Annex A: Network

Table 1. List of the networking activities during the project.

Occasion	Place	Time
Nordic mussel workshop in Sweden	Storåbränna, Jämtland, Sweden	28–30.6.2011
Kick-off meeting of the project	Rovaniemi, Finland	11–12.8.2011
Project partner meeting	Pudasjärvi, Finland	18.11.2011
Project partner meeting	Tromsö, Norway	13.12.2011
Steering group meeting	Rovaniemi, Finland	13.3.2012
Project partner meeting	Svanvik, Norway	28–29.3.2012
Meeting with Kainuu ELY-centre	Kajaani, Finland	20.2.2012
CEN-meeting	Aberdeen, Scotland	21–22.3.2012
Meeting with Prof. Jürgen Geist, Technical University of Munich: Genetic studies	Jyväskylä, Finland	23–26.4.2012
Meeting with Ostrabothnia ELY-centre: Planning of *Margaritifera* database	Oulu, Finland	15.5.2012
Project partner meeting	Braganca, Portugal	3.9.2012
CEN-meeting	Braganca, Portugal	3–4.9.2012
International mussel congress in Portugal	Braganca, Portugal	4–7.9.2012
Project partner meeting	Pudasjärvi, Finland	January 2013
Meeting with the project "Kainuu pearl fishers": Planning of co-operation	Pudasjärvi, Finland	February 2013
CEN-meeting	Belfast, Northern Ireland	13–14.2.2013
International mussel seminar in Ireland	Letterkenny, Ireland	15.2.2013
Workshop between other cross-border projects in metsähallitus	Rovaniemi, Finland	19.2.2013
Meeting between environmental authorities in Finland: Action Plan for freshwater pearl mussel in Finland	Oulu, Finland	April 2013
Steering group meeting	Rovaniemi, Finland	13.3.2013
Informative meeting with the forestry sector: Mussel friendly forestry activities in Ostrabothnia area	Oulu, Finland	April 2013
World congress of malacology	Ponta Delgada, Azores, Portugal	21–28.7.2013
Project partner meeting	Konnevesi, Finland	16–19.4.2013
Informative meeting with the forestry sector: Mussel-friendly forestry activities in Lapland	Rovaniemi, Finland	5.6.2013
Steering group field excursion	Lutto catchment, Finland	2–3.9.2013
Meeting with Prof. Jürgen Geist and his project team: Co-operation in genetic analyses and possible future projects	Freising, Germany	June 2013
Project partner meeting	Haltia, Espoo, Finland	4-5.12.2013
International mussel congress in Austria	Kefermarkt, Austria	13–15.11.2013
Project partner meeting	Kefermarkt, Austria	14.11.2013
CEN-meeting	Windermere, England	13–14.3.2014
Steering group meeting	Rovaniemi, Finland	12.5.2014
Project's final seminar	Rovaniemi, Finland	13–15.5.2014

Annex B: State of the freshwater pearl mussel populations in northern Fennoscandia

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1 Introduction

Since 2000, the present freshwater pearl mussel distribution 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 presence of freshwater pearl mussel populations was studied in old pearl-fishing areas in Inari, the Pasvik Valley and Petchenga in Finland, Norway and Russia (Oulasvirta *et al.* 2004, Oulasvirta 2006, Oulasvirta *et al.* 2006) respectively. In 2007–2008, inventories were carried out in the Tornionjoki (Swedish Torneälven) river basin in Finland and Sweden (Oulasvirta *et al.* 2008). The main focus in these investigations was to find new unknown populations. Proper population status assessments were not carried out, but the preliminary results revealed big differences in the state of the freshwater pearl mussel populations both between the catchment areas and between the different rivers inside the catchment areas. Most of the breeding populations were usually found from the upper parts of the river systems. However, in many rivers even in remote areas the recruitment rate of freshwater pearl mussel was low or totally lacking. The aim of this study was to estimate the viability status of some of the northern Fennoscandian freshwater pearl mussel populations. In addition, we have tried to evaluate the reasons that have led to the decline of the populations. Most of the work was done in Finland, where knowledge of the populations was most scarce.

In Sweden and Norway, the state of the populations are monitored regularly as part of a regional monitoring programme (Länsstyrelsen 2009) or national monitoring programmes (Naturvårdsverket 2005, Lundberg & Bergengren 2008, 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 monitoring programme for freshwater pearl mussel. 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. Based on the results of the population studies, our aim was to prepare a list of rivers which would be suggested for the future monitoring programme in Finland.

2 Study areas

The project area covers the whole northern of Fennoscandia (Figure 1) and consists of 30 different rivers from 14 different drainage areas in northern Finland, Sweden and Norway (Table 1).

Four rivers were investigated in Sweden. In River Juojoki the work was carried out by Finnish partners within the project. Personnel from the County Administrative Board of Norrbotten did the work in Rivers Harrijaurebäcken, Silpakbäcken and Kääntöjoki. In three of the rivers (Harrijaurebäcken, Silpakbäcken and Kääntöjoki) it was known that freshwater pearl mussel existed due to earlier (mid-2000) investigations. These investigations were carried

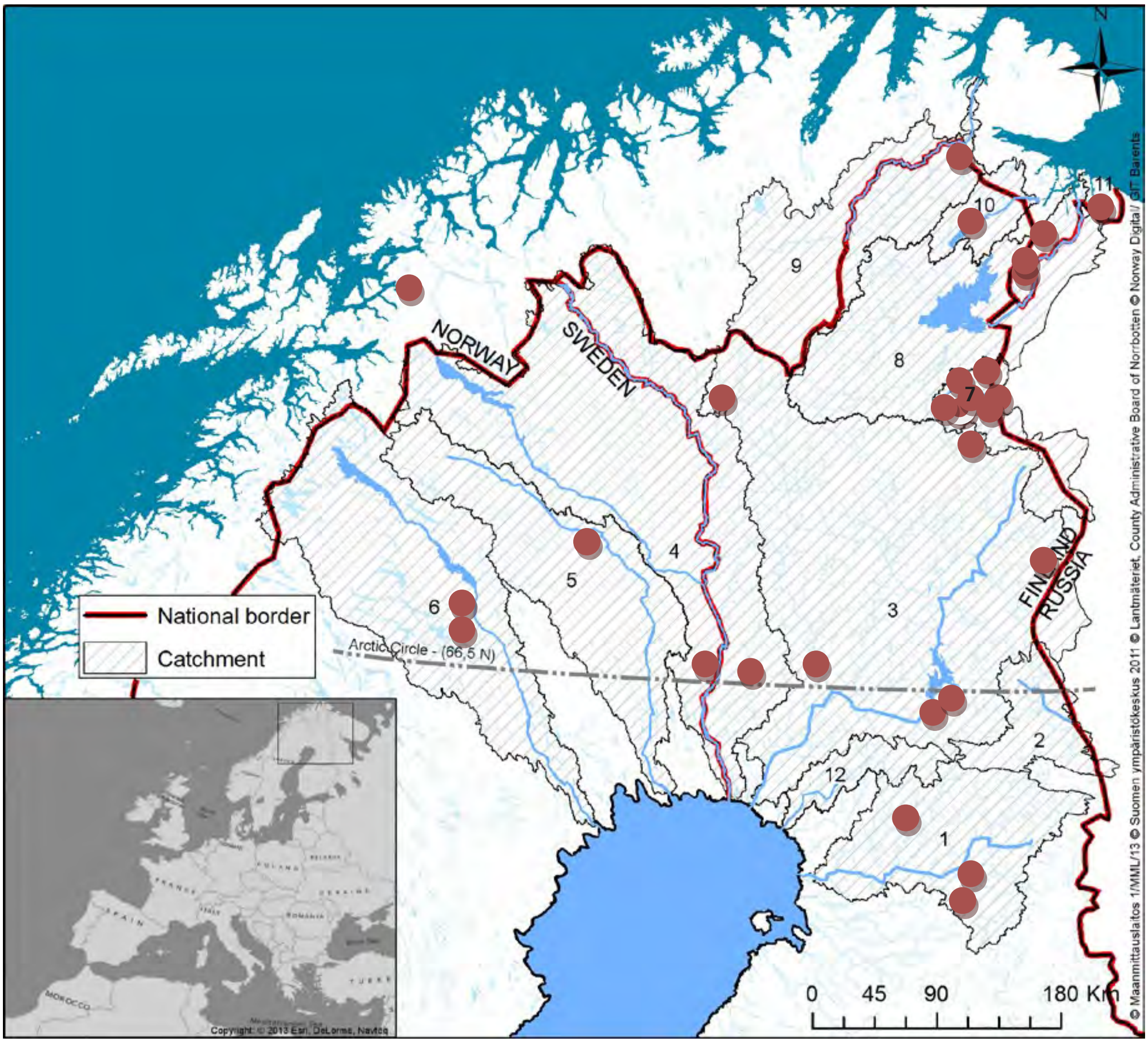


Figure 1. Project area and the target rivers (red dots). Main cathment areas: 1. Iijoki, 2. Koutajoki, 3. Kemijoki, 4. Tornionjoki, 5. Kalixälven, 6. Luleälven, 7. Lutto (Tuloma), 8. Pasvik, 9. Teno, 10. Näätämö, 11. Karpelva, 12. Simojoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15, © Läntmäriet, County Administrative Board of Norrbotten, © Norway Digital / GIT Barents.

out in order to determine whether the freshwater pearl mussel was present or not, and were and not thorough investigations. Only big mussels were found in earlier investigations. These rivers were chosen in order to acquire a better knowledge of the populations and to determine whether recruitment occurred.

The forth river, Juojoki, was chosen based on the fact that this is one of only three known freshwater pearl mussel rivers in the River Torneälven catchment area, the only one on the Swedish side. Small mussels have been found earlier, but the status of the population was unknown.

In Finland, altogether 21 rivers in seven different catchments were investigated (Table 1). Usually the area investigated covered the known distribution range of the mussels. In some cases, as in Rivers Livojoki and Suomujoki, the investigations were focused on the main population area only. The investigations were carried out by the field staff of Metsähallitus in 2011–2013. The criteria for selecting the rivers were: (1) the geographical distribution (rivers from all main catchments), (2) to include both functional and non-functional populations, (3) to include both small brooks and bigger streams. The background information on the freshwater pearl mussel populations was obtained from the previous investigations of freshwater pearl mussels in the area (Oulasvirta 2006, Oulasvirta *et al.* 2006, Oulasvirta 2010a, Oulasvirta 2010b, Valovirta 1990a, Valovirta 1996, Valovirta

1997, Valovirta & Huttunen 1997, Valovirta *et al.* 2003, Metsähallitus, unpublished data, Lapland ELY-centre, unpublished data).

Rivers in Norway

Five rivers were investigated in Norway. The results of Norwegian rivers are presented in a separate report (Aspholm, in preparation).

3 Methods

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. These were studied on the randomly chosen transects. Since the field methods differ in detail between countries, the methods in Sweden and Finland are presented separately in chapters 3.2 and 3.3. All the field investigations were carried out in 2011–2013.

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 the juvenile mussels (Geist & Auerswald 2007). The readings in the field were corrected according to the temperature (Denic 2009). The values obtained from the interstitial water were compared to the recording obtained from the free flowing water. More than 20% loss from the free flowing water value is generally considered to be unfavourable for the juvenile mussels. With temperature corrected values, the values Eh > 400 mV are typical for rivers with a recruiting freshwater pearl mussel population, and values < 300 mV represent anoxia (Degerman *et al.* 2009, Geist & Auerswald 2007).

Water quality and pollutants were studied in 12 rivers with temperature/DGT (Diffusive Gradient Thin film) -loggers. In addition, water samples were taken from 19 rivers. The results of the water quality analyses are presented in greater detail in Annex C. The water quality was compared against the threshold values in the rivers with a functional freshwater pearl mussel population (Table 2).

Table 1. Target rivers for the population status assessment.

River	Catchment	Country
Hanhioja	Lutto (Tuloma)	Finland
Haukijoki	Kemijoki	Finland
Haukioja	Iijoki	Finland
Hirvasjoki	Lutto (Tuloma)	Finland
Juojoki	Tornionjoki/Torneälven	Sweden
Juumajoki	Koutajoki	Finland
Kiertämäoja	Lutto (Tuloma)	Finland
Kopsusjoki	Kemijoki	Finland
Koutusjoki	Tornionjoki/Torneälven	Finland
Kuutusoja	Lutto (Tuloma)	Finland
Livo	Iijoki	Finland
Lovttajohka	Teno	Finland
Lutto*	Lutto (Tuloma)	Finland
Norssipuro	Iijoki	Finland
Näätämö*	Näätämö/Neiden	Finland
Onnasjoki	Kemijoki	Finland
Saukko-oja	Kemijoki	Finland
Siikajoki	Kemijoki	Finland
Suomujoki	Lutto (Tuloma)	Finland
Toramo	Kemijoki	Finland
Torkojoki	Lutto (Tuloma)	Finland
Ruohojärvenoja	Lutto (Tuloma)	Finland
Harrijaurebäcken	Luleälven	Sweden
Kääntöjoki	Kalixälven	Sweden
Silpakbäcken	Luleälven	Sweden
Karpelva**	Karpelva	Norway
Skjellbäcken**	Pasvik	Norway
Löksebottenelva**	Löksebottenelva	Norway
Föllelva**	Pasvik	Norway
Spurvbekken**	Pasvik	Norway

*Population size was not estimated
**Results not presented in this report

Table 2. Habitat requirements for sustaining a viable population of freshwater pearl mussels according to Degerman *et al.* (2009).

Water temperature	< 25 °C	maximum
pH	6.2	minimum
Nitrate	< 125 µg/l	median
Total phosphorus	< 5–15 µg/l	average
Turbidity	< 1 FNU	average, spring flood
Water colour	< 80 mg Pt/l	average, spring flood
In-organic aluminium	< 30 µg/l	maximum
Fine-grain < 1 mm	< 25%	maximum
Redox potential	> 300 mV	minimum
Number of host fish	> 5/100 m^2	minimum
Filamentous algae	< 5%	maximum

3.1 Data analyses

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 (Table 3). In the Swedish method, the viability of the population is basically determined according to the proportion of < 20 mm (~10 years) and < 50 mm (~20 years) mussels in samples. The proportion of these size classes was calculated from samples taken from random transects. In addition, usually a sample of 100 mussels was taken from the area thought to be optimal for juveniles. If there were no significant difference in the size distribution between the optimal area and random transects, then the data from the optimal site was combined with the length data from random transects, In those cases, where a specific recruitment area could be identified, this was notified when estimating the viability of the population.

The shell length of the mussel correlates to some extent with the age of the mussel. An obvious source of error here is the fact that the growth rate of the mussels varies between the rivers and even within the river (Aspholm 2012). According to Dunca & Mutvei (2009), the mussels of 20 mm in length are in Swedish populations between 6–18 years and mussels 50 mm in length 16–27 years, depending on the growth rate of the mussels. In this study, we took few samples of shells under 50 mm and counted their year rings. The results were in line with Dunca's & Muvei's (2009) findings, although showing generally fast rather than slow growth rate of the mussels.

Table 3. Criteria for determining the viability status of the freshwater pearl mussel populations (Bergengren et al. 2010, Söderberg et al. 2009).

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

Table 4. Criteria for determining the conservation value of the population. The first six criteria have been used in Sweden (Bergengren et al. 2010). The number of haplotypes and unique alleles are genetic parameters that were added into the criteria based on the results of our project.

	Points					
Criterion	1	2	3	4	5	6
Population size 1000x	<5	5–10	11–50	51–100	101–200	>200
Mean density m^2	<2	2.1–4	4.1–6	6.1–8	8.1–10	>10
Distribution km	<2	2.1–4	4.1–6	6.1–8	8.1–10	>10
Smallest mussel mm	>50	41–50	31–40	21–30	11–20	<11
% < 20 mm	1–2	3–4	5–6	7–8	9–10	>10
% < 50 mm	1–5	6–10	11–15	16–20	21–25	>25
Number of haplotypes	3	4	5	6	7	8
Unique alleles	if found					

Conservation status	Points (scores if no genetic data available)
I Normal	1–8 (1–7)
II High	9–19 (8–17)
III Very high	20–43 (18–36) or if salmon dependent population and/or if there is ≤ 3 known freshwater pearl mussel rivers in the whole catchment

Table 5. Limits for freshwater pearl mussel populations that are used in the Swedish work with the classification of water bodies according to the EU Water Framework Directive (Caruso *et al.* 2013).

