den genetiske strukturen til elvemuslingen, og ved å kartlegge årsakene til reduksjonen av bestanden, samt måter og metoder for å opprettholde og gjenopplive sterile populasjoner, og på den andre hånd utvikle kostnadseffektive metoder for å finne tidligere ukjente bestander av elvemuslinger. Prosjektet skulle formidle informasjon om hvordan det må tas hensyn til elvemuslingen ved f.eks. skogsdrift eller andre aktiviteter som påvirker miljøet i elvene. Feltarbeidet foregikk i til sammen 187 ulike elver i 15 større vassdrag. I løpet av prosjektet ble det oppdaget 12 nye bestander av elvemusling. I tillegg viste det seg at elvemusling-glochidier kan oppdages med det blotte øye hos yngre ørret i forbindelse med fisking med elektriske pulser. Denne metoden var et nytt søkeverktøy i disse elvene. Det ble utarbeidet ny informasjon om bestandenes tilstand fra 30 elver, 21 i Finland, 4 i Sverige og 5 i Norge. Dessverre viste det seg at tilstanden til bestandene var verre enn fryktet: Reproduksjonen til muslingene ble vurdert som bærekraftig hos bare 1–3 bestander på lang sikt. Den genetiske strukturen til bestandene ble undersøkt i 21 elver. Basert på resultatet ble bestandene klassifisert i henhold til levedyktighet og beskyttelsesstatus, og et forslag som omhandlet elver som bør inkluderes i overvåkingsprogrammet for elver med elvemusling i Finland ble lagt fram. Testing av vertsfisk avslørte et skille mellom elvemuslingsbestander som var avhengige av laks og ørret i frittløpende lakseelver og de i ørretbekker. Forplantningstester viste at det er mulig å dyrke elvemusling-glochidier i laboratorier, og samarbeid med et fiskeoppdrettsanlegg viste at det er mulig å overføre glochidier til et stort antall vertsfisk for potensielle transplantasjonsformål. I tillegg til denne rapporten, utarbeidet prosjektet et hefte om vern av vassdrag som er voksesteder for elvemuslingen. Dette heftet er spesielt beregnet på skogbruksarbeidere, men er et nyttig verktøy for myndigheter med ansvar for å beskytte elvemuslingen, Nature Inventory Officers og fotturister. elvemusling, Margaritifera margaritifera, glochidier, elvemiljø, status til vassdrag, laks, ørret, vertsfisk, genetisk mangfold, forskningsfiske med strøm, skogbruk, fangstområder, vassdrag
NØKKELORD	elvemusling, *Margaritifera margaritifera*, glochidier, elvemiljø, status til vassdrag, laks, ørret, vertsfisk, genetisk mangfold, forskningsfiske med strøm, skogbruk, fangstområder, vassdrag
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Preface

This a final report of the Finnish-Swedish-Norwegian project ”**Restoration of the freshwater pearl mussel populations with new methods**”. The project was financed by the European Union Interreg IV A North program, Norwegian Interreg Nord IVA and the national financers Centre for Economic Development Transportation and the Environment of Lapland, Metsähallitus Natural Heritage Services Lapland, University of Jyväskylä, County Administrative Board of Norrbotten, Norwegian Ministry for Environment, the **Troms County Council,** the County Governor of Nord Trøndelag, the Directorate of Nature Management and Norwegian Water Resources and Energy Directorate.

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1 Background

Since 2000, the distribution of the freshwater pearl mussel (*Margaritifera margaritifera*) and state of the populations has been investigated in two Interreg projects and in one Micro-Tacis project in the North Calotte. In 2003–2006, the distribution of freshwater pearl mussel populations was mapped in old pearl-fishing areas in Inari, the Pasvik Valley and Petchenga in Finland, Norway and Russia (Oulasvirta *et al.* 2006, Oulasvirta *et al.* 2004, Oulasvirta 2010a, b). In 2007–2008, inventories were carried out in the Tornionjoki (In Swedish Torneälven) river basin in Finland and Sweden (Oulasvirta *et al.* 2008). The main task in these projects was searching for new, as yet unknown populations and ascertaining whether freshwater pearl mussels still exist in rivers that were known as pearl fishing areas before pearl fishing was banned, while only preliminary data was collected on the state of the populations. These preliminary findings revealed, however, major differences in the state of the freshwater pearl mussel populations both between the catchment areas and between the different rivers inside a catchment area. Breeding populations were mainly found from the upper parts of the river systems. Even in remote areas the recruitment rate of freshwater pearl mussel was often low or totally lacking.

Thoughts and ideas on how to save these freshwater pearl mussel populations, which would otherwise gradually become extinct, arose during the meetings and discussions of the previous Interreg projects and meetings thereafter. In these discussions, it was agreed, that it is important to widen and deepen the cross-border co-operation that has started between the authorities and research institutes responsible for the management and research of water courses by extending this co-operation to concrete measures for restoring the declining freshwater pearl mussel populations. Also, it was understood that new, more effective mapping methods should be developed in order to search for as yet unknown populations in the river systems, where the presently known freshwater pearl mussel populations are too small to survive. In addition, it was considered to be important to disseminate information on freshwater pearl mussel river conservation and management to different target groups such as state and municipal decision makers, industries, forest economy and other bodies, whose activities may effect the river environment. Furthermore, it was agreed that the harmonization of freshwater pearl mussel monitoring methods is an important task so as to ensure the comparability of the results between the Nordic countries. Therefore, we wanted to bring into this new project partners both from Finland, Sweden and Norway, so that the monitoring, conservation and restoring measures of the freshwater pearl mussel rivers would be uniform and so that information and experience on mussel conservation methods would be exchangeable between countries.

In Sweden and Norway, the state of the populations is monitored regularly as part of a regional monitoring programme (Länsstyrelsen Norrbotten 2009) or national monitoring programmes (Bergengren & Lundberg 2009, Larsen *et al.* 2000, Direktoratet for Naturforvaltning 2006). However, these monitoring programmes do not fully cover all the populations in northern Sweden and Norway, and new, previously unknown populations are still being found. In Finland, there is neither a management plan nor a monitoring programme for freshwater pearl mussels. As a consequence, the state of the populations in Finland is mostly unknown. Moreover, there are still vast areas in all of the three countries, where basic mapping of the populations has not been carried out.

2 Freshwater pearl mussel

The freshwater pearl mussel (*Margaritifera margaritifera*), the longest living species in our fauna, can attain an age of at least 150 years. According to some studies, the oldest mussels are more than 200 years old, the record being 280 years (Olofsson 2005). The life cycle of the freshwater pearl mussel (Fig. 1) is complex and includes critical stages at which mortality is very high. It is estimated that only one in a hundred million mussel larvae reaches the adult stage. The great loss in larvae and mussels at the juvenile stages is compensated for by their long life span and huge larvae production. An indispensable part of the life cycle is the Atlantic salmon (*Salmo salar*) or the brown trout (*Salmo trutta*), the host species for the freshwater pearl mussel larvae.

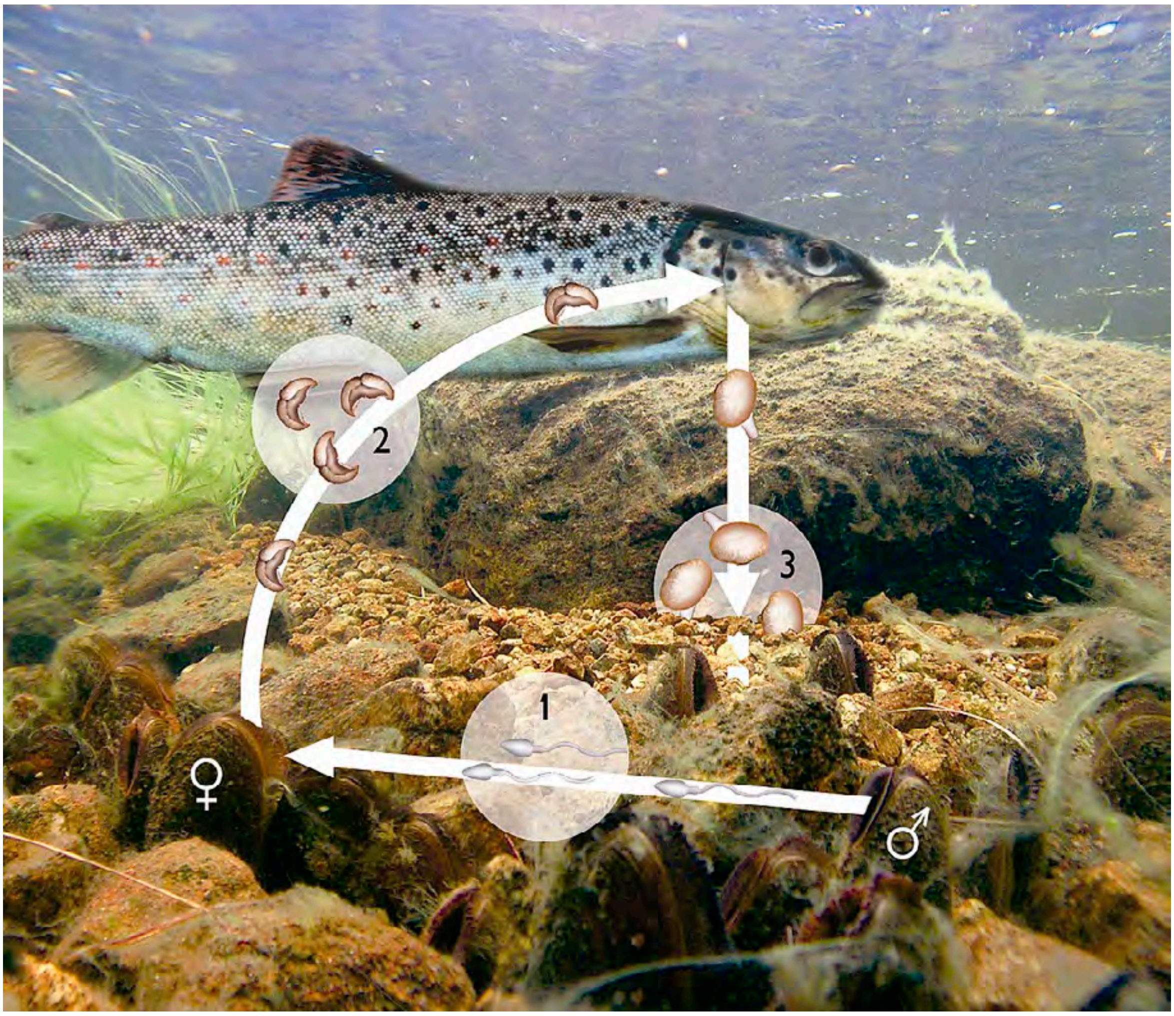

Figure 1. Life cycle of the freshwater pearl mussel. 1. Male mussels release their sperm into the water. The sperm enters female gills with the current and fertilizes the egg cells. 2. Glochidia larvae are released in the autumn. Some of the larvae attach themselves to the gills of a host fish, where they live as parasites over the winter. During the parasitic stage, the larvae metamorphose into juvenile mussels. 3. After dropping off the host fish, the juveniles burrow into the bottom substrate, where they live submerged for 1–7 years. They eventually become visible on the surface of the sediment at a length of 7–9 mm. Source: Oulasvirta et al. 2006.

During its parasitic stage in the host fish, the freshwater pearl mussel metamorphoses from a glochidium into a small, 0.35–0.45 mm long, juvenile mussel. The duration of the parasitic stage depends on the water temperature: the colder the water, the slower the development. In northern Fennoscandia, the parasitic stage lasts over the winter, during which time the mussel may also be dispersed with its migrating fish host.

In spring or early summer, the juvenile mussels release themselves from the fish gills and drop onto the river bottom. Relatively little is known about this stage of the life cycle, which, together with the glochidium stage, constitutes another "bottleneck" in the life cycle. It is widely believed that the juvenile mussels disperse into the sediment, where they spend the first 5–8 years of their life submerged. After growing to a length of 7–25 mm, they become visible on the surface of the sediment. Still at a length of 30–50 mm, only about 25–50% of the individuals are visible (Degerman *et al.* 2009). The mortality of juveniles is very high. For the juveniles to survive, the bottom substrate must be oxygen-rich and free from organic sediments and humus.

The freshwater pearl mussel becomes fertile at an age of 10–20 years and remains fertile for the rest of its life. Mortality is much lower among adults than it is among juveniles. Discounting humans, the mussels do not have many natural enemies, as only a few predators, e.g. otter, mink and muskrat, are able to crack their thick shells. In addition, beavers may destroy the mussel habitats by altering the current flow in the river. At low water level, birds such as crows and gulls can pick mussels from the river bottom (cf. Berrow 1991, Larsen & Bjerland 2012). They crack them against roads or rocks, leave them, and then eat the flesh when the mussels are dying or have died.

Indicator species, umbrella species and flagship species

A vital freshwater pearl mussel population with stable recruitment of young mussels always indicates clean water and of the natural state of the river ecosystem. Adult mussels are much better able to tolerate negative changes in the environment than are larvae and juveniles. Hence, if a population consists of only adult mussels, this indicates that negative changes have taken place in the environment. This means that the freshwater pearl mussel can be considered to be a top **indicator** of river ecosyste1ms, because it indicates the state of the environment, both good and bad. In fact, most of the present freshwater pearl mussel populations are as described above: A small or moderate population of adult mussels is living in the rivers, but recruitment of young mussels has not taken place for decades. The remaining large populations with stable recruitment are found mainly in northern Europe and north-western Russia. Therefore, this area is crucially important for the conservation of freshwater pearl mussel.

An abundant and vital freshwater pearl mussel population does not only indicate clean water; it also produces it. An adult mussel filters around 50 litres of water per day through its body, at the same time purifying it (Fig. 2). Indeed, dense mussel populations play an important role in maintaining the health of the ecosystem. By purifying the water, they benefit the spawning success of many fish species, including their host fish, salmon and brown trout. In addition, the mussels dump part of the filtered material on the bottom, where it is an important food source for benthic invertebrates, which, in turn, are the

Figure 2. Freshwater pearl mussels filter feeding. While filtrating food particles from the water the mussels at the same time purifies the water and this way maintains the health of the ecosystem. Photo Panu Oulasvirta.

most important food for young salmon and trout. Such species, which maintain the diversity of the ecosystem and create habitats for other species, are known as **umbrella species** of the ecosystem. If an umbrella species is destroyed, the function of the whole ecosystem suffers. Correspondingly, projects that promote a good environment for the freshwater pearl mussel with high environmental demands also create good conditions for many other species in the ecosystem. Thus, the freshwater pearl mussel can be seen as a **flagship species** in conservation work.

Distribution and state of the populations

The distribution of the freshwater pearl mussel covers western and northern Europe (Fig. 3) and north-eastern North America. Populations of the mussel have declined almost everywhere. According to some estimates, the decline in the populations in central and southern Europe, for example, is as high as 95%. At present, the largest known populations are in Norway and north-western Russia. In Norway, the freshwater pearl mussel is currently known from 413 rivers/localities (updated from Larsen 2010). Very recent recruitment (mussels < 20 mm found) takes place in approximately 1/3 of the populations (Larsen 2010). On the other hand, 130–140 populations are in danger of becoming extinct. The species is known to have become extinct already in 114 rivers. In Sweden, the current number of known populations is today 628 (RUS 2014). Mussels of less than 50 mm in length are found from 45% of the rivers. In Finland, the species was found in more than 200 rivers at the beginning of the 20th century (Valovirta 2006), but today it is known to exist in 120 rivers, mainly in the northern part of the country.

The freshwater pearl mussel is protected at both a national and international level. In Finland, it has been protected by the Nature Conservation Act since 1955. In Sweden, it has been protected since 1994, although in Norrbotten County, pearl fishing has been forbidden since 1954. In Norway, the freshwater pearl mussel is a species protected by national legislation since 1993 according to the Act on freshwater fish and salmon. An action plan for freshwater pearl mussels has been implemented in Norway since 2006. Furthermore, the Nature

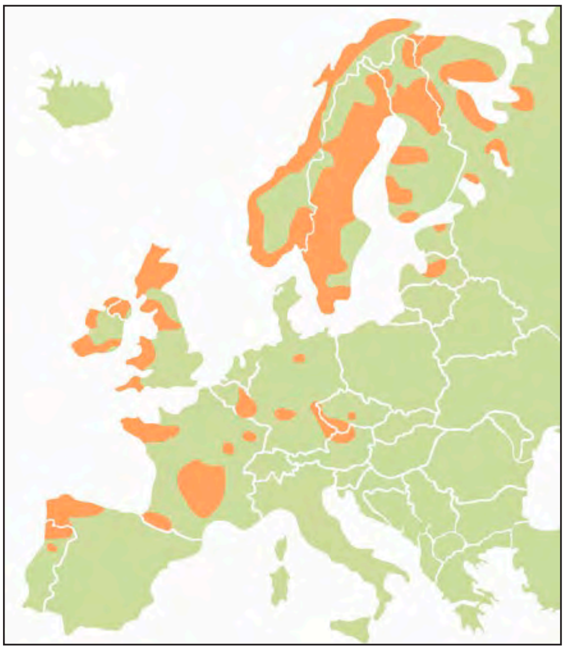

Figure 3. Current distribution of the freshwater pearl mussel in Europe (Larsen 2005 with modifications). The map is only indicative, e.g. distribution shown for northern Sweden and Finland is inaccurate.