High status bottom fauna (e.g. freshwater pearl mussel)	Population > 500 individuals and > 20% of the mussels are < 50 mm
Good status bottom fauna (e.g. freshwater pearl mussel)	Population > 500 individuals and mussels < 50 mm found. Or population <500 individuals with more than 10% < 50 mm.
Moderate status bottom fauna (e.g. freshwater pearl mussel)	Population made up only of individuals > 50 mm. Or earlier documented populations that now are gone.

Table 6. Criteria used in Norrbotten and Västerbotten counties in Sweden (Bothnian Bay Water District) to classify water bodies with freshwater pearl mussel, additional to the criteria by Caruso *et al.* 2013 (Olofsson 2013).

High status bottom fauna (e.g. freshwater pearl mussel)	Population > 500,000 individuals and > 10% of the mussels < 50 mm
Good status bottom fauna (e.g. freshwater pearl mussel)	Simple investigation (only a few transects investigated). "Population" < 500 individuals and mussels < 50 mm found.
Moderate status bottom fauna (e.g. freshwater pearl mussel)	Thoroughly investigated (Swedish standard or likewise). Relatively low densities and low population size together with few small mussels. Population < 8,000 individuals and 0% < 20 mm and < 5% < 50 mm and density < 2.5 individuals/m^2 (mean value of all transects investigated).

The freshwater pearl mussel is listed in Annex II of the European Union Habitats Directive as a species whose habitat must be protected for its survival. In addition, the species is protected at a national level in Sweden, Finland and Norway. Knowing the limited resources for conservation work, sometimes it may be necessary to prioritize some populations above others. In Sweden, there are various ways to classify a freshwater pearl mussel population. Apart from classifying the viability of the population (see Table 3), the protection value of the population has been classified according to six different criteria, such as population size, mean density, length of the distribution area, proportion of the < 20 mm and < 50 mm mussels, and size of the smallest mussel (Bergengren *et al.* 2010). In this study, we developed the Swedish system a little further based on the results of the genetic studies and host fish experiments in this project (see Annexes D and E). 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 in their reproduction. Also the high genetic diversity (number of haplotypes) and unique alleles raises the conservation value of the population (Table 4). Moreover, the highest conservation status was given to the population if there are only three or less known freshwater pearl mussel rivers in the whole catchment area.

The populations are also used to classify the river's (e.g. water bodies) ecological status according to the EU Water Framework Directive. Since no common EU criteria have been developed, Sweden has developed a way of using the freshwater pearl mussel for this purpose (Table 5).

In order to classify the populations according to the tables above, you need to have a very good knowledge of the populations; the investigations of the populations have to been conducted with the Swedish standard survey method or the like. Far from all the freshwater pearl mussel rivers in northern Sweden, Finland or Norway have been investigated that thoroughly. In order to use freshwater pearl mussel results from less thoroughly investigated rivers and to be able to classify the ecological status in these waters, the counties of Norrbotten and Västerbotten in Sweden (i.e. Bothnian Bay Water District Authority) have further developed the criteria from Caruso *et al.* 2013 (Table 6).

In rivers where the standard method has been used, the classification of bottom fauna (e.g. freshwater pearl mussel) has also determined the overall ecological status. In rivers where a less thorough method has been used, the classification of bottom fauna (e.g. freshwater pearl mussel) is used as a support parameter to the other classified parameters in order to determine the ecological status of the water bodies.

In 2013, 154 water bodies with freshwater pearl mussels were classified in the Bothnian Bay Water District using the above mentioned system. Nine water bodies were classified as high status, 73 good status and 72 moderate status.

3.2 Field methods in Sweden

Mussel investigations

Before the inventory of the mussel population began, the upper most and lower most mussels in each river was located in order to determine the distribution range of the populations. Each distribution range was then divided into three equally long stretches and 20 x 20 metre squares were drawn onto a map on these stretches. The squares were then numbered, and six squares from each of the three stretches were chosen randomly. Coordinates from the 18 sites chosen were taken in order to be investigated. (Bergengren *et al.* 2010).

In River Juojoki a so-called "optimal site" was also chosen where the conditions for finding many small individuals seemed to be the best. This site was not chosen randomly.

The 18 randomly chosen sites were investigated using an aquascope and wading trousers, following the Swedish standard method for investigating freshwater pearl mussel populations (Bergengren *et al.* 2010). A twenty metre-long transect was established, and every visible mussel within this area was counted. The start and end points of the transects were marked out with spray paint on trees and stones next to the river. The coordinates for the start point were taken by GPS. The length of the smallest mussel within the transects was measured, and the 15 first randomly found mussels above or below the transects were measured for length, width and height. These measurements were then used to determine the length distribution of the mussels within the population.

In River Juojoki the investigation was done using snorkelling equipment (see Finnish Field methods).

Habitat analyses

At each site, a description of the habitat in the water and the surrounding environment was carried out as described in Bergengren *et al.* (2010). In River Juojoki, the description was made according to the Finnish system (see Finnish habitat analyses).

Redox potential

In six of the 18 transects investigated, redox potential was measured after the mussel investigation was completed. If possible, the sites where chosen in order to measure redox at two "good sites" (high densities of mussels and small mussels (< 50 mm) present), two "average sites" (medium–high densities, only large (> 50 mm) mussels) and two "bad sites" (few large mussels or no mussels present). If these criteria were not met, the sites were evenly distributed between the lower, middle and upper sections of the distribution area and chosen to match as closely as possible the criteria described above.

Within the transects chosen, redox potential was measured 5 cm down in the bottom substrate at three spots in a straight line from one side of the river to the other. This was done on four lines evenly distributed within each transect, so that a total of twelve measurements were carried out in the bottom substrate in each transect (Figures 2–3). The redox value in free-flowing water was measured once at each line.

3.3 Field methods in Finland

Mussel investigations

The field investigations were carried out basically in the same way as in Sweden (see previous chapter), with some exceptions to the method, however. Instead of wading and aquascoping the 20 metre-long transects were investigated by snorkelling (Fig. 4). The upper and lower limits of the transects were marked with chains, and their positions were recorded with GPS. In addition, bottom chains across the river

Figure 2a. Measuring redox potential (E_h) from the interstitial water with a redox probe (red marking) and reference probe (blue marking). The redox probe was pushed 5 cm or 10 cm deep down in the sediment (see Fig. 2b). Photo Panu Oulasvirta, Metsähallitus.

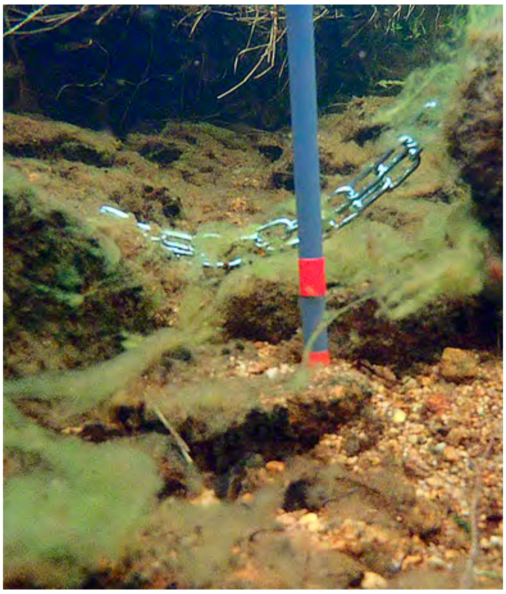


Figure 2b. Redox probe pushed in the sediment. Red tapes are the 5 cm and 10 cm markings. Chain marks the end of the transect. Photo Panu Oulasvirta, Metsähallitus.

Figure 3. Redox measuring points (stars). Photo County Administrative Board of Norrbotten.

Figure 4. Investigating random transects by snorkelling. Tape measure on the right shore marks the 20 metre long transect. Photo Aune Veersalu, Metsähallitus.

Figure 5. Measuring the length of the mussel. Photo Juha Syväranta, Alleco Ltd.

channel were laid at five metre intervals between the start and end points. After that, a diver investigated the transect by swimming upstream and counting all mussels in five metre sections.

In big streams such as in Rivers Livojoki, Lutto and Suomujoki, the transects were established from shore to shore across the river channel. In these cross-transects, the diver counted mussels from a one metre- wide area on both sides of the bottom rope.

The number of random transects was 15–40 per river depending on the length of the river and type of transect. In 2011, transects were chosen randomly in the same way as in Sweden. In 2012–2013, the method was changed, so that only the lowermost transect downstream was chosen randomly and after that the other transects were located with even distances from that upstream until reaching the upper limit of the mussel distribution area. Transects were focused only on the previously known distribution area of the freshwater pearl mussel. Sometimes, the available information on the distribution was, however, too sparse to focus the random transects exactly on the right stretch of river.

After counting the mussels in the transect, the diver randomly collected the first 15 mussels for length measurements (Fig. 5). This sample was taken in the vicinity of each random transect either upstream or downstream of it. The length measurements were used for determining the size distribution of the mussel population. In addition, the smallest observed mussel was measured.

Apart from the mussel samples mentioned above, a random sample of the first 100 mussels was taken for length measurements from an "optimal" area, i.e. from the area with the highest proportion of juvenile mussels. The aim of this sample was to ascertain whether the juvenile mussels occupy their own specific habitats in the river. However, usually no specific area could be identified as optimal for recruitment. In these cases, the length data from the "optimal" area were combined with the length data from the random transects.

Habitat analyses

The habitat in each transect was evaluated using 45 parameters such as river size, current speed, depth, bottom substrate, aquatic vegetation, human influence on the drainage area, etc. The list of parameters recorded from field work is shown in Appendix 1.

Redox potential

The substrate quality studied by measuring redox potential was measured at selected sites, 1–3 sites per river. As in Sweden, the sites where chosen in order to measure redox at "good sites" (juvenile mussels present) and in "bad sites" (only adult mussels present). Within the chosen transects, redox potential was measured first in free-flowing water and after that in 10 parallel spots 5 cm down in the bottom substrate. In some cases, redox potential was also measured 10 cm inside the sediments.

4 Results

4.1 Results from Sweden

Torneälven river catchment

The Torneälven (Finnish Tornionjoki) is a cross-border river basin between Finland and Sweden (Figure 6). The catchment area covers 40,130 km^2, of which 14,280 km^2 lies in Finland, 25,851 km^2 in Sweden and some small parts in Norwegian territory. The proportion of lakes in the catchment area is 4.63% (Ekholm 1993). The main rivers in the system are the Könkämäeno-Muonionjoki (Swedish Könkämäälven-Muonioälven), a border river between Finland and Sweden that rises in Lake Kilpisjärvi, Finland, and the Torneälven in Swedish territory, which rises in Lake Torneträsk. These two main branches join at the national border 170 km from the coast to form the main channel of the Torneälven, which then runs south as a border river to the Bothnian Bay. The length of the river is ca. 520 km from Lake Kilpisjärvi and 420 km from Lake Torneträsk. River Torneälven and its tributaries (except for the River Tengeliönjoki sub-basin in Finland) are protected by Natura 2000, and in Sweden it is also a so called "National River", where water regulatory and other activities connected to hydro power is forbidden by Swedish law.

The freshwater pearl mussel was investigated in the Torneälven catchment in 2007 in a Finnish-Swedish Interreg North project (Oulasvirta *et al.* 2008). Besides the three already known freshwater pearl mussel rivers, no new populations were found in the study. The three known freshwater pearl mussel rivers are Koutusjoki and Luomalanjoki on the Finnish side and River Juojoki on the Swedish side of the catchment (Fig. 6). In this study, the status of the freshwater pearl mussel population was investigated in Rivers Juojoki and Koutusjoki. The description and results from the Koutusjoki are presented in chapter 4.2.

River Juojoki

Juojoki is situated in Torneälven river basin area in Övertorneå municipality. It starts from Lake Kaitajuojärvi at 150 metres above sea level and

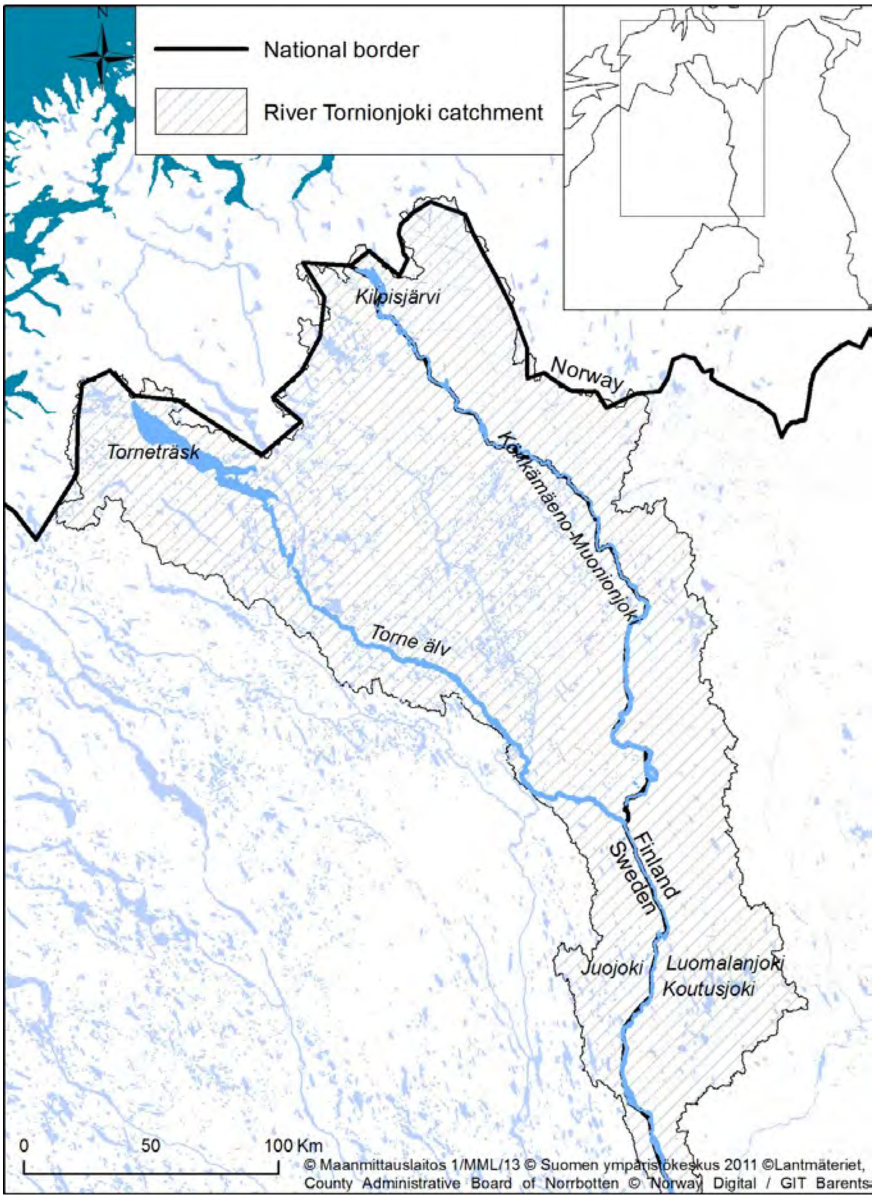


Figure 6. Torneälven river basin in Finland and Sweden. The three known freshwater pearl mussel rivers are Juojoki in Sweden and Luomalanjoki and Koutusjoki in Finland. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15, © Läntmäriet, County Administrative Board of Norrbotten, © Norway Digital / GIT Barents.

runs down to River Ylinenjoki, at 50 metres above sea level, which has it outlet in River Torneälven (Fig. 7). The total elevation is 100 metres, the total length of Juojoki is 9.3 kilometres and its mean width 5.0 metres. The total catchment area is 74.7 km^2 and this is made up of 83.7% forest, 11.7% clear cuts, 3.8% surface water, 0.7% wetland and 0.1% agricultural land (SMHI SVAR VERSION 2012-2).