Diversity Act (from 2009) is the leading act in Norway for protecting biological diversity through conservation and sustainable use. The act puts emphasis on nature's dynamics and the need for measures in order to reach the national target to halt the loss of biological diversity. The act makes it possible to designate certain species as priority species, and the Norwegian Environment Agency has proposed the freshwater pearl mussel as a priority species in Norway.

Internationally, the freshwater pearl mussel is listed on the IUCN Red List of Threatened Species as an endangered taxon (EN). The freshwater pearl mussel is also listed in Annex II of the European Union Habitats Directive as a species whose habitat must be protected for its survival. In Finland, for example, the 1955 Act protected the freshwater pearl mussel from pearl fishing but not from the destruction of its habitats.

Since the era of pearl fishing, the reasons for the declining populations have included the clearing of rivers for timber floating, the construction of hydropower plants, eutrophication, pollutants, the building of forest roads and other forestry operations such as drainage of forest and peat lands, which have led to the silting of rivers.

3 Objectives of the project

The overall objectives of this project were to widen and deepen Nordic cross-border co-operation between environmental authorities and research institutes and to develop this co-operation towards concrete measures to restore declining populations. Another objective was to evaluate the state of freshwater pearl mussel populations in northern Fennoscandia and to ascertain the reasons why these populations are declining in many northern watercourses. Related to this, we aimed to develop and test methods for how to restore these declining and non-breeding populations. One important goal was also to provide updated information on the conservation and management of freshwater pearl mussel populations for those target groups involved with the management of river environment or whose decisions or activities may impact the state of the river ecosystems.

These objectives were accomplished in seven different work packages which were following:

- Network
- Analyses of the state of the freshwater pearl mussel populations and their habitats
- Water quality and heavy metals in freshwater pearl mussels and their habitat
- Population genetic analyses of northern freshwater pearl mussel populations
- Host fish and cultivation experiments
- Searching for new mussel populations
- Dissemination of information

The more detailed presentation of the objectives, methods and results of each work package are presented in Chapter 6 and in Annexes A–G.

4 Project partners

Lead partner in the project was **Metsähallitus, Natural Heritage Services Lapland** (Finland). Other project partners were the **University of Jyväskylä** (Finland), **Metsähallitus, Natural Heritage Services Ostrabothnia** (Finland), the **Lapland Centre for Economic Development, Transport and the Environment** (Finland), the **County Administrative Board of Norrbotten** (Sweden), **Bioforsk jord og miljø** (Norway), the **Norwegian Institute for Nature Research NINA** (Norway) and **Akvaplan-niva** (Norway).

The following individuals comprised the key staff on the project (Fig. 4):

- Panu Oulasvirta, project coordinator, Metsähallitus, Natural Heritage Services Lapland
- Jouni Taskinen, scientific coordinator, University of Jyväskylä
- Pirkko-Liisa Luhta, responsible person in Metsähallitus, Natural Heritage Services Ostrabothnia
- Marko Kangas, responsible person in Lapland Centre for Economic Development, Transport and the Environment
- Patrik Olofsson, Swedish coordinator, County Administrative Board of Norrbotten
- Paul Aspholm, Norwegian coordinator, Bioforsk jord og miljø Svanhovd
- Björn Mejdell Larsen, responsible person in Norwegian Institute for Nature Research NINA
- Guttorm Christensen, responsible person in Akvaplan-niva
- Rune Muladal, Bioforsk Nord Holt

The responsible persons in the project administration of different partners were:

- Jyrki Tolonen, Metsähallitus, Natural Heritage Services Lapland
- Samuli Sillman, Metsähallitus, Natural Heritage Services Ostrabothnia
- Matti Manninen, University of Jyväskylä

Figure 4. Key staff on the project. Above in back row from left: Björn Mejdell Larsen, Patrik Olofsson, Panu Oulasvirta, Eero Moilanen, Jouni Salonen, Aune Veersalu. At front: Terho Myyryläinen, Pirkko-Liisa Luhta and Jouni Taskinen. Below: Paul Aspholm, Marko Kangas, Santtu Välilä.

- Jari Ylänne, University of Jyväskylä
- Tiina Kämäräinen, Lapland Centre for Economic Development, Transport and the Environment
- Johan Antti, County Administrative Board of Norrbotten
- Tor-Arne Björn, Bioforsk jord og miljø
- Stein Erik Aagaard, Norwegian Institute for Nature Research NINA
- Anna Wikan, Bioforsk jord og miljø
- Lars Ola Nilsson, Bioforsk jord og miljø

Other people in the project administration or economics were:

- Yrjö Norokorpi, Metsähallitus, Natural Heritage Services Lapland
- Päivi Paalamo, Metsähallitus, Natural Heritage Services Lapland
- Matti Mela, Metsähallitus, Natural Heritage Services Lapland
- Auli Söderholm, Metsähallitus
- Jaana Heikkinen, Metsähallitus
- Marika Kipinoinen, Metsähallitus
- Anna-Greta Eklund, County Administrative Board of Norrbotten
- Judith Ryeng, Bioforsk jord og miljø
- Merja Tähtisaari, Lapland Centre for Economic Development, Transport and the Environment
- Satu Huhtala, University of Jyväskylä
- Tiina Lohiniva, Metsähallitus, Natural Heritage Services Lapland
- Terttu Lehtola, Lapland Centre for Economic Development, Transport and the Environment
- Yvonne Norberg, County Administrative Board of Norrbotten

Other project staff were:

- Agnete Hansen, Bioforsk jord og miljø (field work)
- Andreas Broman, County Administrative Board of Norrbotten (field work, electro fishing)
- Aune Veersalu, Metsähallitus, Natural Heritage Services Lapland (field work, water chemistry, reporting)
- Bård Spachmo, Bioforsk jord og miljø (field work)
- Björn Ekholm, County Administrative Board of Norrbotten (field work)
- Eero Moilanen, Natural Heritage Services Ostrabothnia (field work, reporting)
- Elias Oulasvirta, Natural Heritage Services Lapland (field work)
- Emelie Hedin, County Administrative Board of Norrbotten (field work)
- Felix Luukkanen, University of Jyväskylä (field and laboratory work)
- Jaakko Leppänen, Natural Heritage Services Lapland (GIS work)
- Janne Nyyssölä, Natural Heritage Services Lapland (field work)
- Jarmo Huhtala, Lapland Centre for Economic Development, Transport and the Environment (expert)
- Jarno Turunen, University of Jyväskylä (field and laboratory work)
- Jouni Salonen, University of Jyväskylä (host fish experiments, reporting)
- Juho Vuolteenaho, Natural Heritage Services Lapland (field work)
- Jukka Salmela, Natural Heritage Services Lapland (field work)
- Laila Saksgård, Norwegian Institute for Nature Research NINA (temp log data)
- Lasse Kangas, Lapland Centre for Economic Development, Transport and the Environment (field work)

Figure 5. Part of the steering group and field team on a field excursion by the River Kuutusoja Finland in September 2013. From left: Aune Veersalu, Linda Johansson, Juho Vuolteenaho, Tupuna Kovanen, Yrjö Norokorpi, Panu Oulasvirta and Taina Kojola. Photo Paul Aspholm.

- Marie Rönnqvist, County Administrative Board of Norrbotten (field work)
- Markku Kilapala, County Administrative Board of Norrbotten (field work, electro fishing)
- Motiur Chowdhury, University of Jyväskylä (cultivation experiments)
- Olli Nousiainen, University of Jyväskylä (field work)
- Pentti Pieski, Metsähallitus (interpater)
- Raimo Kurtti, Natural Heritage Services Ostrabothnia (field work)
- Randi Saksgård, Norwegian Institute for Nature Research NINA (host fish studies)
- Sally Luhta, Natural Heritage Services Ostrabothnia (assistant)
- Santtu Välilä, Natural Heritage Services Lapland/ University of Jyväskylä (genetic studies, seminar arrangements)
- Tapani Säkkinen, University of Jyväskylä (field and laboratory work)
- Terho Myyryläinen, Natural Heritage Services Lapland (field work)
- Timo Lettijeff, Lapland Centre for Economic Development, Transport and the Environment (expert)
- Vesa Mikkonen, Natural Heritage Services Lapland (field work)

The project had also a steering group, which had following members:

- Jaakko Erkinaro, Chairman, Game and Fisheries Research Institute, Finland
- Taina Kojola, Vice Chairman, Centre for Economic Development, Transport and the Environment in Lapland, Finland
- Tupuna Kovanen, Centre for Economic Development, Transport and the Environment in Ostrabothnia, Finland

- Minna Turunen, Arctic Centre, Finland
- Snorre Hagen, (vice person Tor-Arne Björn) Bioforsk jord og miljø, Norway
- Harald Muladal, County Governor of Finnmark, Norway
- Jyrki Tolonen (vice person Yrjö Norokorpi), Metsähallitus, Finland
- Linda Johansson, County Administrative Board of Norrbotten, Sweden
- Tauno Haltta, Sami parliament, Finland
- Guttorm Christensen, Akvaplan-niva, Norway
- Tuula Sinisalo, University of Jyväskylä, Finland

The steering group held three meetings and organised one field excursion (Fig. 5) during the project.

5 Project area and actions

The project area covered the whole of northern Fennoscandia (Fig. 6) and consisted of 187 different rivers in 15 different drainage areas in northern Sweden, Norway and Finland. The actions carried out in the fieldwork were:

- Evaluation of the state of the populations in 30 rivers (Work package B)
- Evaluation of the water chemistry and toxic substances in 24 rivers (Work package C)
- Genetic analyses in 21 rivers (Work package D)
- Host fish experiments in 11 rivers (Work package E)
- Searching for new populations in 161 rivers (Work package F)

List of all rivers and actions are shown in Appendix 1.

Figure 6. Project area. Main catchment areas: 1. Iijoki, 2. Koutajoki, 3. Kemijoki, 4. Tornionjoki (In Swedish Torne älv), 5. Kalix älv, 6. Lule älv, 7. Lutto (Tuloma), 8. Paatsjoki (In Norwegian Pasvik), 9. Teno (In Norwegian Tana), 10. Näätämö (In Norwegian Neiden), 11. Karpelv, 12. Simojoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15, © Läntmäriet, County Administrative Board of Norrbotten, © Norway Digital / GIT Barents.

6 Results

Work package A.
Network

The main purpose of this work package was to widen and deepen the Nordic co-operating network of experts and institutes involved with freshwater pearl mussel management and conservation work. Furthermore, in this work package we aimed to promote the exchange of information and experiences across nation borders. In this respect, this project was a direct follow-up to the Interreg projects carried out in northern Fennoscandia in 2003–2008 (Oulasvirta *et al.* 2006 and 2008) in which cross-border co-operation was started. In the present project, the existing network was both widened by taking new partners into the co-operation (e.g. the University of Jyväskylä, the Norwegian Institute for Nature Research NINA and Akvaplan-niva) and deepened by taking concrete actions to restore freshwater pearl mussel populations.

The networking was carried out during the project in meetings, workshops and congresses. In practice the planned Nordic network was widened to consist of all the European countries that have freshwater pearl mussel in their fauna. For instance, our project coordinators (Panu Oulasvirta, Paul Aspholm and Björn Mejdell Larsen) participated into the work of a CEN working group, which is aiming to produce guidance standards on monitoring freshwater pearl mussel populations and their environment (Fig. 7). Nationally, co-operation has been encouraged between environmental authorities and between different stakeholders such as the forestry sector, for example, in order to introduce guidelines for environmental friendly forestry methods in the vicinity of freshwater pearl mussel rivers.

The list of meetings, workshops and congresses in which our project was involved is presented in Annex A.

Work package B.
Analyses of the state of freshwater pearl mussel populations and their habitats

Background:

The knowledge of the freshwater pearl mussel populations in northern Fennoscandia is often very sparse. In many cases information is restricted to the awareness of the presence of the species, but the data on the distribution of the population or its state is lacking. This is especially true in Finland, where regular monitoring of the population has not been carried out. In this work package, the goal was to:

1. Evaluate the state of the key freshwater pearl mussel populations in the different catchments in the northern Fennoscandia.
2. Define the habitats providing successful recruitment for young mussels.

Figure 7. CEN working group meeting in Aberdeen, Scotland March 2012. Photo Paul Aspholm.

3. Reveal the negative factors preventing and/ or impeding the recruitment of freshwater pearl mussel.

4. To establish a network of transects, which could also be used as monitoring sites in the future monitoring program in Finland.

Study area and methods

Population status assessment was conducted in 30 different rivers in 14 different drainage areas. Four populations were investigated in Sweden, five in Norway and 21 in Finland. The results of the Norwegian rivers are not presented in this report.

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 (Fig. 8). These were studied on randomly chosen transects. Depending on the country and size of the river, either the use of an aquascope or diving was used in conducting mussel counts.

The quality of the substrate was studied by measuring the redox potential inside the sediment. Redox potential in the sediment reflects the oxygen conditions in the interstitial water, which is essential for the survival of juvenile mussels (Geist & Auerswald 2007).

Water quality was studied in 10 rivers. The water quality was compared with the threshold values in the rivers with a functional freshwater pearl mussel population (Table 2 in Annex B).

The state of the population was evaluated by applying Swedish criteria, where the population status is based on the population size and proportion of juvenile mussels in the population (Söderberg *et al.* 2009, Bergengren *et al.* 2010, Table 3 in Annex B). Six different viability classes were distinguished: (1) *Viable*, (2) *Viable?* (= maybe viable), *Non-viable*, (4), *Dying-out*, (5) *Almost extinct* and (6) *Extinct*.

As mentioned previously, the freshwater pearl mussel is both a nationally and internationally protected species listed in the Habitat's Directive. Thus, all of its populations and living habitats should be saved. However, knowing the limited resources applied to conservation, it sometimes makes sense to focus the conservation measures on certain populations above others. So, apart from classifying the viability of the population, the **conservation value** of the population was classified into three categories (I) ***Normal conservation status***, (II) ***High conservation status*** and (III) ***Very high conservation status***. The conservation value of the population was ranked according to six different criteria, such as population size, mean density, length of the distribution area, proportion of < 20 mm and < 50 mm mussels, and size of the smallest mussel (Bergengren *et al.* 2010). In addition, genetic diversity and host fish specificity were counted if there was data available on those. For example, regardless of the other scores, the highest conservation value was automatically given to the main river populations, which are mostly dependent on salmon for their reproduction. Also, the high genetic diversity (number of haplotypes) and unique alleles raises the conservation value of the population (Table 4 in Annex B). Moreover, conservation status was given to the population if there were only three or less known freshwater pearl mussel rivers in the whole main drainage area.

Figure 8. Size distribution of the mussels was one of the criterium when evaluating the viability of the population. Photo Paul Aspholm.

Results

Only one out of 24 studied populations could be classified as v*iable*. Two other populations were classified as v*iable?*. 18 populations were classified as *non-viable*, two as *dying-out* and one population as a*lmost extinct*. Sometimes parts of the population, usually in the upper course, could be classified as *viable* or *viable?*, although the population in whole was classified as *non-viable*. However, when only considering the presence of mussels under < 50 mm in length (indicating recent recruitment) or < 20 mm in length (very recent recruitment) the number of populations was 21 and 8 respectively. This underlines the fact that the result of the estimate largely depends on where the sample is collected – juvenile mussels often occupy their own micro-habitats (frequently in the upper course of rivers, where the anthropogenic pressure is lower).

The biggest populations were observed from Rivers Karpelva (approx. 700,000 mussels), Suomujoki (133,000 mussels) and Koutusjoki (131,000 mussels). The conservation value of the populations studied was ranked as high (16 populations) or very high (8 populations) (Table 9 in Annex B).

Conclusions

The results show that the freshwater pearl mussel is seriously threatened even in the remote wilderness areas of northern Fennoscandia. Especially alarming is the situation in the big main rivers such as Rivers Livojoki and Lutto in Finland, where the Atlantic salmon used to migrate before these rivers were harnessed to hydropower production. Apart from River Karpelva in Norway, none of the mussel populations in the main rivers have been functional for decades. Without urgent restoration measures, the extinction of the freshwater pearl mussel in the main rivers is inevitable, and the distribution of the freshwater pearl mussel will be fragmented into a few isolated headwater populations, which are vulnerable to extinction even without human influence. The conservation of freshwater pearl mussel in northern Fennoscandia would require actions at different levels: (1) Searching for new populations (especially from big main rivers such as River Utsjoki in Finland and all the present/previous salmon rivers in Sweden), (2) Status assessment and monitoring of known populations, (3) Restoration of damaged catchment areas, (4) Construction of fishways to the old salmon rivers and (5) Captive breeding in the most threatened populations.

Figure 9. Temperature logger on the river bottom. Photo Paul Aspholm.

Work package C.
Toxicological analyses

Analyses of water quality were based on (1) national monitoring samples, (2) water samples taken in this study and (3) data collected with the DGT (Diffusive Gradient Thin film) -samplers, which also detect heavy metals from the water. Also the water temperature was monitored by automatic loggers in three rivers (Fig. 9). Besides water samples, pollutants were also analysed from the river sediments and from the freshwater pearl mussel shells and soft tissue. Results of the water analyses and toxicological analyses are presented in Annex C.

Work package D.
Population genetic analyses of northern freshwater pearl mussel populations

Background

Knowing the genetic structure of *Margaritifera margaritifera* populations is an important baseline for conservation acts. Low genetic diversity is a matter of concern, as it may reduce the ability of species to adapt to changes in the environment. Therefore, maintaining genetic diversity has been identified as one of the key elements in successful conservation programmes.