Small mussels were found in five out of 18 investigated transects, and no mussels were found in three transects (Fig. 7). The estimated freshwater pearl mussel-population size was 39,400 individuals, and the distribution range was 8.8 km (Table 7). The mean density of the population was 0.9 individuals/m^2. The highest densities were found in the upper part of the river. In the lower parts, only a few mussels were found in the transects investigated. Only a few small mussels were found (Fig. 8), which indicates a low recruitment rate. The smallest mussel that was found was 22 mm in length. No mussels have been found in River Pyhäjoki above Lake Kaitajuojärvi.

There is not a big difference when comparing the results from the standard methodology (18 randomly chosen transects) and the "optimal site". 159 mussels were measured in connection to the 18 transects, and 104 mussels were measured at the "optimal site". No mussel smaller than 20 mm in length was found with either of the methods, and the proportion of mussels smaller than 50 mm in length was 3.8% using the standard method and 4.8% at the "optimal site".

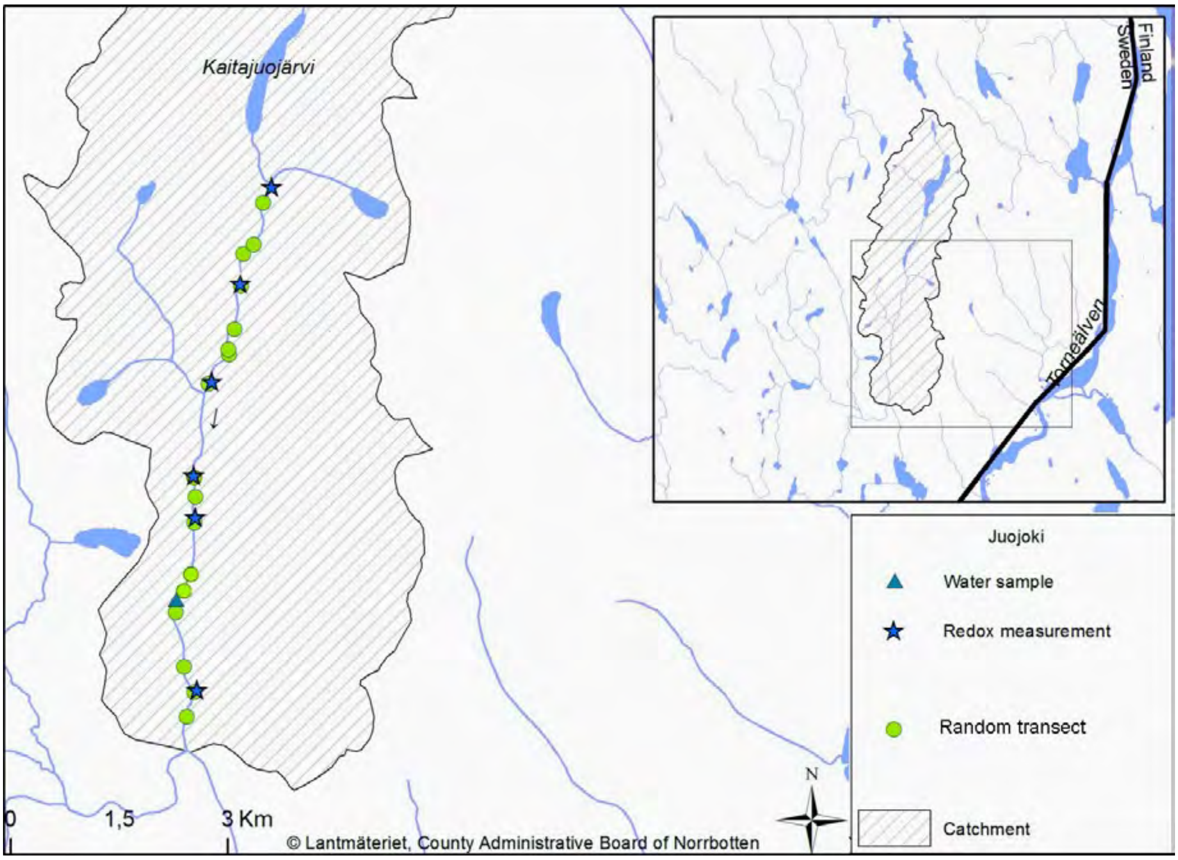


Figure 7. Study sites on River Juojoki. © Metsähallitus 2015, © Läntmäriet, County Administrative Board of Norrbotten.

River Juojoki is the only river from the River Tornionjoki catchment where we took a water quality sample. The sample was taken in the autumn of 2013. Both phosphate (NH_4) and total phosphorus were elevated above limits suitable for the freshwater pearl mussel. A high iron level (750 µg/l) is probably natural for this river, although we noted during the field work in August 2013 that iron bacteria clouds covered up to 50% of the river bottom at some spots. Low alkalinity value revealed that Juojoki is sensitive to acidification. The detailed results of the water analyses are given in Annex C.

Compared to Finnish rivers, the water in Juojoki was browner even on the upper parts of the river, probably because of iron; in the lower parts of the river humus was also added in addition, leading to a visibility around 1.5 to 2 metres. At one beaver dam the visibility was 1.2 metres.

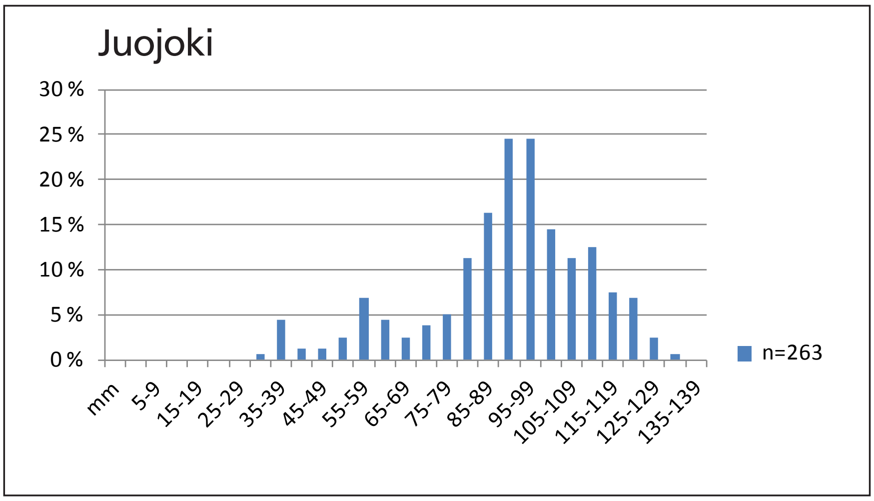


Figure 8. Size distribution of the mussels in River Juojoki. No clear recruitment area could be distinguished and, therefore, the samples from random transects and from an "optimal site" were combined.

Figure 9. Eroding river banks in River Juojoki. Photo Aune Veersalu, Metsähallitus.

Figure 10. Sediment covering mussels in River Juojoki. Photo Aune Veersalu, Metsähallitus.

The water level was low at the time when the investigation was carried out. The low water level revealed deep, eroding river banks (Fig. 9) on the lower part of Juojoki. The water temperature of Juojoki was surprisingly cold in spite of low water/weak current, probably because of a lot of springs and cold water from River Seittijärvenoja were coming in (upstream from the Seittijärvenoja mouth the temperature was 17 °C, downstream about 13–14 °C).

Quite a large amount of sediment was discovered even at sites of good recruitment. This could partly be explained due to the low water and weak current situation. At sites where only big mussels were found, the mussels were almost completely covered with sediment (Fig. 10).

The mean depth in Juojoki at the time of the investigation was 0.5 m, and the mean maximum depth was 0.9 m. The mean water current in the transects investigated was 0.1 m/sec. Very little algae were present in the river, and the dominating bottom substrates were gravel and various sizes of stones. The average coverage of filamentous algae on random transects was 9.17% during the field work in August 2013.

Juojoki has earlier been used for timber floating, and the river has been stretched and cleared of larger stones and boulders in order to make it easier to transport the timber. This has altered the habitat for the freshwater pearl mussel and trout, and most likely the populations have declined due to this. The eroding river banks along some parts of the river are probably causing fine materials to be transported into the river, especially at higher water levels and floods. This fine material will sediment and go into the bottom substrate in slower flowing parts and in pockets between larger stones and in the worst case will kill young mussels and fish eggs. There are also ditches that are leaking finer material into the river at a couple of places along the river.

According to Bergengren *et al.* (2010), the freshwater pearl mussel population in Juojoki has a *very high protection value* (16 points, genetic values included) and a *non-viable* population status (Tables 8 and 9 pp. 125–126). The ecological status is set to good based on Caruso *et al.* 2013. The status would be the same independent of which result was used (standard method or "optimal site").

Since the beginning of 2010, small-scale ecological restorations have been carried out in Juojoki as part of an education programme run by Tornedalens Folkhögskola, a residential college for adult education. The results of this have not been evaluated, but considering that the work that has been done is on a very small scale, it is hard to believe that this work would have had a significant positive effect on the freshwater pearl mussel population.

Ecological restorations on a larger scale are proposed, focussing on the host fish and the freshwater pearl mussel habitat and also taking measures in order to reduce the negative effect of eroding river banks. The leaking ditches should also be dealt with. Electro fishing is also proposed to study the fish populations in the river.

Two of the transects studied (9 and 10) had a median redox value difference between the bottom substrate and the free flowing water of less than 20% (Fig. 11). The loss in redox potential in the other transects studied differed between 31% and 59%. The mean value in the bottom substrate for the six transects studied was 365 mV (corrected value), min 184 and max 532 mV (corrected value).

According to Degerman *et al.* (2009) and Geist & Auerswald (2007), looking at the redox results we could expect to find small individuals in transects 2, 9 and 10. Site 10 correlated with what was expected but not the other transects studied. Small individuals of freshwater pearl mussel were found at sites 10, 14 and 18. There was no freshwater pearl mussel at site 9; older individuals were found at sites 2 and 7. What is a little strange is that that two of the worst redox transects (14 and 18) were two of the best transects as regards freshwater pearl mussel, 302 individuals (three < 50 mm) and 81 individuals (one mussel of 36 mm) respectively.

With a mean redox value of 365 mV together with other results, the conclusion is that Juojoki has some parts which are favourable for recruitment and there are possible measures to be taken to improve the habitat so as to ensure further and improved recruitment within the population.

Kalix catchment

The Kalix River (Swedish Kalixälven) is 461 km long and flows from the Kebnekaise mountain range in Kiruna municipality down to its outlet in Bothnian Bay near the town of Kalix. The main rivers in the system are River Ängesån and River Kalix, and these two main branches join at the town of Överkalix, 67 km from the coast. The catchment area covers 18,130 km^2, and River Kalix and its tributaries are protected by Natura 2000. It is also a so called "National River" where water regulatory

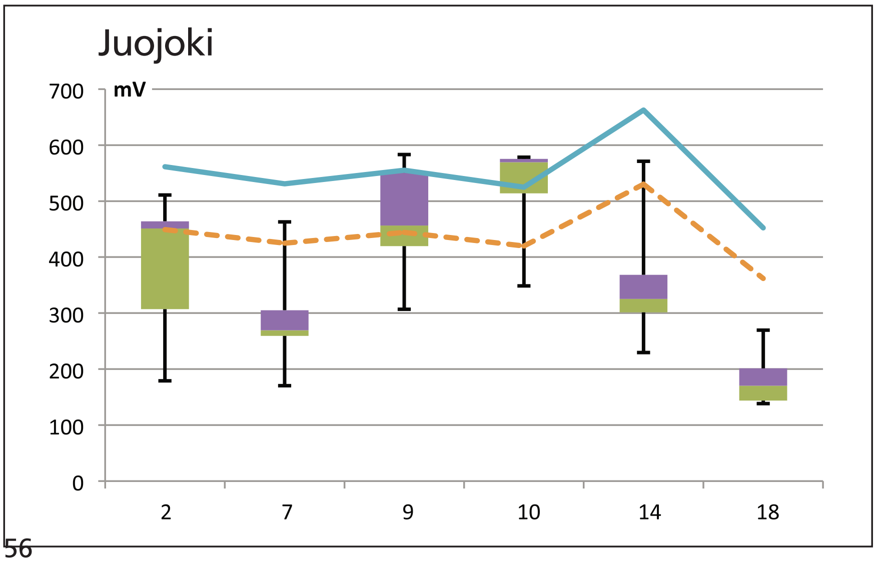


Figure 11. Redox potential measurements in River Juojoki. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. The numbers in the x-axis refer to the numbers of random transects (see Fig. 7).

and other activities connected to hydro power are forbidden by Swedish law. River Kalix gets around half of its water from River Torneälven through a bifurcation in River Tärendöälven. This is considered to be the world's second largest bifurcation.

River Kääntöjoki

Kääntöjoki is situated in the River Kalix catchment area in Gällivare municipality (Fig. 12). It starts from Lake Kääntöjärvi and has its outlet into River Kalix (Fig. 13). The total length of Kääntöjoki is 7.7 km and its mean width is 9.6 m. The elevation is 63 metres, from 324 metres above sea level from the outlet of Lake Kääntöjärvi down to the outlet into River Kalix at 261 metres above sea level. The total catchment area is 86,8 km^2 and is made up of 70.5% forest, 12.2% surface water, 12.9% wetland, 3.4% clear cuts, 0.8% open land and 0.1% agriculture land (SMHI SVAR VERSION 2012-2). The environment around Kääntöjoki (50 metres on both sides of the river) is mainly wetland and mixed forest and the terrain is relatively flat. The close environment around the river (5 metres on both sides of the river) is dominated by grass and half grass (*Carex* sp.), brush (*Salix* sp.), herbs (meadowsweet, *Filipendula ulmaria*) and trees (birch, alder, spruce). At many parts of the river the insolation is quite high due to a lack of shade since the number of trees in these parts is small. The air temperature at the time of the investigation was 7–20 °C and the weather alternated between rain, sun and cloud.

Only a total of four mussels were found in three of the eighteen transects investigated. The estimated freshwater pearl mussel-population size

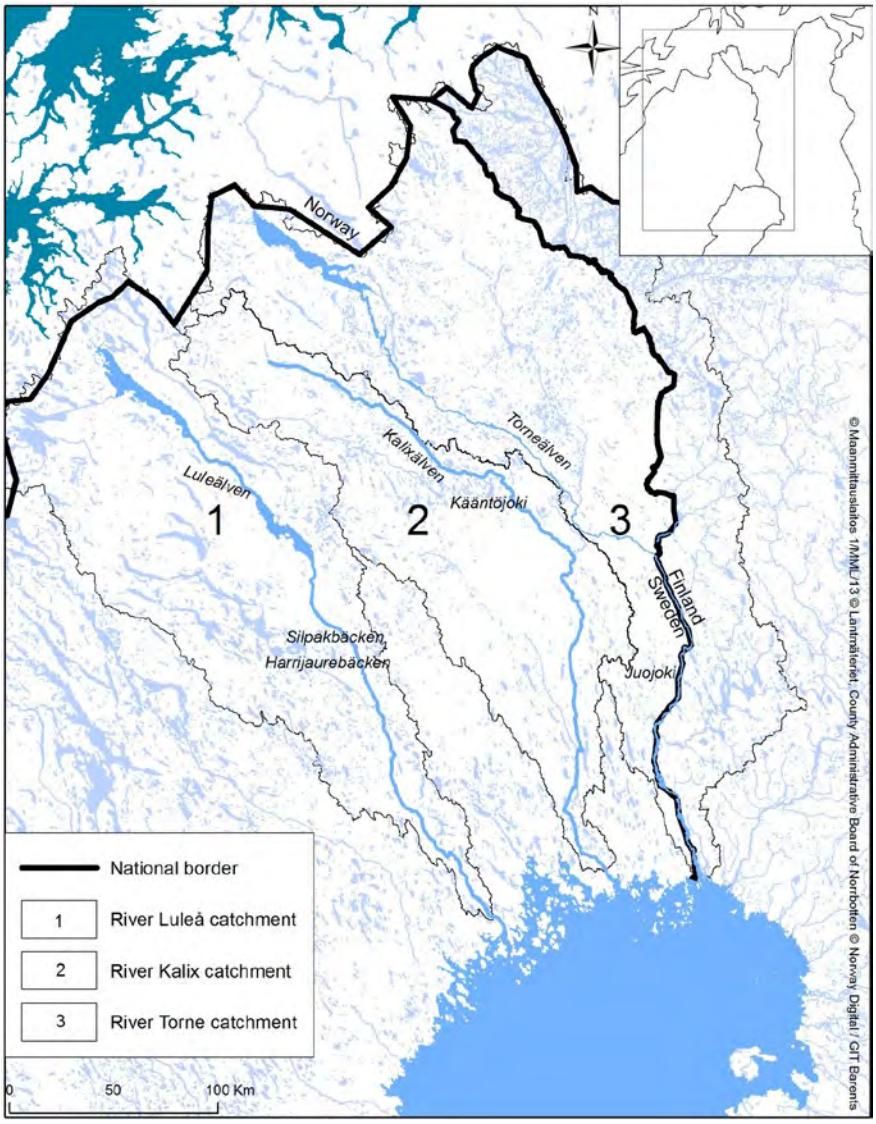


Figure 12. Investigated rivers in Sweden. © Metsähallitus 2015, © National Land Survey of Finland 1/MML/15, © Läntmäriet, County Administrative Board of Norrbotten, © Norway Digital / GIT Barents.