Methods

In this study, we examined the genetic structure and diversity of 21 mussel populations in the project area. We used mitochondrial DNA *COI* sequences and nine microsatellite loci to generate genetic information. A total of 609 *COI* sequences were obtained, and there were 18 variable nucleotide positions and haplotypes. The most suitable evolutionary model for the sequence data was determined by using MEGA 5.2 software. This was the HKY85 model, and it was used to calculate the genetic distances between haplotypes.

Results

The number of observed haplotypes per population (Haplotype richness) ranged from 1 in River Hirvasjoki to 10 in River Karpelva. Genetic structure and differentiation of populations were analysed by using an analysis of molecular variance (AMOVA). Populations were divided into different groups by their drainage system and by their host fish stock (salmon vs. brown trout rivers). There was no noticeable genetic differentiation between different drainage systems or between salmon and brown trout rivers, i.e. the available host fish is salmon or brown trout respectively. Hierarchical AMOVA revealed that 1% of the genetic variation was among drainage systems, 31.04% among populations within drainages, and 69.95% within populations. The effect of geographical distance on the differentiation between populations was examined using the Mantel test. The results of the Mantel test ($r = -0.041$ $P = 0.662$) confirmed that there was no isolation by distance of population. When the population-wise averages were used as the statistical unit, both the mean observed haplotype richness and mean expected haplotype richness were higher in salmon rivers ($n = 4$) than in brown trout rivers ($n = 17$). The observed haplotype numbers (± standard error of mean) were on average 7.0 ± 1.2 and 4.0 ± 0.4 in salmon and brown trout rivers, respectively, the difference being statistically significant (ANOVA, $F_{1,20} = 9.547$, $p = 0.006$). An average of 4.7 alleles (standard deviation SD = 2.9) were observed for the nine microsatellite loci used in this study. The number of alleles per locus ranged from one to a maximum of 24 different alleles. Among the Finnish populations, the highest mean allelic richness was in the River Livojoki ($A_R = 6.6$), while the lowest richness was found in River Hanhioja ($A_R = 2.7$). Expected and observed heterozygosities were calculated by using GENEPOP version 4.0. Among the Finnish populations, the expected heterozygosity (H_E) per population varied between 0.380 for River Sarriojoki (River Kemijoki drainage), and 0.584, for River Lovttajohka (in the Tenojoki drainage). Observed heterozygosity (H_O) ranged between 0.360 (Sarriojoki) and 0.564 (Lohijoki, Iijoki drainage) in Finnish populations. Pair-wise F_{ST} values for pearl mussel populations spanned a wide range, and 88% of all differences in pair-wise comparisons were highly significant ($P < 0.001$).

Conclusions

Results of mtDNA and microsatellite data analysis were largely consistent with each other. Both F_{ST} values and NJ phenogram indicate a structured genetic differentiation pattern of pearl mussel populations, suggesting that different conservation units should be considered in the management of the species. Additionally, the observed genetic population structure is not correlated with the drainage systems to which the populations belong. Higher levels of genetic diversity e.g. haplotype richness, the number of alleles per locus and allelic richness were found in salmon rivers as compared to brown trout rivers. It is not known whether this is due to higher mussel population size in salmon rivers, or, for example, the more isolated nature of mussel populations in brown trout rivers.

In different drainage systems, high genetic diversities were observed in the Rivers Livojoki, Luttojoki, Koutusjoki, Skjellbekken, Karpelva, Siikajoki and Onnasjoki (of the Iijoki, Tuloma, Torniojoki, Pasvik, Karpelv and Kemijoki drainage basins, respectively). Conservation of these rivers and catchment areas should be given a high priority. Large population size was not clearly connected to a higher number of mtDNA haplotypes or a higher expected haplotype richness. However, in the large-sized pearl mussel populations, the number of microsatellite alleles per locus was higher. Thus, the present results indicate that larger freshwater pearl mussel numbers in a given river favour maintenance of diverse genotypes. This means that, for the sake of genetic diversity of the freshwater pearl mussel, high mussel densities and large mussel stocks should be the target of conservation efforts.

Work package E.
Experiments with host fish and juvenile mussel cultivation

Introduction

An important part of the freshwater pearl mussel life cycle is the parasitic stage in the gills of the fish host. Atlantic salmon *Salmo salar* and brown trout *Salmo trutta* are the fish hosts of the European freshwater pearl mussel, while in the North America the brook trout, *Salvelinus fontinalis*, has also been thought to serve as the host. For the conservation of the species, it would be important to know whether (1) pearl mussel populations differ in their preference for Atlantic salmon or brown trout, and whether (2) the freshwater pearl mussel is better adapted to their local fish host population, and whether (3) the North American invader, brook trout, is a suitable host for the freshwater pearl mussel here in Europe. The answers for these questions were sought in field cage and laboratory infection experiments with freshwater pearl mussels. In addition, a process associated with the suitability of fish as host, i.e. the possible (4) acquired immunity of host fish against pearl mussel glochidium larvae, was also studied in a laboratory experiment.

Many of the freshwater pearl mussel populations are threatened or even extinct, and there is a need for artificial cultivation methods. Thus, the target of the present project was also (5) to carry out preliminary studies on laboratory rearing of freshwater pearl mussel glochidia and juveniles, and (6) to test infection of to-be-stocked juvenile salmonids at a fish farm with freshwater pearl mussel glochidia. Furthermore, the target was (7) to examine the results of a previous planting experiment of lab-reared freshwater pearl mussel juveniles in the Iijoki area.

Methods

The caging experiments included placing different fish species and strains in cages in the target river before the annual shedding of freshwater pearl mussel glochidia and the subsequent microscopic examination of fish gills. Caging experiments were performed in 2011–2013 in seven tributaries of River Iijoki (Fig. 10), in two tributaries of River Luttojoki and in River Simojoki. The juvenile fish used – River Iijoki Atlantic salmon, different strains of brown trout (both resident, local and sea-migrating) and brook trout – were obtained from fish farms or were electrofished from the rivers. In the laboratory experiments, the fish were exposed to freshwater pearl mussel glochidia collected from different rivers and transported to the University of Jyväskylä Konnevesi research station.

Rearing experiments with juvenile freshwater pearl mussels were performed at Konnevesi research station by infecting brown trout with the glochidia and by collecting the juvenile mussels that drop off the fish gills after larval development has been completed. The trial with infesting to-be-stocked juvenile salmonids was carried out on a commercial fish farm that was delivering fish for stocking purposes in the River Iijoki area. The success of a previous planting experiment of laboratory-reared freshwater pearl mussel juveniles was studied in River Jukuanoja and a reference river in the River Iijoki drainage by excavating and sieving the bottom sediment.

Figure 10. *In situ* host fish experiments with fish cages in the tributary of River Iijoki. Photo Pirkko-Liisa Luhta.

Results

Suitability of different salmonid host species and strains

Both the field cage experiments and laboratory infection experiments showed that brook trout was not a suitable host for the freshwater pearl mussel. Numbers of glochidia established in brook trout were low and their development was slow.

Both the field cage experiments and the laboratory infection experiments indicated that, in the large northern salmon rivers where the Atlantic salmon has spawned previously (River Livojoki, River Iijoki catchment and River Luttojoki, River Tuulomajoki catchment) or in which the Atlantic salmon is still spawning (River Simojoki), the Atlantic salmon – River Iijoki and River Simojoki strain – was clearly a better host than the sea-migrating River Iijoki brown trout. In River Livojoki, the Atlantic salmon was generally also a better host than any of the different brown trout strains used in caging experiments, although the Rautalampi strain brown trout proved to be almost as good as the Atlantic salmon.

On the other hand, both field and laboratory experiments showed that, in the smaller tributaries where Atlantic salmon did not ascend for spawning, brown trout was a better host than salmon for the freshwater pearl mussel. The results of the caging experiments in these smaller tributaries also suggested some degree of local adaptation of the freshwater pearl mussel to use the local brown trout as a host, and a weak signal of local adaption could also been observed in River Livojoki and River Simojoki freshwater pearl mussels with respect to Atlantic salmon. However, in only one out of the three supposed former-sea-migrating-brown-trout-tributaries of River Iijoki, namely River Jukuanoja, the sea-migrating River Iijoki brown trout was clearly a better host than the River Iijoki Atlantic salmon.

Thus, to summarize, the results indicate that freshwater pearl mussels in salmon rivers are adapted to use Atlantic salmon, and those in brown trout rivers are adapted to use brown trout as their preferred host. In addition, among the resident brown trout and Atlantic salmon, some signals could be seen of adaptation by the freshwater pearl mussel to better infect the local host fish population.

Acquired immunity

The results of the laboratory experiment indicated to some extent the development of acquired immunity in the host fish to the freshwater pearl mussel. The percentage of infected fish was about the same (100% or close to it) both in immunologically naïve fish and in the fish infected a year before, but the number of glochidia was much lower in the latter group. Moreover, the size of larvae indicates acquired immunity: larvae developed fastest in naïve fish and slowest in fish which were exposed to a high dose of pearl mussel larvae earlier.

Glochidia development

Development and excystment (drop off) of freshwater pearl mussel glochidia was observed to be temperature-dependent; an increase in water temperature in spring and early summer resulted in an increase in the excystment rate. The juvenile mussels were collected and put into rearing tanks with sand and gravel, and they will be monitored over the coming years after the present project.

Success of juvenile planting

One 9 mm long juvenile freshwater pearl mussel was observed when excavating below the area where 20,000 juvenile mussels were planted in River Ala-Haapuanoja in 2007. The age of the mussel was estimated to be 7 years, which indicates that the individual was one of the juveniles planted in 2007. No juveniles were found above the planting site but excavation in a reference river (River Haukioja) revealed that the method used should reveal small freshwater pearl mussels.

Conclusions

The fish host results emphasize (a) the importance of maintaining the remaining salmon populations and their spawning migrations, and (b) the importance of restoring the lost salmon stocks and rivers, including free migration from the sea to the spawning grounds. In the light of present results, it is also highly recommended that stocking of eggs, embryos or juvenile salmon in River Livojoki should be started immediately so as to provide the preferred host fish for freshwater pearl mussel in that river. Adaptation of the freshwater pearl mussel to local fish host populations may exist, but signals of local adaptation were not strong. This does not mean that, in possible freshwater pearl mussel restoration projects, the use of local (or as local as possible) freshwater pearl mussel population would not be advisable.

The results of the immunization experiment indicate that glochidia infestation does not protect the fish from another infestation later: the prevalence of glochidia infestation among previously infected fish was almost as high as among naïve fish. On the other hand, the acquired immunity was manifested as lower glochidia numbers and slower development rate of glochidia among fish that were infected a second time. Considering the bigger size of the 1+ year class fish (and hence the larger surface area of their gills), they might still serve as good hosts for the freshwater pearl mussel even though they would have been infested by glochidia earlier. However, the development and growth of the glochidia in fish infected a second time should be monitored longer than the three months in our study in order to ensure the size of the glochidia at the time of their detachment.

Results of juvenile drop off monitoring indicates that the development of freshwater pearl mussel glochidia can be affected by regulating water temperature; after the glochidia detachment has started, even a slight temperature increase will trigger metamorphosis and peak excystment of glochidia.

Results of the fish farm experiment encourage us to further develop this approach. It is possible to infect the to-be-stocked salmon and trout in commercial fish farms, but attention should be paid to suitable host fish strains and species. For example, the glochidia of the present study, River Jukuanoja, infected the sea-migrating River Iijoki brown trout very effectively but the Atlantic salmon in the same river were infected poorly.

The results of the River Ala-Haapuanoja sediment excavation and sieving indicated that some of the juvenile *Margaritifera* stocked in 2007 are still alive.

Work package F.
Searching for new populations

Introduction

Although many of the freshwater pearl mussel populations have been found either accidentally over time or as a result of active searching, a number of unknown populations probably still exists in the northern Finland, Sweden and Norway. On the other hand, there may be a need to study the fate of the freshwater pearl mussels in rivers or river sections where the species is known to have lived previously, but where the current occurrence is unknown. It is also possible that the freshwater pearl mussel is known to inhabit a certain part of a river while several other sections are unmapped, even though they would provide optimal habitats for the freshwater pearl mussel. In addition, monitoring of the status of the freshwater pearl mussel populations may require repeated checking of their occurrence.

Searching of freshwater pearl mussels is traditionally done by SCUBA diving, snorkelling or by using an aquascope. These methods are accurate, but time and resource demanding, which often prevents large scale mapping projects. Moreover, dark or turbid water, a stony bottom, aggregated distribution or a low density of mussels or some other obstacles may limit usage of the traditional methods, making them laborious or impossible. An alternative method could be the capture of host fish and their examination for pearl mussel glochidia microscopically, or with the naked eye at the site.

For the above reasons, the aim was to (1) search for new, previously unknown freshwater pearl mussel populations in the northern areas of Finland and Norway, and (2) to develop and test a new search technique, the electrofishing method, in which the occurrence of mussels is investigated by studying the gills of host fish for the parasitic glochidium larvae freshwater pearl mussel.

Study areas and methods

In the Näätämö, Teno and Paatsjoki river basins, electrofishing surveys were conducted in 44 rivers, and diving surveys in a total of 27 different locations. In the River Iijoki catchment, a total of 78 sites in 50 rivers were surveyed by electrofishing, out of which 40 sites in 40 tributaries were also studied with traditional methods (aquascope, snorkelling, diving).

Gills of salmonids were inspected with the naked eye for the occurrence of pearl mussel glochidia (Fig. 11). If the catch was large enough, a subsample of 1–5 salmonids was killed, stored on ice and transported to the laboratory for a microscopic examination.

Figure 11. Electrofishing for catching freshwater pearl mussel host fish. Glochidia infestation was inspected from the gills (small picture). Photos Jouni Salonen (left) and Marko Kangas (above).

Results

Suitability and reliability of electrofishing method for finding freshwater pearl mussels

In an experiment conducted in the previously known freshwater pearl mussel rivers Jukuanoja and Koivuoja in the River Iijoki catchment in the spring and early summer of 2011 the infection status (infected/uninfected) assessed by electrofishing method was 17 fish out of 18 in River Jukuanoja and 17 out of 22 fish in River Koivuoja. No false positive records were achieved, and the *in situ* inspection of gills was 100% correct in all cases when the number of glochidia per fish was at least 20. On the other hand, when the electrofishing was carried out in the autumn, the infection status was scored as 'uninfected' even though the fish were infected by freshwater pearl mussel glochidia. This indicates that in the autumn the new, recently attached glochidia are too small in size to be observed with the naked eye.

In 2012 the three independent observers conducted the encystment intensity scoring in the field. Repeatability of the scoring between the observers was usually reasonably good, although the scoring by the experienced observer was most frequently closest to the real glochidia number. The mean field scores by the three observers correlated statistically significantly with the real number of glochidia.

Surveys in River Teno and River Näätämö catchments

Brown trout or Atlantic salmon parr were caught in 28 out of 44 streams and rivers. Salmon and brown trout parr measuring less than 10 cm in length were caught in 15 different rivers or streams. However, no salmonids infected with the freshwater pearl mussel glochidia were found.

Besides electrofishing, a total of 3,885 metres of river in 27 different locations was investigated by snorkelling. These surveys did not reveal any freshwater pearl mussel populations or remnants of their shells. Brown trout or salmon were observed in 17 different rivers / streams.

Surveys in the River Iijoki catchment

New, previously unknown freshwater pearl mussel populations were found by the electrofishing method from three out of 38 rivers surveyed. In addition, surveys with traditional methods (aquascope, snorkelling, diving) revealed six new, previously unknown freshwater pearl mussel populations. Thus, the total number of freshwater pearl mussel populations known in the River Iijoki catchment now totals 29 populations, while the number before this project was 20. The estimated number of mussels varied from 1 (River Välijoki) to 50,000 (River Lohijoki), with 11 populations estimated to harbour at least 10,000 mussels.

Conclusions

The present results show that glochidia infestation can be accurately observed from fish gills with the naked eye *in situ*. This provides a reliable, non-destructive method to search for reproductive *Margaritifera* populations, as the fish can be released after inspection. However, seasonally the applicability of the method is restricted to spring and early summer, when the glochidia are big enough to be observed with the naked eye. Moreover, the method is suitable for finding populations with relatively high glochidia production, because it turned to be reliable only when the number of glochidia per fish was more than 20.

The vast areas investigated for the freshwater pearl mussels in the River Näätämö and River Teno water systems, both by the electrofishing method and by diving did not reveal any new freshwater pearl mussel populations. In the River Iijoki catchment, the investigations revealed nine new freshwater pearl mussel populations, resulting in a total of 29 freshwater pearl mussel populations in the River Iijoki drainage area. This is a significant improvement in our knowledge of freshwater pearl mussel distribution and occurrence in the River Iijoki area, and further emphasizes the value of the River Iijoki catchment nationally and internationally for the conservation of the freshwater pearl mussel.

Work package G.
Disseminating information

Lack of knowledge often prevents the effective conservation of freshwater pearl mussel populations. In forestry operations, for instance, operators were unaware that mussels have been killed because their presence in the river was not known. Even the knowledge of the population does not necessarily protect the mussels, if the forestry contractor does not know what actions should be avoided when operating near mussel rivers. Sometimes also attitudes towards protection may be indifferent or even negative, if the importance of the freshwater pearl mussel in the ecosystem is not understood. The aim of this work package was to disseminate information on the distribution and state of freshwater pearl mussel populations and their importance in the river ecosystem.