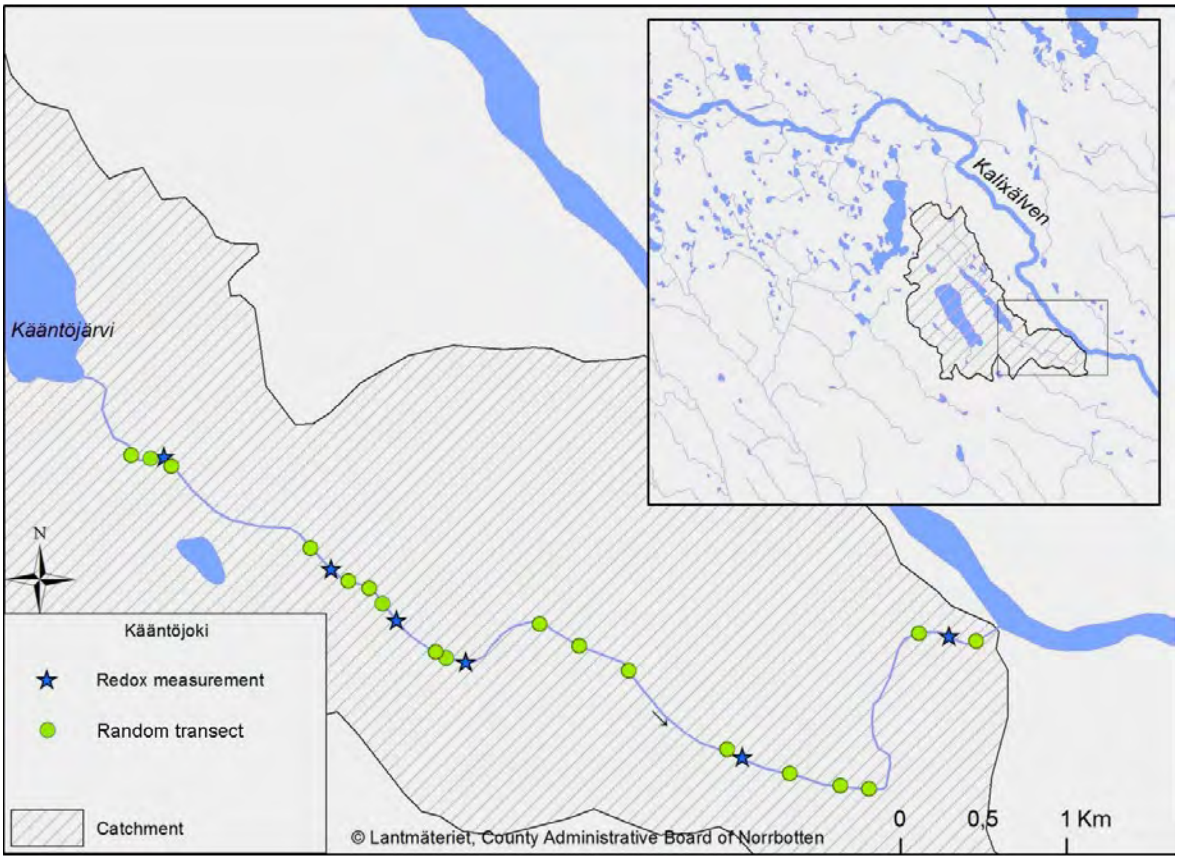


Figure 13. Study sites in River Kääntöjoki. © Metsähallitus 2015, © Läntmäriet, County Administrative Board of Norrbotten.

was 73 individuals, and the distribution range was 7.0 km (Table 7 p. 125). The mean density of the population was 0. 001 individuals/m^2. The smallest mussel that was found was 85 mm in length; the other three were between 95–99 mm.

The mean depth in Kääntöjoki at the time of the investigation (3–11.7.2013) was 0.5 m, and the water level was around average. The water temperature was between 10 and 16 °C and the dominating bottom substrates were boulders/stone/gravel/sand. The water current varied between a gushing, strong current and calm water. The water colour was clear with no turbidity. The vegetation in the river was dominated by fouling algae (surface coverage 51–100%) but also mosses and long shoot plants grows in the river.

Overall there were good conditions for freshwater pearl mussel with nice gravel beds and a good water current, and a lot of trout were also observed.

Kääntöjoki has earlier been used for timber floating. From the nineties to the beginning of 2000 ecological restoration of the river has taken place. According to local people and observations made during the investigation, it seems as if the restoration has had a negative impact on the mussel population, and the number of mussels may have declined due to the measures taken. A track of a heavy machine across the river was noticed in the upper part, which could be tracks from a machine used in the restoration work (Fig. 14).

The County Administrative Board of Norrbotten (CAN) has known of the occurrence of freshwater pearl mussel in Kääntöjoki since the beginning of 1980, and have also made investigations in the river earlier. In 1993 an overall search for freshwater pearl mussel was done with aquascope in the upper part of the river. Results showed a density of around 0.0002 individuals/m^2, and the smallest mussel that was found was 51 mm in length. In 2006 five sites were investigated with an aquascope. A total of 12 mussels were found; the smallest one was 73 mm in length and the average density of mussels was 0.02 individuals/m^2.

The paucity of the result from the investigation made in 2006 and earlier resulted in CAN making a new investigation in Kääntöjoki in

Figure 14. Forest machine trail across River Kääntöjoki. Photo County Administrative Board of Norrbotten.

the summer of 2007. First a description of the habitats in the river was made in order to find the best habitat to look for mussels in. Four sites were then snorkelled in search of mussels. Nineteen mussels were found on a total investigated length of 725 metres (0.003 individuals/m^2). The original idea was to collect mussels and move them closer to each other, but after five sites were electrofished (7 and 8 of June) and glochidia was found on the gills of trout, it was decided otherwise. Trout were caught at four of the fished sites, and on two of these sites glochidia was found on 7.9% and 16.7% of the trout. It was then decided that, since glochidia had been found, nothing more was to be done and the suggestion was to follow this up in the future in order to see whether small mussels could be found and whether the freshwater pearl mussel population might have recovered. (Broman 2007)

On the 11 and 12 of June 2014 three of the earlier (2006) electrofished sites were reinvestigated. The sites were electrofished and the gills were examined by naked eye to look for glochidia (Fig. 15). Trout was caught on all sites

Figure 15. Freshwater pearl mussel glochidia the brown trout gills in River Kääntöjoki. Photo Andreas Broman, County Administrative Board of Norrbotten.

(salmon was caught on two of the sites) and glochidia were found on 4.8%, 10% and 16.3% of the trouts, quite similar to the result from 2006. No glochidia were found on salmon. The numbers of glochidia on the gills of the trouts were low (1–10), maybe due to low numbers of mussels in the river or the fact that most of the glochidia had already dropped off due to a mild winter. Two of the earlier snorkelled sites were reinvestigated showing about the same number of mussels as in 2006. No small mussels were detected.

According to Bergengren *et al.* (2010), the freshwater pearl mussel population in Kääntöjoki is *value protecting* (7 points), but the viability status is *almost extinct* (Tables 8–9 pp. 125–126). The ecological status is set to moderate based on Caruso *et al.* (2013).

Obviously, there is something wrong with the freshwater pearl mussel population in Kääntöjoki. There seems to be good conditions for the freshwater pearl mussel, with suitable habitats and a good population with host fish. The high amount of fouling algae could indicate that there is an addition of nutrients to the river, perhaps from forestry, although the number of clear cuts in the catchment area was quite low (3.4%). There could also be a problem with waste water from private households in the village Kääntöjärvi although it seems unlikely due to the low number of residents in the village.

There is a possibility that, before the ecological restoration of Kääntöjoki was done, the trout population could have been very low for a long period of time. This could have led to a decline in the freshwater pearl mussel population due to a lack of host fish. The glochidia that was found on trout in 2007 could perhaps have been among the first trout infected with glochidia in Kääntöjoki for decades. If these glochidia had developed into mussels they would not be very large size in 2013–2014. Small mussels combined with a high amount of fouling algae and brook moss (*Fontinalis*) could make them hard to detect.

One proposed measure to consider is to move mussels from River Välijoki (situated upstream Kääntöjoki between Lake Mettäjärvi and Lake Kääntöjärvi) in order to enhance the population in Kääntöjoki. Välijoki is approximately 1 km in length and freshwater pearl mussel has been investigated overall three times, 1993, 2005 and 2014. All investigations revealed small mussels (< 50 mm) with densities between 0.03–0.80 individuals/m^2. The possibility to move mussels from Välijoki to Kääntöjoki will be considered and could perhapse take place already this fall. One suitable place to put the mussels in was located in June; approximately 50 m upstream one of the electro fished sites were there where a good amount of host fish and it would make a good opportunity to follow up the glochidia study in the future.

Since so very few mussels were found, no length measurements were taken, and therefore a size distribution graph is missing.

All of the transects studied had a median redox value difference between the bottom substrate and the free flowing water of less than 20% (Fig. 16). The mean value in the bottom substrate for the six transects studied was 526

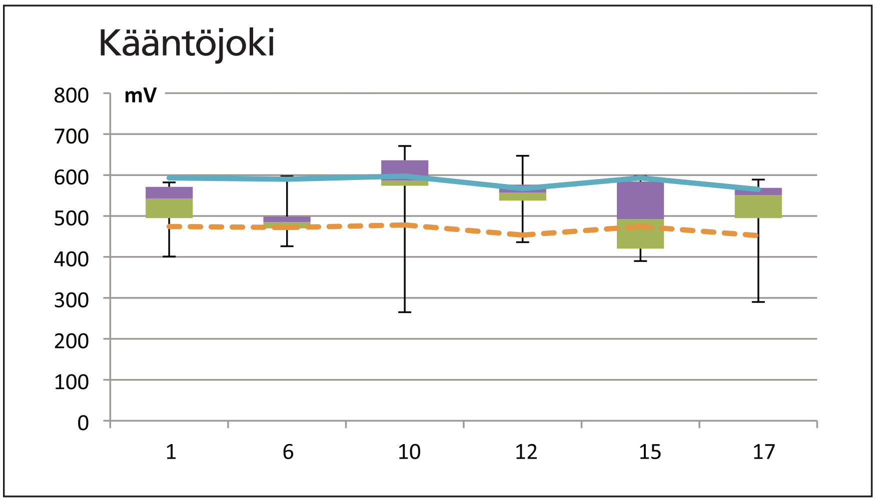


Figure 16 . Redox potential measurements in River Kääntöjoki. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. The numbers in the x-axis refer to the numbers of random transects.

mV (corrected value). A few older individuals of freshwater pearl mussel were found in transects 10, 12 and 17. There seems to be favourable conditions for the young mussels in Kääntöjoki, with a mean redox value well above the suggested 400 mV for recruiting freshwater pearl mussel populations.

River Luleälven catchment

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

River Silpakbäcken

River Silpakbäcken is situated in the River Stora Luleälven catchment area in Jokkmokk municipality (Fig. 12). It starts from a couple of tarns called Silpaktjärnarna and has its outlet into River Messaurebäcken which continues down to River Luleälven (Fig. 17). The total length of Silpakbäcken is 3.5 km and its mean width is 2.9 m. The elevation is 47 metres, from 293 metres above sea level from the outlet of Silpaktjärnarna down to the outlet into Messaurebäcken at 246 metres above sea level. The total catchment area is 11.5 km^2, and is made up of 78.8% forest, 15.9% wetland, 3.0% clear cuts and 2.4% surface water (SMHI SVAR VERSION 2012-2). The environment around Silpakbäcken (50 metres on either side of the river) is mainly mixed forest, and the terrain is hilly. The close environment around the river (5 metres on either side of the river) is dominated by grass and half grass (*Carex* sp.), trees (birch and alder) and herbs (meadowsweet *Filipendula ulmaria*). The vegetation around the river gives good shade. The air

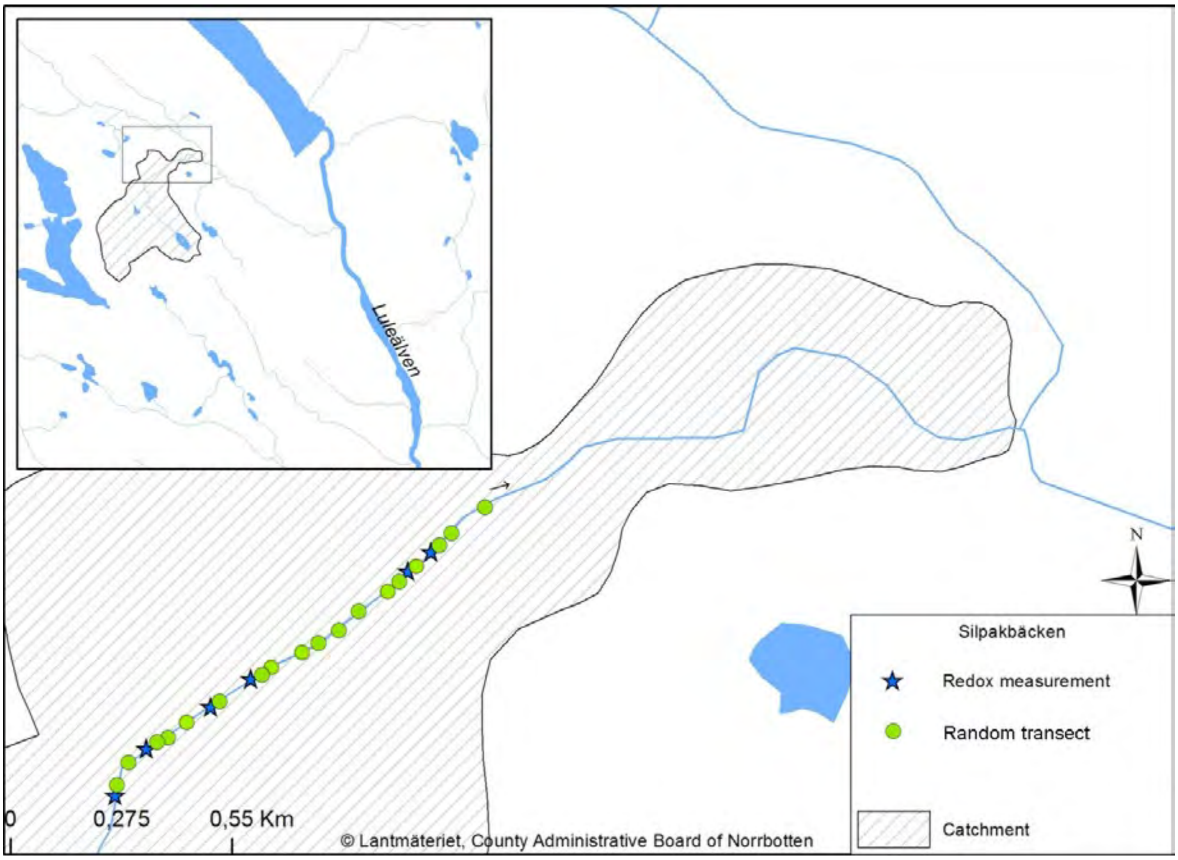


Figure 17. Study sites in River Silpakbäcken. © Metsähallitus 2015, © Läntmäriet, County Administrative Board of Norrbotten.

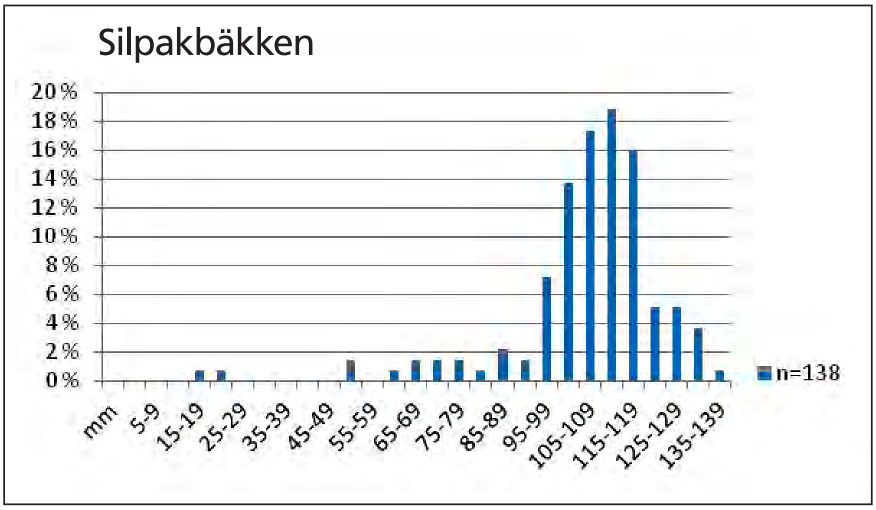


Figure 18. Size distribution of the mussels in the samples taken from a random transect in Silpakbäkken.

temperature at the time of the investigation (24.7.–6.8.2013) was between 14 and 23 °C, and the weather altered between rainy, sunny and cloudy.

The mussels are situated between parts with wetland (mires) in the upper part of the river. There were high densities of mussels in some parts of the river, mainly in the slower flowing parts below white water rapids. A larger number of shells were found in some transects, for instance 97 shells (65%) were found together with 52 living specimens in one of the transects in the middle of the distribution area. Small mussels were found in five out of eighteen transects investigated, and no mussels were found in five transects.

The estimated freshwater pearl mussel-population size was 17,600 individuals and the distribution range was 1.3 km (Table 7 p. 124). The mean density of the population was 4.7 individuals/m^2. The size distribution (Fig. 18) shows that the population mainly is made up by old individuals, only 1.4% of the mussels where smaller than 50 mm in length. The smallest mussel that was found was 13 mm in length.

The mean depth in Silpakbäcken at the time of the investigation was 0.4 m, and the water level was low. The water temperature was between 15 and 19 °C, and the dominant bottom substrates were big boulders and fine sediment; some parts were dominated by bedrock. The water current is varied, evenly distributed between strong currents and calmer parts. The water was clear with no turbidity. There was a good amount of heavy dead wood, fine detritus and long shoot plants in some parts of the river, also a lot of above-water plants, mainly bog-bean (*Menyanthes trifoliata).* The vegetation in the river was dominated by filamentous algae (surface coverage 51–100%).

There are a few natural migrations barriers for fish (falls). Overall, very little human influence was seen in and around the river, except for a power line that crosses the river in its middle part (Fig. 19).

According to Bergengren et al. (2010), the freshwater pearl mussel population in Silpakbäcken has a *high* conservation value (13 points) and a *non-viable* population viability status (Tables 8 and 9 pp. 125–126). The ecological status is set to good based on Caruso *et al.* (2013).

It looks as if this is a small population where the mussels are situated where the habitat is suitable (e.g. not in the slower flowing parts surrounded by mires). A large number of small mussels was not found, and only two small mussels were found during the length measurements in connection with the transects investigated. It is hard to speculate why not a larger number of small individuals was found since there was very little visible human impact on the river, and the habitat in general seems suitable for freshwater pearl mussels. The natural migration barriers for fish could have a negative impact if trout have declined in the upper part of the river for some reason, and they could have a problem in recolonizing from downstream. The crossing power line would not have a major negative impact on the freshwater pearl mussel population. The suggestion for Silpakbäcken is to monitor the population regularly in the future, and it would

Figure 19. Transect 17 in the upper course of River Silpakbäcken. Photo County Administrative Board of Norrbotten.

also be a good idea to look closer at the densities and distribution of host fish within the river. Half of the studied sites (4, 12, and 16) had a median redox value difference between the bottom substrate and the free flowing water less than 20% (Fig. 20). The loss in redox potential in the other sites studied (3, 13 and 18) differed between 42–53%. The mean value in the bottom substrate for the six sites studied was 429 mV (corrected value), minimum 276 and maximum 638 mV (corrected values). Small individuals of mussels were found in sites 13, 16 and 18. No mussels were found in site 4 and only big mussels in sites 3 and 12.

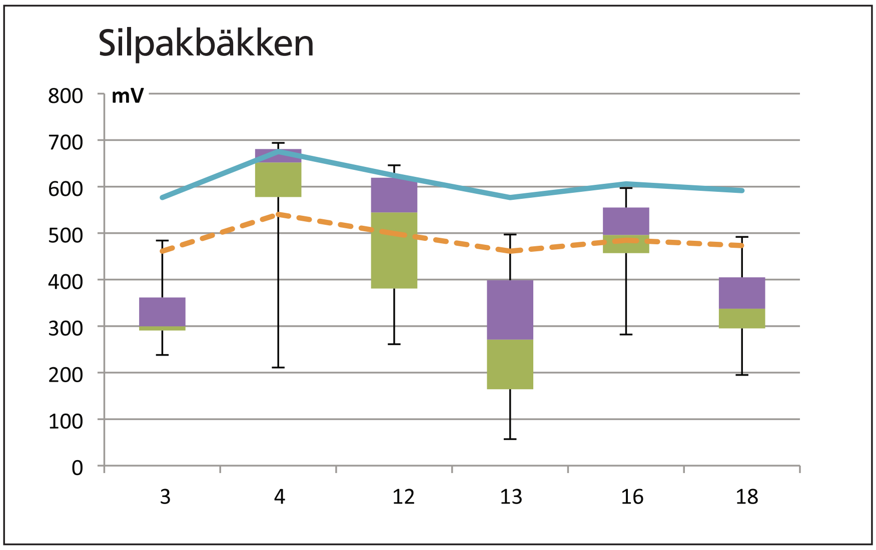


Figure 20. Redox potential measurements in river Silpakbäcken. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. The numbers in the x-axis refer to the numbers of random transects.

River Harrijaurebäcken

River Harrijaurebäcken is situated in the River Luleälven catchment area in Jokkmokk municipality (Fig. 12 p. 57). It starts from Lake Harrijaure and runs in a steady incline down to its outlet into River Lilla Luleälven (Fig. 21). The total length of Harrijaurebäcken is 5.7 km and its mean width is 5.7 m. The elevation is 66 metres, from 280 metres above sea level from the outlet of Lake Harrijaure down to the outlet into River Lilla Luleälven at 214 metres above sea level. The total catchment area is 77.9 km^2 and this is made up of 64.7% forest, 17.4% surface water, 13.4% wetland, 4.1% clear cuts and 0.5% open land. (SMHI SVAR VERSION 2012-2). The environment around Harrijaurebäcken (50 metre on either side of the river) is mainly mixed forest. The close environment around the river (5 metres on either side of the river) is dominated by grass and half grass (*Carex* sp.), herbs (meadowsweet (*Filipendula ulmaria*) and brushes (*Salix* sp. and juniper). The number of trees around the river is low, so the insolation is quite high (shade less than 5%). The air temperature at the time of the investigation (7–15.8.2013) was between 13 and 21 °C and the weather alternated between rainy, sunny and cloudy.

Most mussels were found in the middle part of the river where there was a strong current to slow water. The densities were very low at all transects investigated. Small mussels were found in three out of eighteen transects investigated, and no mussels at all were found in four transects. The main part of the small mussels was found in the lower region of the river close to the outlet into River Lilla Luleälven.

The estimated freshwater pearl mussel-population size was 1,900 individuals, and the distribution range was 3.0 km (Table 7 p. 124). The mean density of the population was 0.1 individuals/m^2. The smallest mussel that was found was 27 mm in length and the size distribution shows that the freshwater pearl mussel population in Harrijaurebäcken is recruiting relatively well (Figure 22).

The mean depth in Harrijaurebäcken at the time of the investigation was 0.5 m, and the water level was low. The water temperature

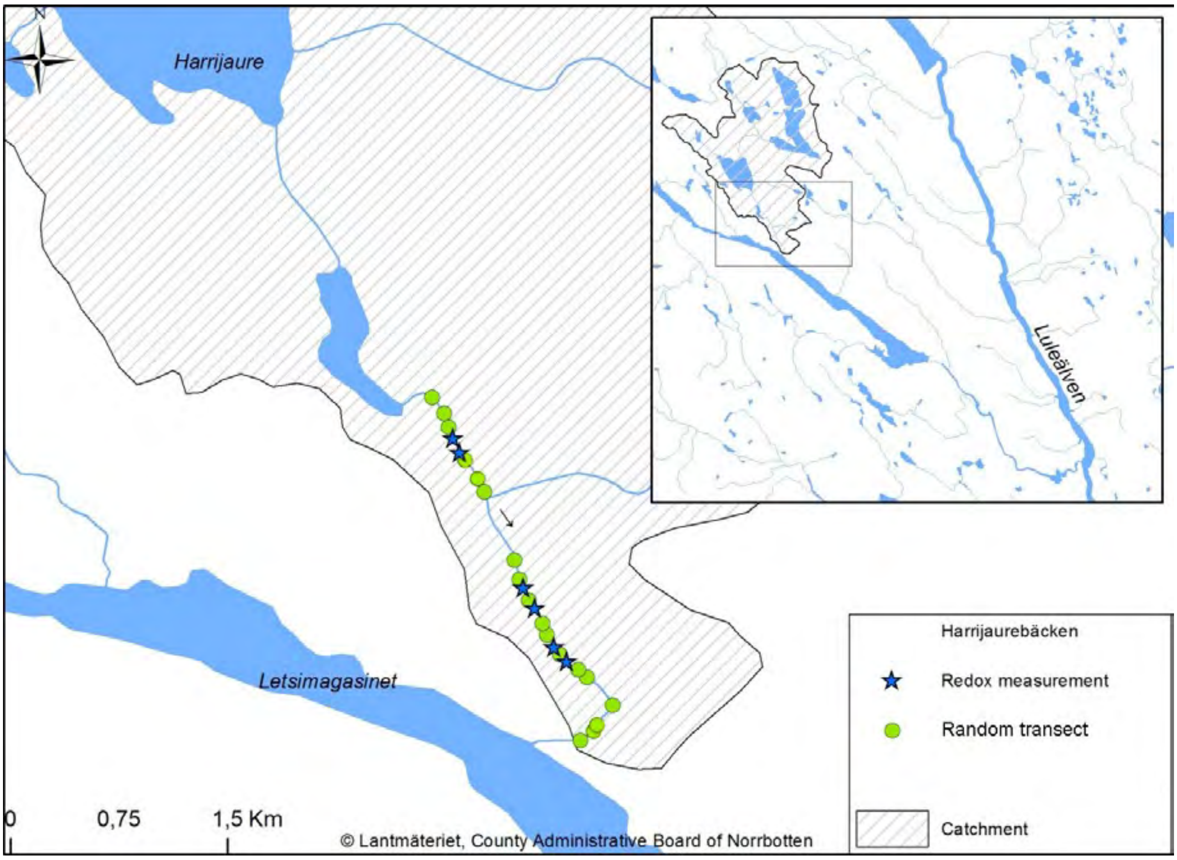


Figure 21. Study sites in River Harrijaurebäcken. © Metsähallitus 2015, © Läntmäriet, County Administrative Board of Norrbotten.

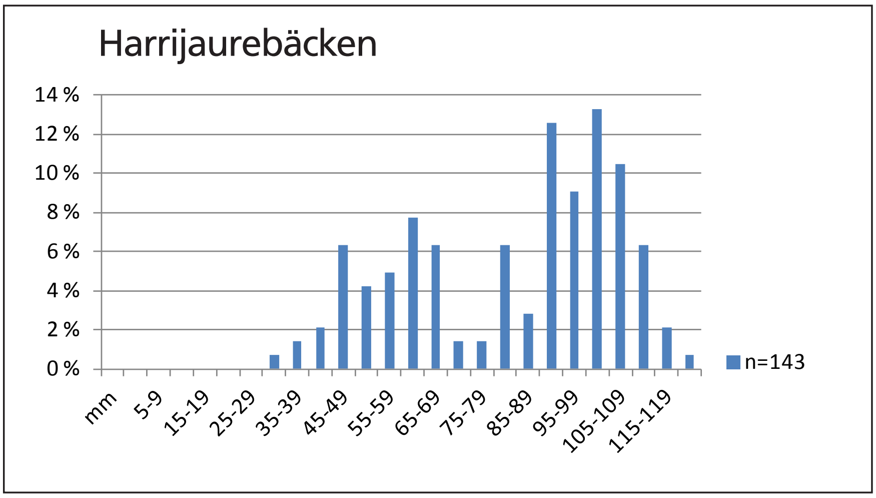


Figure 22. Size distribution of the mussels in the samples taken from a random transect in Harrijaurebäcken.

was between 15 and 17 °C, and the dominant bottom substrates were coarse and fine boulders with some bedrock (Fig. 23). The water current is dominated by gushing and streaming parts, but there were also parts with slow flowing water. The water was clear with no turbidity. The vegetation in the river was dominated by fouling algae (surface coverage 51–100%) and there were also a lot of mosses. The amount of dead wood and sediment was small. Some trout and pikes were observed in the river.

The River Lilla Luleälven is regulated for hydro power, and this would affect the trout population that uses Harrijaurebäcken for spawning. The

Figure 23. Boulders in Harrijaurebäcken at Site 14. Photo CAN.

river has been heavily cleared for timber floating; big boulders and bedrock have been blown up with dynamite and the river has been straightened in some parts. Parts of the shattered rocks are now lying on the bottom of the river together with the natural bottom substrate. The effect of the timber floating is most visible in the lower parts of the river, but the whole river is affected. A small road runs along the river, as close as fifteen metres in some places.

According to Bergengren *et al.* (2010), the freshwater pearl mussel population in Harrijaurebäcken is a *non-viable* population (Table 8 p. 125). The conservation value is *high* (11 points) (Table 9 p. 126). The ecological status would be good according to Caruso *et al.* (2013), but due to low population size and low densities together with the knowledge of the human impact on the river, the status has been set to moderate. The proportion of mussels smaller than 50 mm in length was 10.5% in Harrijaurebäcken, which does not fit the criteria in Table 6 p. 49. There will always be results that do not fit any given criteria, and in order to make a good judgement in determining status, all knowledge of a river has to be taken into account.

The most obvious reason for the bad result in Harrijaurebäcken is the impact the timber floating has had on the river, with altered habitats for both trout and freshwater pearl mussel. Gravel and finer material has been flushed down to deeper and slower flowing parts, where the water speed has increased after the removal of larger stones and boulders. In order to improve the habitats, it is necessary to add new gravel and spawning grounds for trout and also to improve the habitat for older fish and places for the younger fish to grow up. Bigger boulders can be put back into the river in order to keep the water flow down. At same parts of the river it may be necessary to remove shattered pieces of boulder from the bottom in order to reveal the old, original bottom. Electrofishing should be done to look at the densities of host fish. The situation is urgent, and the measures have to be taken in the near future or this small population will become extinct.

All of the studied transects, except number 12 that was measured on 10 cm depth, had a median redox value difference between the bottom substrate and the free flowing water less than 20%. The loss in redoxpotential in transect number 12 (10 cm) was 35%. The mean value in the bottom substrate for all six studied transects was 654 mV (corrected value). When only looking at the redox result we could expect to find young mussels in all transects. Small mussels where found in transects 6, 10 and 12. A few large individuals where found in transect 7 and 3. In transect 15 no mussels at all were found. The bottom substrate in Harrijaurebäcken seems to be in good condition with good oxygen conditions and suitable for young mussels.