The information was delivered on the internet, in newspapers and journals, and on radio and TV as well as in briefings, meetings and congresses by posters and in oral presentations (Figs 12–13). The project end seminar was held in Rovaniemi, Finland on 12–15 May 2014. Altogether 60 participants 10 different countries took part to the seminar (Figs 14–15).

The list of the project's main media or other information activities is shown in Annex G. Apart from this report, we also produced a fact sheet about the management and conservation of freshwater pearl mussel (Raakkuvesien suojelu 2014, see Fig. 16). This fact sheet was particularly targeted at the forestry sector in order to give guidelines for mussel-friendly forestry operations, but it can be also utilized by management people and the authorities involved with river conservation work.

7 Discussion

The results of the population status assessments showed that the state of the freshwater pearl mussel populations in northern Fennoscandia was worse than expected: According to the criteria used, only one population showed recruitment of young mussels adequate to maintain the population. In addition, in two other populations the recruitment rate was perhaps adequate. A major part of the populations was

Figure 12. Some of the newspaper and magazine articles published during the project. Photo Panu Oulasvirta.

Figure 13. Panu Oulasvirta presenting the project poster in the International mussel congress in Braganca, Portugal September 2012. Photo Jouni Salonen.

Figure 14. Pirkko-Liisa Luhta giving an oral presentation in the project´s end seminar, Rovaniemi, Finland May 2014. Photo Jouni Salonen.

Figure 15. Participants of the project end seminar in Rovaniemi, Finland May 2014. Photo Arctic Centre.

Figure 16. Fact sheet about the management and conservation of the freshwater pearl mussel. Photo Panu Oulasvirta.

considered to be *non-viable* in the long run. In some cases, recruitment took place in certain areas in the river (usually in the upper course), while the degree of recruitment was not adequate regarding the whole population. Considering the northernmost populations, where the mussels are living at the extreme limits of their distribution range, it is also possible that the criteria used for determining the viability of the population do not fully apply. There are some indications that, in these extreme circumstances, recruitment would not take place every year but only in favourable years. An indication of this is, for example, the very long, almost 12-month development time of the glochidia (see Annex E).

Especially alarming is the state of the big main river populations, which prefer Atlantic salmon as their host fish (see Annex E). Apart from River Karpelva in Norway, all of these previous or current salmon river mussel populations are rapidly declining because of the low or zero recruitment rate. According to our genetic studies (see Annex D) the genetic diversity of the mussels was highest in these salmon-dependent main river populations, which in that way also serve as a source population for the smaller head water populations. Thus, the extinction of these source populations will result in a fragmented distribution of the species, where the species exists only in a couple of isolated head water populations in which the risk of extinction is high even without human influence.

The most important threats to the mussel populations in the project area are harnessing of rivers to hydropower production and forestry activities, including forest and bog land ditching operations, clear cuts and ploughing of the ground and building of forest roads, which have led to sand, silt, humus and nutrients entering the river and siltation of the river bottoms. The hydropower dams have prevented Atlantic salmon from ascending to their spawning grounds, which has been especially destructive of the salmon-dependent mussel populations in the main rivers. For instance, the construction of the Upper-Tuloma dam in Russia in the early 1960s is probably the principal reason for the low recruitment rate of the mussels in River Lutto and its main tributary River Suomu.

The influence of ditching operations is visible both in main rivers and in tributaries. The biggest damage was done already in the 1960–1970s, when most of the ditching operations especially in Finland were done. Indeed, according to some estimates, almost 40% of the world's forest ditches are in Finland (Joosten & Clarke 2002). In the mussel populations, the effect of the forest operations can be seen in the termination of recruitment or as a dip in the age class of the mussels that are 40–50 years old.

Apart from the above-mentioned anthropogenic factors, there are also other, less obvious reasons for the poor state of the freshwater pearl mussel populations in the northern Fennoscandia. It is noteworthy that the populations were in a poor state also in the areas beyond any forestry activities or in rivers not harnessed for hydropower production (River Näätämö, for instance). In some of the rivers, the low recruitment rate might at least partly be explained by natural reasons, i.e. the hard climatic conditions, as mentioned earlier. Most probably there are other reasons too, however. These may include airborne pollutants combined with the acidification-sensitive ground in the catchment area (see Annex C). Moreover, the levels of nutrients, especially nitrogen and ammonium, were high in many rivers. In this context, the effect of reindeer herding should also be studied more closely.

8 Conclusions

The conservation of freshwater pearl mussel in northern Fennoscandia would require actions on different levels: (1) Searching for new populations, (2) Status assessment and monitoring of known populations, (3) Restoration of damaged catchment areas, (4) Construction of fishways to the old salmon rivers, and (5) Captive breeding in the most threatened populations.

Searching for new populations should be focused especially on the big main rivers, such as River Utsjoki in Finland and all the northern salmon rivers in Sweden. Moreover, vast unmapped areas still exist, especially in the Kemijoki, Simojoki, Teno and Koutajoki river basins in Finland.

Baseline surveys of the population status in the known freshwater pearl mussel populations should be continued. After this study, the population status is still unknown in approximately 80% of the known freshwater pearl mussel populations in northern Finland, 60% in northern Sweden and 74% in northern Norway. The viability status of these populations should also be evaluated.

Restoration of the damaged catchments areas would be the biggest task. This will be especially challenging in the large main river drainage areas. However, as mentioned before, the genetically diverse mussel populations in these main rivers serve as a source for the smaller head water populations, and should thus be given priority in the conservation. Examples of successful restorations programmes are not many, the best known being the River Lutter restoration in Germany, where the natural reproduction of freshwater pearl mussel began after decades of restoration efforts (Altmüller 2013).

Building of fishways is a prerequisite, especially in the old salmon rivers in Finland. These include the hydropower plants, for example, in Rivers Iijoki and Kemijoki. However, it is notable that in these rivers the building of fishways would not alone be an adequate action; restora-

Table 1. Rivers suggested for a regular freshwater pearl mussel monitoring programme in Finland.

Main catchment area	River
Karjaanjoki	Mustionjoki
Kokemäenjoki	Ruonanjoki
Ähtävänjoki	Ähtävänjoki
Oulujoki	Nuottijoki
Iijoki	Livojoki
Iijoki	Haukioja
Iijoki	Norssipuro
Simojoki	Simojoki*
Koutajoki	Juumajoki
Kemijoki	Siikajoki
Kemijoki	Pikku-Luiro
Kemijoki	Toramojoki
Kemijoki	Onnasjoki
Tornionjoki	Koutusjoki
Lutto (Tuloma)	Lutto*
Lutto (Tuloma)	Suomujoki
Lutto (Tuloma)	Hanhioja
Lutto (Tuloma)	Kiertämäoja
Teno	Lovttajohka
Teno	Utsjoki*

* A proper baseline mapping of the population is required before monitoring

tion of the rivers and catchments would also be required. Another example is the Upper-Tuloma hydropower dam in Russia. Building a fishway there would allow Atlantic salmon migrations to the River Lutto on the Finnish side, which would probably start the natural recruitment of freshwater pearl mussel there and in its tributary, River Suomujoki. Since the decline of the freshwater pearl mussel population has already begun in Lutto and Suomu, there is not much time for this action.

Captive breeding of the mussels can never be a final solution for restoring the freshwater pearl mussel population. However, in cases where the population is near to extinction, it may give extended time for the other, more sustainable, restoration measures. Example rivers, where captive breeding is probably the only option to give a chance to the freshwater pearl mussel population to survive, are basically all the rivers where the known population size is smaller than 500 specimens (e.g. River Näätämö and almost all the rivers still containing freshwater pearl mussels in southern Finland).

As mentioned before, most of the actions harmful to freshwater pearl mussel took place decades ago. However, there are still on-going human activities, especially forestry operations, which have a negative impact on the rivers. In order to avoid further damage, all kinds of actions in the catchment area of freshwater pearl mussel rivers that could affect the hydrological circumstances or lead to siltation or eutrophication of the river should be avoided. Detailed guidelines for forestry operations in the vicinity of freshwater pearl mussel rivers are given in a separate fact sheet produced by our project (Metsähallitus 2014).

In Finland, an action plan for the freshwater pearl mussel is required. As part of the action plan, regular monitoring of selected populations should be started. Based on the data of the present work and some earlier studies (e.g. Geist *et al.* 2006, Geist & Auerswald 2007, Oikarinen & Sihvonen 2004, Oulasvirta 2006, Oulasvirta 2010a, Oulasvirta 2010b, Oulasvirta 2010c, Oulasvirta *et al.* 2004, Oulasvirta *et al.* 2006, Oulasvirta *et al.* 2008, Oulasvirta *et al.* 2012, Oulasvirta & Syväranta 2012, Valovirta 1990a, Valovirta 1990b, Valovirta 1993, Valovirta 1996, Valovirta 1997, Valovirta & Huttunen 1997, Valovirta *et al.* 2003), a list of the rivers suggested for regular monitoring in Finland is given in Table 1. The monitoring should be carried out by following the methods used in the other Nordic countries or, if a CEN standard is approved, this should be implemented as a guidance standard on monitoring freshwater pearl mussel populations in Finland.