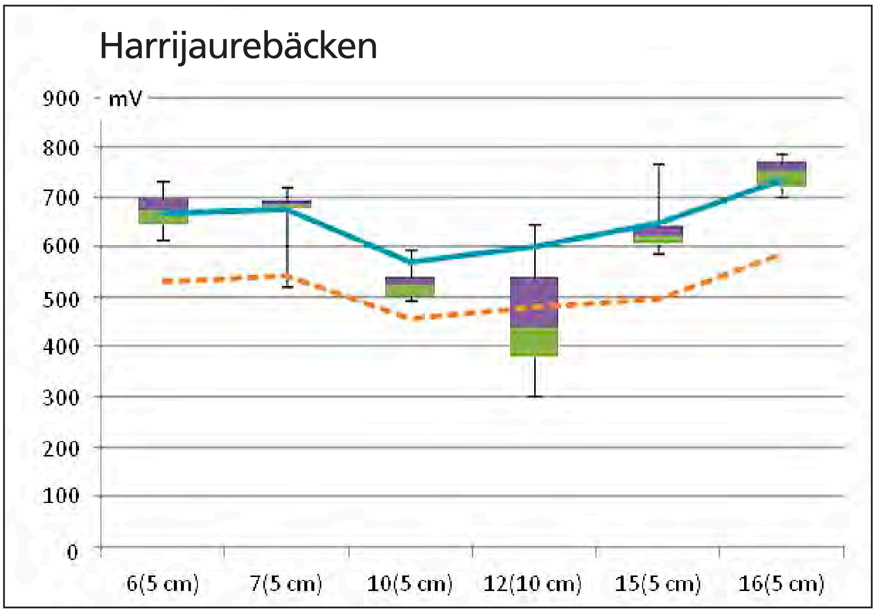


Figure 24. Redox potential measurements in river Harrijaurebäcken. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values.

4.2 Results from Finland

Lutto (Tuloma) catchment

River Lutto is the upper part of the river Tuloma catchment. Major part of the catchment is in Russian territory and the Tuloma river itself meets the sea near the City of Murmansk, Russia. In Finland, Lutto has its origins in the Saariselkä fell range and runs ca. 70 km before it crosses the Finnish-Russian border. At the border the river is almost 100 metres wide. The total catchment area on the Finnish side covers 3,241 km^2 (Ekholm 1993). The main tributary on the Finnish side is River Suomujoki, which runs from south to the Lutto. Other bigger tributaries are the Kulasjoki, Nahkimaoja, Kattajärvenoja, Kolmosjoki and Hirvasjoki (Fig. 25).

In the past, the Lutto and its tributaries were famous pearl fishing areas (Oulasvirta *et al.* 2006). Currently, the freshwater pearl mussel is known from 23 different rivers in the Lutto drainage system (Metsähallitus, unpublished data). Freshwater pearl mussel populations in the Lutto system have been investigated by the working group of WWF Finland and by the Metsähallitus field team in 2003–2005 (Valovirta 1997, Oulasvirta *et al.* 2006). The Lutto main channel population has been investigated only in small parts, but the rough estimate by Valovirta (1997) for the population was 150,000 mussels and the number of mussels in the whole drainage area in Finnish side 600,000–1,000,000 specimens (Oulasvirta *et al.* 2006). The upper limit of the distribution in the main channel is just below Lake Luttolompolo, and the lower limit in Finland is at the national border. The distribution in Russia is mostly unknown. According to Golubev and Golubeva (2010), in the main channel of the Lutto on the Russian side there is on average one mussel/m^2. Juvenile mussels are missing. On the other hand, the freshwater pearl mussel population in River Kola, which is the main tributary of River Tuloma, is in good condition (Golubev & Golubeva 2010).

Especially in the main channels of the Lutto and Suomujoki rivers, the major problem for recruitment is the Upper-Tuloma hydropower plant, which has prevented salmon from ascending to the Lutto's Finnish parts since its construction in the 1960s. The results of host fish experiments in our project show that the freshwater pearl mussel in old salmon rivers, like in Rivers Livojoki and Lutto, prefer salmon as their host (Annex E). This would at least partly explain the low recruitment rate of freshwater pearl mussel in these rivers.

In this project, population status assessment was done in the Lutto drainage area in Rivers Suomujoki, Kuutusoja, Kiertämäoja, Hirvasjoki, Hanhioja, Torkojoki and Ruohojärvenoja. In addition, two cross-river transects were established into the main channel of River Lutto.

River Lutto

In this study, the field studies in the Lutto main river were restricted to a small area at the upper limits of the freshwater pearl mussel distribution (Fig. 26). Two random transects across the river channel were established there for future monitoring.

The results of the mussel counts in two cross-transects gave 148 specimens in the upper transect and 3 specimens in the lower transect. The size distribution of a random mussel sample taken from the vicinity of the upper transect shows that the population is aged, the mean length of the mussels being 122 mm and the smallest found specimen 113 mm. The status class of the population is *dying-out* (Table 8 p. 125). Because of the salmon-dependent mussels, high genetic diversity and unique haplotypes, the conservation value of the River Lutto population is *very high* (Table 9 p. 126).

Redox potential was measured at one site. The result shows good oxygen conditions in the interstitial water (Fig. 27). This supports the hypotheses that the lack of recruitment in River Lutto mussels is due to a lack of host fish, not the quality of the substrate. The brown trout densities have been studied in the Lutto regularly 2003–2010 (Orell *et al.* 2011). From year to year the 0+ brown trout densities have varied between 0.8 to 8.6 fish/100 m^2. This is probably too little, especially if the brown trout is not the primary host.

The average coverage of filamentous algae on random transects was very high, 90% during the surveys on 2 September 2013. The abundance of filamentous algae indicates high nutrient levels in the river. This was not, however, detected from

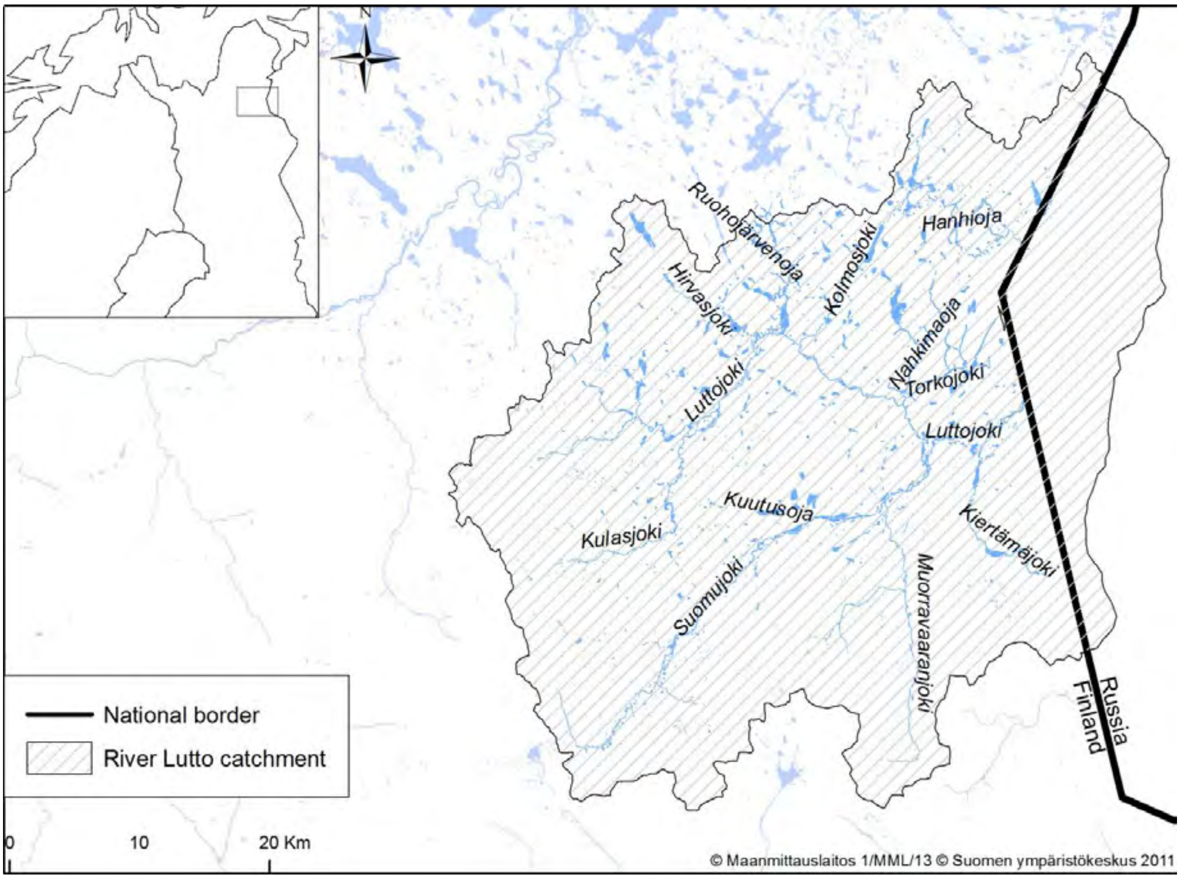


Figure 25. Lutto catchment area in Finland. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

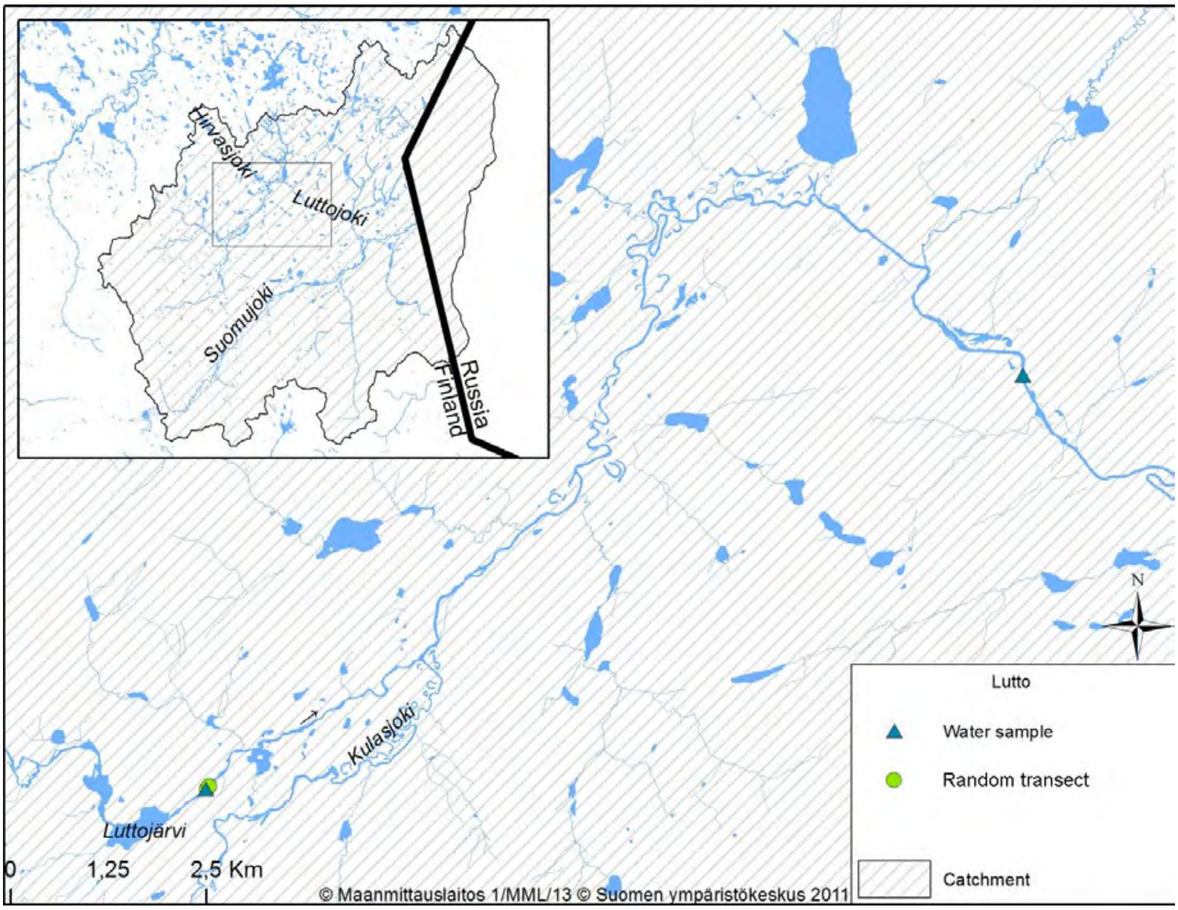


Figure 26. Study sites in River Lutto upper parts. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

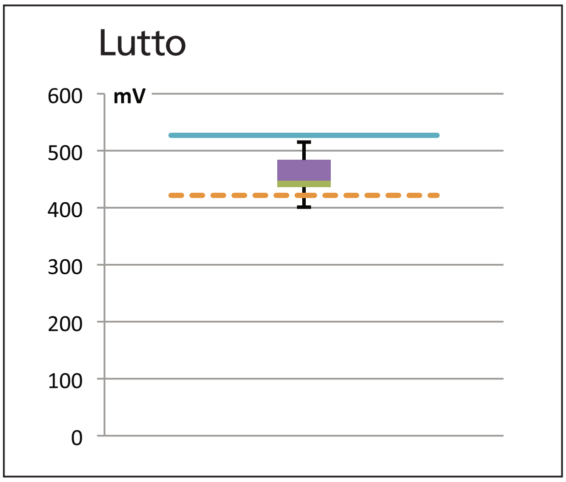


Figure 27. Redox potential measurements in River Lutto 2.9.2013. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values.

the two water samples taken from the upper and lower course in October 2013. Water quality in these samples was good, and did not show elevated nutrient levels. However, in a long-term monitoring series (Finnish Environmental Database Hertta) the levels of oxygen and alkalinity has dropped and total phosphorus, turbidity and the amount of suspended solids is slightly elevated in few samples. Also, some Fe and Al peaks were detected, which can be potentially dangerous for freshwater pearl mussel in low alkalinity/low pH conditions. Still more serious seems to be the increasing frequency of ammonium peaks especially during winter time. The detailed results of the water analyses are given in Annex C.

River Suomujoki

The Suomujoki is the main tributary of the Lutto in Finland. Its origins are in the Saariselkä fell range from where it runs NE ca. 40 km before it joins to the main channel of the Lutto (Fig. 28). The area of the Suomujoki catchment is altogether 611 km^2 (Ekholm 1993), and almost the whole area belongs to the Urho Kekkonen National Park and Natura 2000 area (FI1301701).