Appendix 1. Project rivers and actions

Rivers and actions are listed in the next table. © Metsähallitus 2015, © National Land Survey of Finland 1/MML/15, © Läntmäriet, County Administrative Board of Norrbotten, © Norway Digital / GIT Barents.

Number	River	Population status assessment	Mussel length measurements	Redox measurements	Searching for new populations: Dive transect/Aquascope	DNA sample	Mussel transfer	Host fish caging experiments	Planting of juvenile mussels	Electrofishing	Logger	Water sample
R1	Ahmaoja									●		
R2	Ahvenjoki				●							
R3	Ahvenjärvenoja									●		
R4	Aili-oja									●		
R5	Aimojoki				●					●		
R6	Alahaapuanoja							●	●		●	
R7	Askanjoki				●					●		
R8	Aviljuuha									●		
R9	Bajit Boratbokcajohka				●							
R10	Basejohka									●		
R11	Bavvalasjohka1				●							
R12	Bavvalluoppal				●							
R13	Cieskada				●							
R14	Coarvejohka									●		
R15	Coollmasjuuha									●		
R16	Cuokka				●							
R17	Duolbajohka				●							
R18	Elehvänoja									●		
R19	Follelva					●						
R20	Gakcavarjohka									●		
R21	Galddasjohka									●		
R22	Guottoveajohka				●							
R23	Hacastamajuuha									●		
R24	Halthajohka				●							
R25	Hanhioja	●	●	●		●		●				●
R26	Hanhivuotso									●		
R27	Haratjohka				●							
R28	Harjajoki									●		
R29	Harrijaurbäcken	●		●								
R30	Harrioja									●		
R31	Haukijoki	●	●	●								
R32	Stream from Haukijärvi lake									●		
R33	Haukioja	●	●	●					●	●		
R34	Heinioja				●							
R35	Hepo-oja				●							
R36	Hietajoki				●					●		
R37	Hirvasjoki	●	●	●		●						●
R38	Hirvipuro				●							
R39	Hukkajoki					●						
R40	Iijoki. Hepokangas									●		
R41	Iivanajoki				●							

Number	River	Population status assessment	Mussel length measurements	Redox measurements	Searching for new populations: Dive transect/Aquascope	DNA sample	Mussel transfer	Host fish caging experiments	Planting of juvenile mussels	Electrofishing	Logger	Water sample
R42	Ivvanasjohka				●							
R43	Jaaskamonoja				●					●		
R44	Jouvsajärvi-Sevettijärvi									●		
R45	Jukuanoja									●		
R46	Junnonjoki				●							
R47	Juojoki	●	●	●		●						
R48	Juumajoki	●	●	●								
R49	Juurikaisenpuro									●		
R50	Kalajoki										●	
R51	Kallo-oja									●		
R52	Karhuoja									●		
R53	Karpelva					●						
R54	Keräsjärvi				●							
R55	Kevojoki				●							
R56	Kiertämäoja	●	●	●								●
R57	Kietsimä									●		
R58	Kirppupuro				●							
R59	Kisosjoki				●					●		
R60	Koiraoja									●	●	
R61	Koivuoja							●	●	●	●	
R62	Kokko-oja				●							
R63	Kolmosjoki							●				
R64	Kopsusjoki	●	●									●
R65	Koronoja				●							
R66	Korvuanjoki									●		
R67	Kostonlammenoja									●		
R68	Kotajärvi-Teppanakotajärvi									●		
R69	Koutusjoki	●	●	●		●						
R70	Kuksajoki				●							
R71	Kurtte-Sollomusjärvi									●		
R72	Kutinjoki									●		
R73	Kuutusoja	●		●		●						●
R74	Kylmäjoki				●					●		
R75	Kylmäluomanoja									●		
R76	Kääntöjoki	●		●								
R77	Lahnasenoja									●		
R78	Laivajoki				●							
R79	Lakioja				●							
R80	Latvajoki									●		
R81	Latvajoki (Loukusa)									●		
R82	Leaibejohka				●							

Number	River	Population status assessment	Mussel length measurements	Redox measurements	Searching for new populations: Dive transect/Aquascope	DNA sample	Mussel transfer	Host fish caging experiments	Planting of juvenile mussels	Electrofishing	Logger	Water sample
R83	Liimakaisenpuro				●							
R84	Livojoki	●	●	●		●		●	●	●		
R85	Lohijoki					●		●				
R86	Lohioja									●		
R87	Loukusanjoki									●		
R88	Lovattajohka	●	●			●						
R89	Lukkarinjoki				●					●		
R90	Lukkarinoja									●		
R92	Luomalanjoki					●						
R93	Luomusjohka									●		
R94	Lutto	●				●						●
R95	Majovanoja									●		
R96	Majovanoja (Kylmävaaranpuro)									●		
R97	Martinjoki				●					●		
R98	Moalkejohka									●		
R99	Myllyjoki									●		
R100	Myllypuro				●							
R101	Mäntyjoki									●		
R102	Nikolasjoki									●		
R103	Nilijoki									●		
R104	Norssipuro	●	●	●	●			●				
R105	Nuorttijoki									●		
R106	Nuottijoki				●					●		
R107	Näätäjoki				●							
R108	Näätämö kontinpaistama									●		
R109	Näätämöjoki		●	●			●			●		
R110	Ohtaoja				●					●		
R111	Onnasjoki	●	●	●		●						
R112	Oudonjoki									●		
R113	Paavalijoki									●		
R114	Pahkaoja				●				●	●		
R115	Pahtalampi-Siikajärvet									●		
R116	Paljakkaoja									●		
R117	Petsijoki									●		
R118	Pirinoja				●					●		
R119	Porraslammenoja							●		●		
R120	Porrasoja							●	●	●		
R121	Portinjoki							●			●	
R122	Portinoja					●						
R123	Puhosjoki									●		
R124	Stream Taimenlampi-Vainosjärvi									●		

Number	River	Population status assessment	Mussel length measurements	Redox measurements	Searching for new populations: Dive transect/Aquascope	DNA sample	Mussel transfer	Host fish caging experiments	Planting of juvenile mussels	Electrofishing	Logger	Water sample
R125	Pärjänjoki				●							
R126	Pätsikota-Kurttejärvi									●		
R127	Raanujoki									●		
R128	Rautaperänjoki									●		
R129	Rautujoki									●		
R130	Rautujoki (Utsjoki)									●		
R131	Rekipuro				●							
R132	Riitainjoki				●					●		
R133	Ruohojärvenoja	●	●	●		●						●
R134	Ruokosenpuro				●					●		
R135	Rääpysoja				●					●	●	
R136	Sarriojoki					●						
R138	Saukko-oja	●	●	●		●						
R139	Savujoki									●		
R140	Savzajohka				●							
R141	seimioja				●							
R142	Sevetti-Jänisjärvi									●		
R143	Siikajoki	●	●	●		●						
R144	Siikajärvet-Sanilanlampi									●		
R145	Siiranjoki				●					●	●	
R146	Simojoki							●				
R147	Skaidejohka				●							
R148	Skjellbekken					●						
R149	Slipakbäcken	●		●								
R150	Sorraja				●							
R151	Spurvbekken					●						
R152	Suolusjoki				●							
R153	Suomujoki	●		●		●						●
R154	Suopumaoja									●		
R155	Susioja										●	
R156	Tervajoki				●					●		
R157	Tervaoja				●					●		
R158	Tolpanoja				●					●		
R159	Tonko-oja				●							
R160	Toramojoki	●	●	●								
R161	Torkojoki	●	●	●		●						●
R162	Tsiesekuljoki				●							
R163	Tutulammenoja				●							
R164	Tutuoja									●	●	
R165	Unhorjuuha									●		
R166	Utsjoki				●					●		

Number	River	Population status assessment	Mussel length measurements	Redox measurements	Searching for new populations: Dive transect/Aquascope	DNA sample	Mussel transfer	Host fish caging experiments	Planting of juvenile mussels	Electrofishing	Logger	Water sample
R168	Vaasselijärvi-Kotajärvi									●		
R169	Vaddejohka				●							
R170	Vaijoki									●		
R171	Vainosjoki									●		
R172	Stream to lake Vainosjärvi									●		
R173	Vetsijoki				●							
R174	Virsuoja										●	
R175	Visaoja									●		
R176	Vogojarjohka				●							
R177	Vuoknoljohka				●							
R178	Vuolit Boratbokcajohka				●							
R179	Välijoki				●					●		
R180	Vääräjoki				●					●		
R181	Vääränoja									●		
R182	Väätäjänoja									●		
R183	Ylähaapuanoja									●		
R184	Silisjoki				●							
R185	Karasjohka				●							
R186	Løksabotnelva	●										
R187	Neiden, Norwegian side				●							