Suomujoki, and especially the Lotjanankoski rapids in its middle course, were famous pearl fishing areas before World War II (Oulasvirta *et al.* 2006, Metsähallitus, unpublished data). Nowadays, the main part of the population is

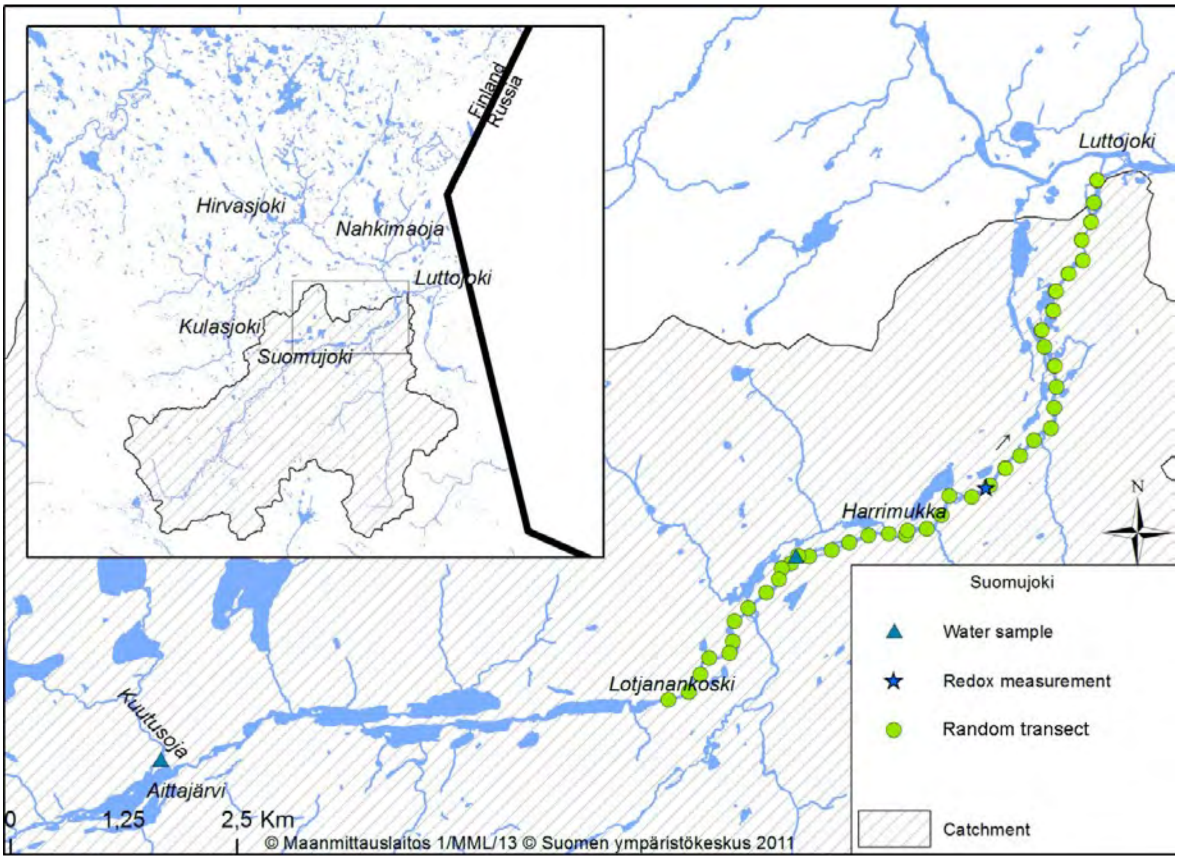


Figure 28. Study sites in River Suomujoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

Figure 29. So called "Blue lagoon" in River Suomujoki. Photo Panu Oulasvirta, Metsähallitus.

in the stretch of river from the Lotjanankoski rapids down to the Harrimukka rapids (Fig. 28). Individual mussels are also found above Lake Aittajärvi.

In the Suomujoki, altogether 41 cross transects were established in the stretch from the Lotjanankoski rapids down to the junction of River Lutto (Fig. 28). The width of the river in the study area was on average ca. 40 metres, but could in shallow areas exceed 100 metres. During the field surveys in August–September 2013, the water level was exceptionally low, which allowed us to investigate the transects by snorkelling, without using scuba. The deepest transects containing freshwater pearl mussel were usually less than 2 metres deep and were possible to observe from the surface because of the clear water (horizontal visibility up to 20 m, Figs 29–30).

The transects were laid at even 230 metres distances from each other except in the key mussel area where the distance between four transects was 115 metres. The estimated population size obtained from the census was 133,500 mussels (Table 7 p. 124). One third of the mussels are situated in the key ca. 500 metre long stretch. Considering the upper course which was not investigated and the mussels that were probably invisible in the sediment or below stones, the rough estimate for the whole Suomujoki freshwater pearl mussel population would be around 200,000 specimens. This is probably much less than what the population has been before. Old time pearl fishers have reported mussel densities of up to 500 specimens/m^2 in the Lotjanankoski rapids, for example (Metsähallitus, unpublished interview data). Now the maximum observed densities were 50–60 mussels/m^2.

The size distribution of the mussels in the samples and the visual observations indicate that the population is aged and the recruitment rate is very low (Fig. 31). This is most probably for the same reason as in River Lutto, the lack of salmon. After construction of the Upper-Tuloma hydropower plant dam, the recruitment has obviously taken place only occasionally with the secondary host, brown trout. According to the Finnish Game and Fisheries Research Institute, the 0+ brown trout densities in Suomujoki river have

Figure 30. Counting mussels in a crystal clear water of River Suomujoki. White rope marks the transect. Photo Panu Oulasvirta, Metsähallitus.

been 4.5–11.5 fish /100m^2 in 2003–2010 (Orell *et al.* 2011). In our study, the smallest mussels found were 40–50 mm long, i.e. 10–25 years old (Dunca & Mutvei 2009). The majority of the mussels were, however, more than 100 mm in length. The status class of the population is *non-viable* (Table 8a p. 125), but the conservation status is *very high* due to the salmon mussel population (Table 9 p. 126).

Water quality samples taken in October 2013 showed good water quality. Previous water quality data was available from 1990 and 2012 (Finnish Environmental Database Hertta). Water quality in those samples was generally also good, with the sole exception being lowered oxygen saturation (77%) in March 2012. The detailed results of the water analyses are given in Annex C.

Despite the low nutrient levels, filamentous algae were quite abundant (51.9% coverage in average) during the field surveys at the end of August 2013.

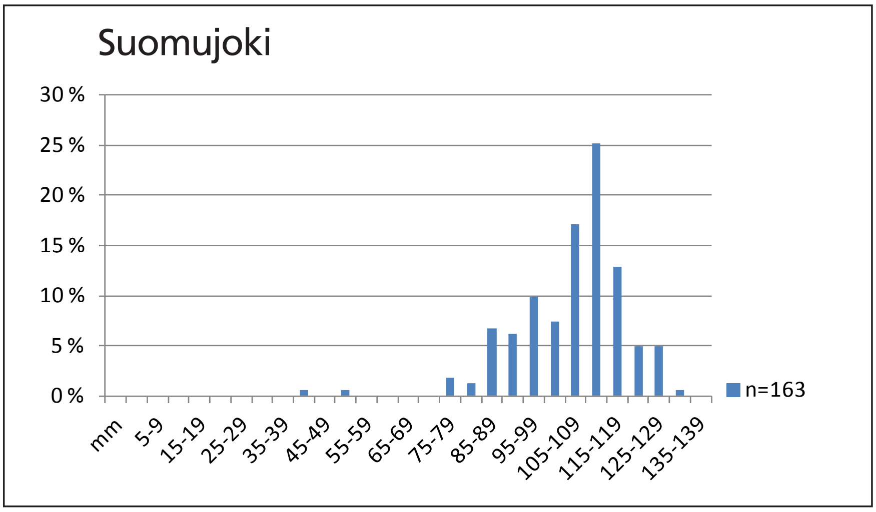


Figure 31. Size distribution of the mussels in the samples taken from a random transect in Suomujoki. The recruitment rate everywhere was low, and therefore the samples were taken only from random transects.

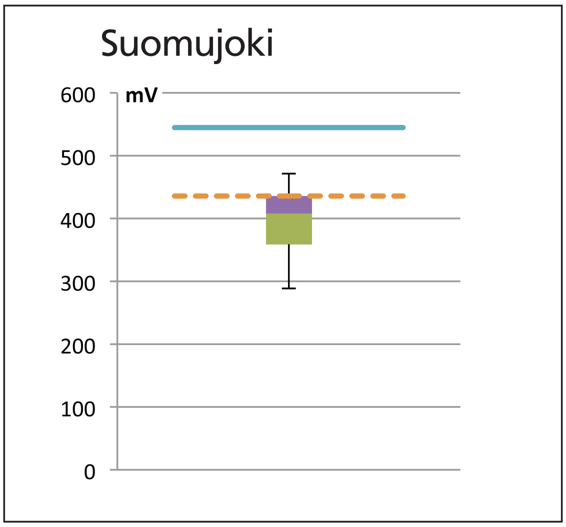


Figure 32. Redox potential measurements in River Suomujoki. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% loss from the water values.

Redox potential was measured only in one spot downstream from the main mussel area (Fig. 28). The measurements indicate that the interstitial environment could be favourable for juvenile mussels. On the other hand, the loss from free water value compared to the interstitial water value was quite big, 25% (Fig. 32). Most probably the redox values would have been better more upstream, in the main mussel area. As a conclusion, it is obvious that the main reason for the poor recruitment rate and decline of the population is the lack of the primary host fish, Atlantic salmon. Reconstruction of the fish lift into the Upper-Tuloma hydropower plant or salmon transfers above the dam would probably be an effective way to restore the freshwater pearl mussel population in the Suomujoki and Lutto rivers. Since the populations are obviously already declining rapidly, there is not much time for these measures.

River Kuutusoja

River Kuutusoja is a small tributary of River Suomujoki in the Urho Kekkonen National Park. Like Suomujoki, it is also included into the Natura 2000 area UK-Park-Sompio-Kemi-haara (FI1301701). The Kuutusoja rises in Lake Kuutusjärvi and runs ca. 2.3 km down to Lake Aittajärvi (Fig. 33). The width of the river is

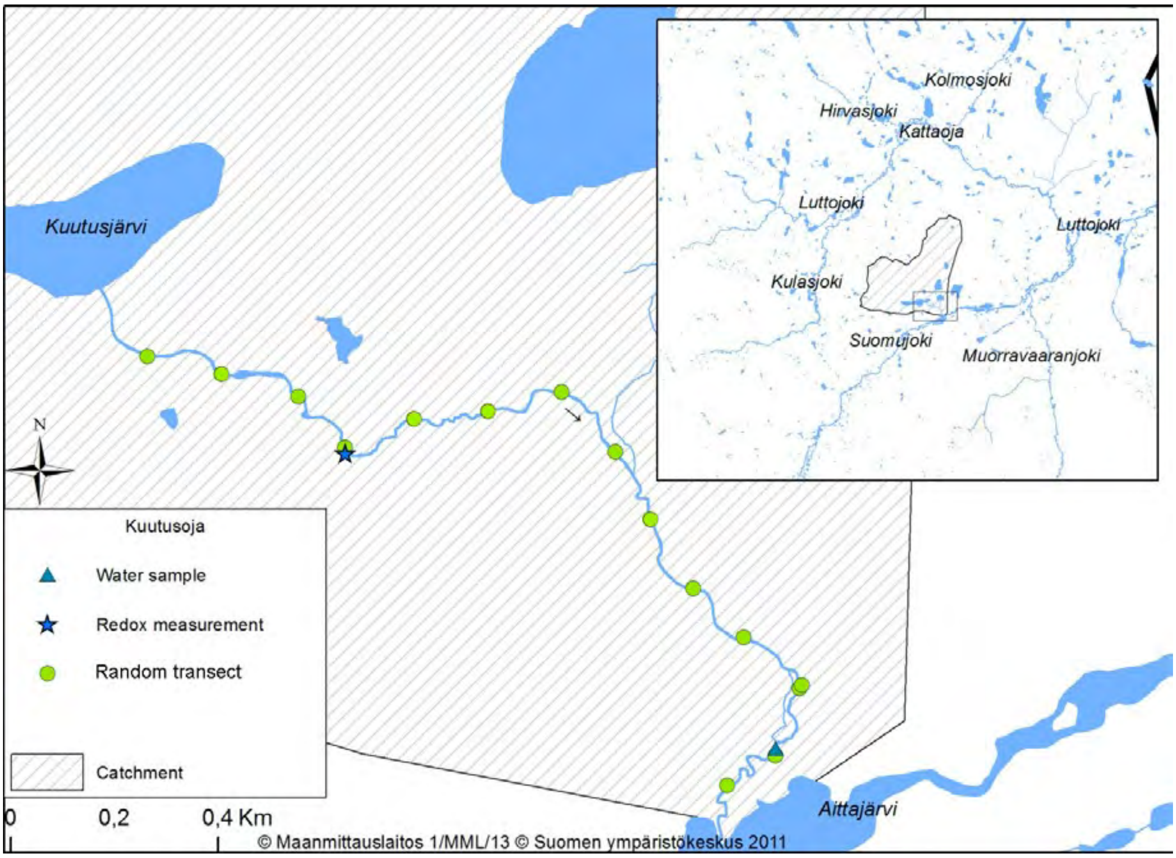


Figure 33. Study sites in River Kuutusoja. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

Figure 34. River Kuutusoja. Photo Panu Oulasvirta, Metsähallitus.

from 2 to 6 metres, and in 2013, when the water level was exceptionally low, the average depth was only 0.1–0.2 metre (Fig. 34).

The investigations in Kuutusoja were carried out in August 2013. The 15 random transects were established in the stream evenly at a 150 metre distances from each other. The results showed that the distribution range of the freshwater pearl mussel contains the entire river. The estimated population size was ca. 3,600 individuals (Table 7 p. 124). Size distribution of the mussel samples shows recruitment of small mussels, which is maybe not on the level to maintain the population in the long run, however (Table 8a p. 125, Fig. 35). The smallest observed mussel was 29 mm. The status class of the population is *non-viable* (Table 8a) and conservation status *high* (Table 9 p. 126).

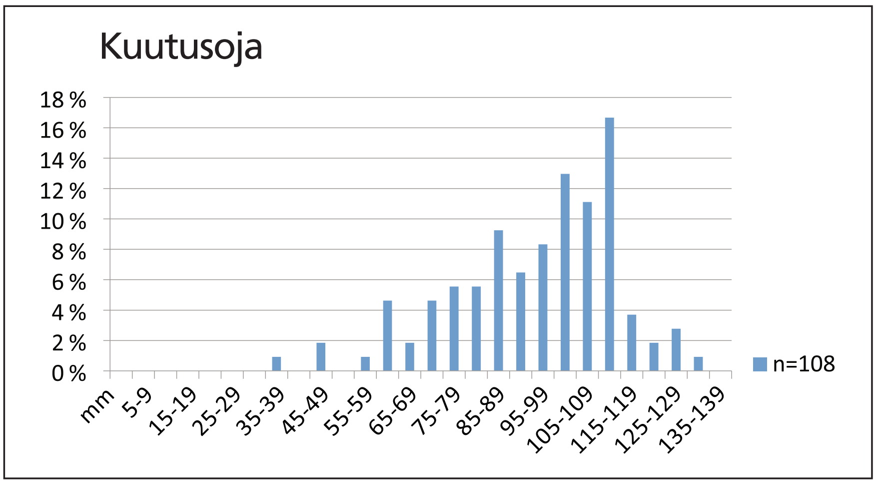


Figure 35. Size distribution of Kuutusoja mussels. A combined sample from the random transect. No sample from an optimal juvenile site was taken in the Kuutusoja.

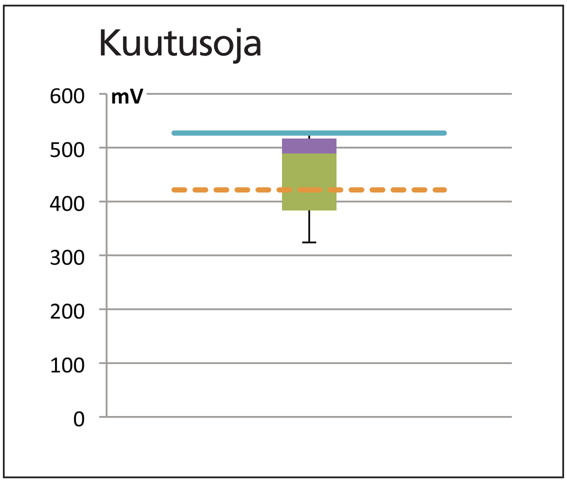


Figure 36. Redox measurements in river Kuutusoja. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values.

Redox potential was measured at one site (Appendix 2 p. 134, Fig. 36). The recorded redox values were good, which is at least partly caused by the ground water effect observed at the measuring site. However, juvenile mussels were not detected in the area.

The coverage of filamentous algae was quite high, 52.8% during the field surveys at the end of August 2013. Still, the water chemistry sample, taken in October 2013, showed good water quality and low nutrient levels (Annex C). No older water quality data was available for this river.

Kuutusoja brown trout densities have been surveyed by Geist *et al.* (2006) in 2004. The densities of brown trout were really low, only 0.21 (0+) and 0.62 (1++) fish/100 m^2. A non-native brook trout (*Salvelinus fontinalis*) was introduced to Kuutusoja in 1977–78. Since then it has spread into the upper courses of the Kuutusoja and also to the tiny streams above Lake Kuutusjärvi. It is not known, whether the brook trout has affected the brown trout population in the Kuutusoja. Nor is there evidence that brook trout could serve as host for freshwater pearl mussel. The experiments with brook trout in Iijoki river tributaries showed a low infection rate of brook trout by freshwater pearl mussel glochidia (Annex E). If so, the brook trout as a competitor for native brown trout might be harmful to freshwater pearl mussel in River Kuutusoja.

River Hirvasjoki

River Hirvasjoki flows from Lake Kurujärvi to River Lutto. The total length of the river is ca. 14 km and the catchment area 76.15 km^2 (Ekholm 1993). Besides Kurujärvi lake, there are two other lakes along River Hirvasjoki, Lakes Kurulompolo and Hirvasjärvi (Fig. 37). The lakes cover altogether 3.22% of the Hirvasjoki river catchment (Ekholm 1993).

The river habitats in the Hirvasjoki are very variable from stony shallow rapids to the deep slowly flowing river channel downstream (Fig. 38). The freshwater pearl mussel population in Hirvasjoki was investigated during the Interreg Kolarctic project in 2003–2005 (Oulasvirta *et al.* 2004, Oulasvirta *et al.* 2006, Oulasvirta 2006). A freshwater pearl mussel population consisting of ca. 6,000 specimens was found in the stretch of the river between lakes Kurujärvi and Hirvasjärvi. Freshwater pearl mussel was not found from the lower course between Lake Hirvasjärvi and River Lutto. Almost half of the mussels are located in the short river section in the middle part of the river (Oulasvirta 2010b).

The random transects were chosen in the main population area between the Kurulompolo and Hirvasjärvi lakes (Fig. 37). The 18 transects were studied in 2011. Ten additional transects were established in 2012 in the densest mussel area. The size of the freshwater pearl mussel population was estimated to be around 4,600 specimens. Thus, compared to the 2005 census, ca. 6,000 mussels (Oulasvirta 2010b), the result was now somewhat smaller and indicates that the population has decreased since 2005. On the other hand, the difference may also be explained by an error of the mean from the random transects. As mentioned earlier, the majority of the mussels in River Hirvasjoki are concentrated into a small area, which causes difficulties for the random sampling. We tried to overcome this by focusing the extra transects especially on this key area.

The size distribution of the Hirvasjoki freshwater pearl mussel shows that the population is aged (Fig. 39). Recruitment takes place in certain areas (the smallest mussels were 15 mm), but it is obvious that the rate of recruitment is not adequate to maintain the population in the long run. Thus, it is possible that at least part

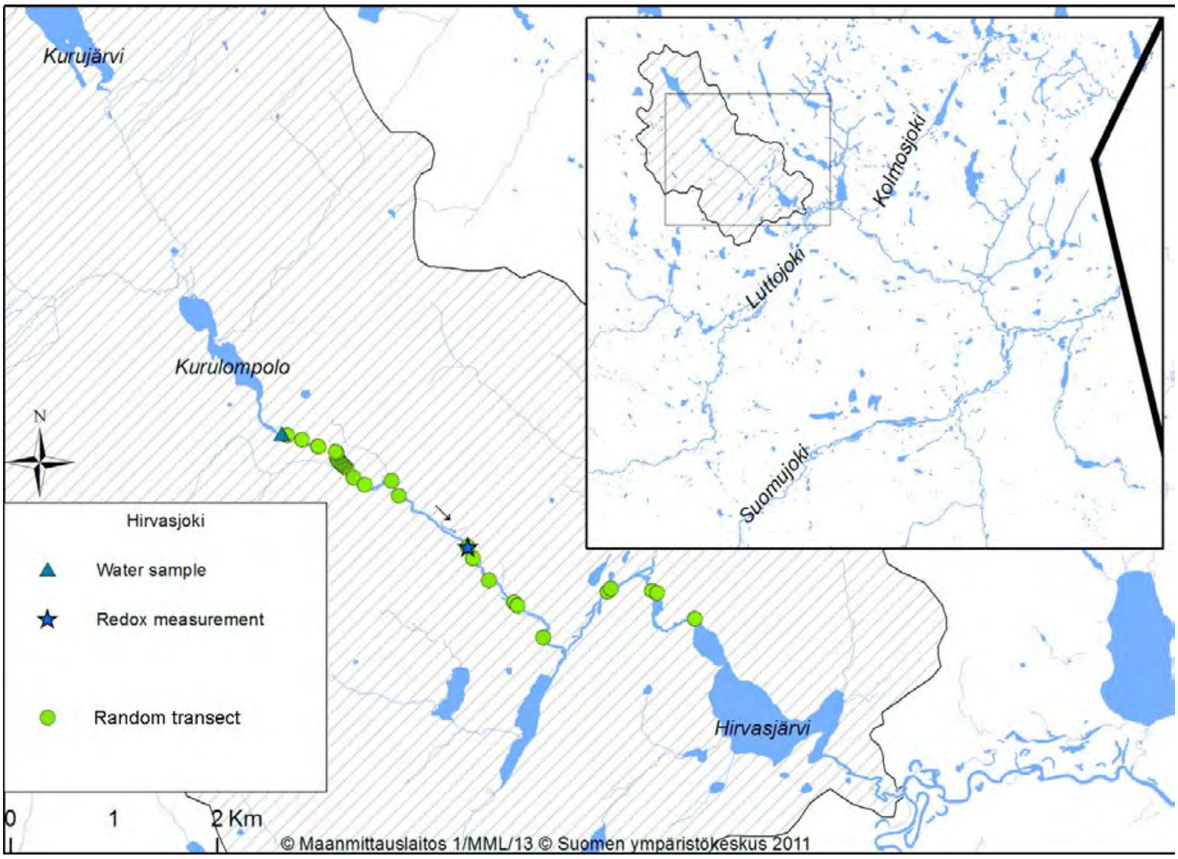
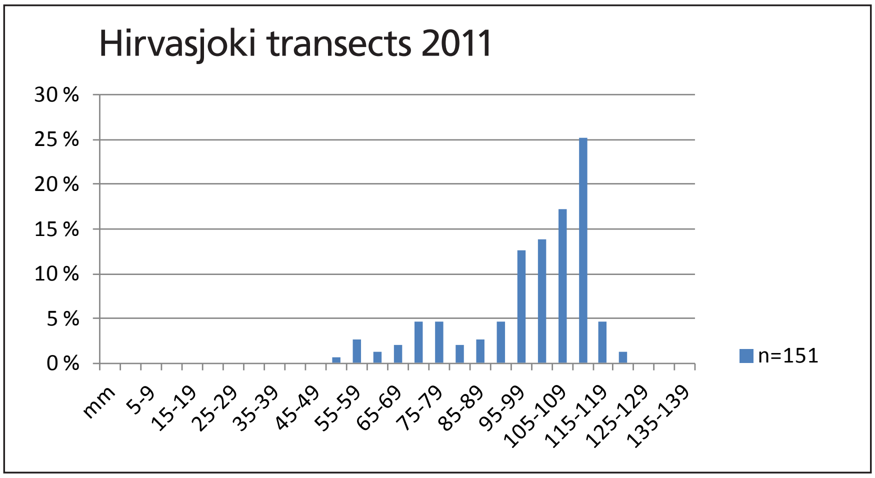


Figure 37. Study sites in River Hirvasjoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

Figure 38. Field surveys in River Hirvasjoki. Photo Panu Oulasvirta, Metsähallitus.



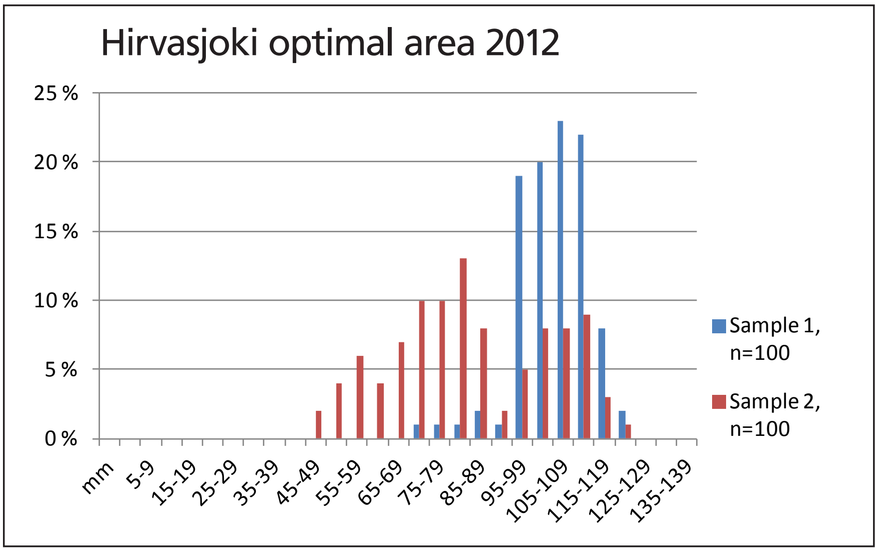


Figure 39. Size distributions of the mussels taken from random transects in 2011 (above) and in two samples taken from the densest mussel area in 2012 (below). Sample 2 represents the optimal area for young mussels.

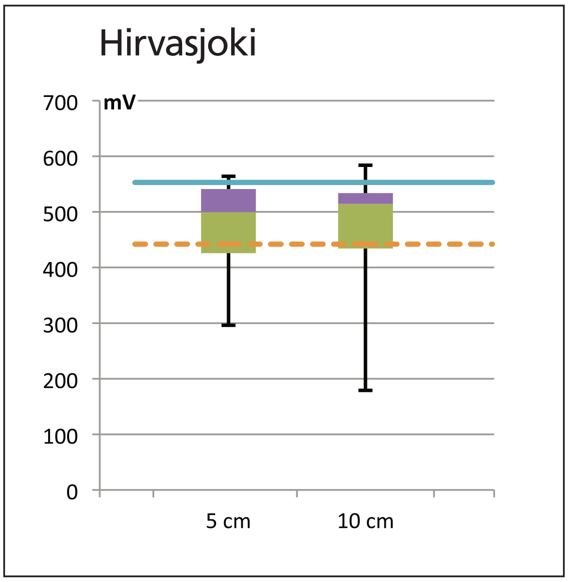


Figure 40. Redox potential measurements in River Hirvasjoki interstitial water 5 and 10 cm deep in the sediment. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values.

of the observed decrease in the mussel numbers from 2005 to 2011–12 is true, and the population is gradually declining. The viability status class of the population is *non-viable* (Table 8 p. 125) and the conservation status *high* (Table 9 p. 126).

It is not quite clear why the Hirvasjoki freshwater pearl mussel population is not recruiting well. The redox values showed quite good interstitial conditions for juveniles (Appendix 2, Figure 40). On the other hand, the coverage of filamentous algae in June 2012 was high, 45.7% on average indicating high nutrient levels. In the dry summer of 2013, the algae were even more abundant. A thick carpet (5 cm and more) of decomposing algae was observed in the beginning of September 2013 with a couple of juvenile freshwater pearl mussels (15–21 mm in length) lying on it. Water quality samples taken in October 2013 showed elevated nutrient levels compared to the water samples taken in the autumn of 1992 by Lapland

Ely-centre (Finnish Environmental database Hertta). Especially the level of ammonium, 21 µg/l, was high. Anthropogenic pressures in the Hirvasjoki catchment include forestry activities and reindeer herding. Both of these may cause nutrient flow into the river. The detailed results of the water analyses are given in Annex C.

There is no regular monitoring of fish stocks in Hirvasjoki. The Fisheries Research Institute has carried out electrofishing in Hirvasjoki in 1991–93 (Niemelä et al 1992, Kylmäaho *et al.* 1993, Kylmäaho & Niemelä 1995). The results showed very low numbers, only 2–4 0+ and 1+ and older brown trout/100 m^2. According to Swedish studies, the density of salmonid parr should be a minimum 5 fish/100 m^2 for successful recruitment (Degerman *et al.* 2009). Also Metsähallitus carried out electrofishing in Hirvasjoki in 2013, but due to the extremely low water level the results are not comparable. Juvenile brown trout were detected, but they were concentrated into certain deeper pools in the river. Still, it is possible that the densities of brown trout are too low to maintain an adequate recruitment of freshwater pearl mussel.

River Ruohojärvenoja

River Ruohojärvenoja is a part of the 60 km^2 wide Kattajärvenoja catchment in the Lutto drainage area (Fig. 41). Ruohojärvenoja originates from two small lakes, Ruohojärvi and Matin-Haukijärvi lakes and runs around 2.6 km before it joins River Uusijoki, which further down has its outlet into Lake Kattajärvi. Waters from Lake Kattajärvi run to Lutto via a short outlet, River Kattajärvenoja.

Freshwater pearl mussel was detected from Ruohojärvenoja during the Interreg Kolarctic project in 2003–2005 (Oulasvirta *et al.* 2006, Oulasvirta 2006). The upper limit of the distribution range is at the junction of two the streams from lakes Ruohojärvi and Matin-Haukijärvi and the lower limit in the junction of River Uusijoki. The 18 random transects in this study were chosen on this river stretch and they were investigated in 2012.

The estimated population size in Ruohojärvenoja was 4,700 mussels (Table 7 p. 124). In 2004 studies the estimate for the same river stretch was 3,200 specimens (Metsähallitus, unpublished data). Most probably the difference is due to the

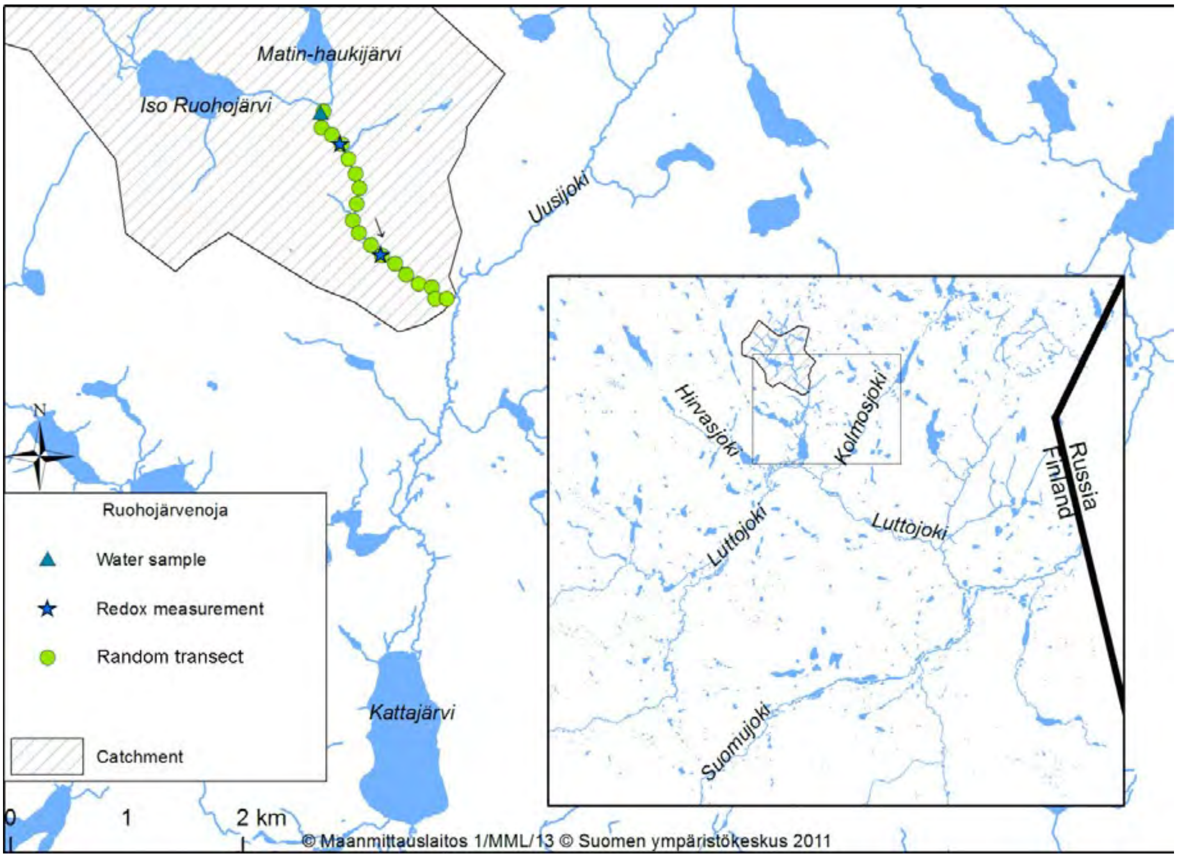


Figure 41. Study sites in River Ruohojärvenoja. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

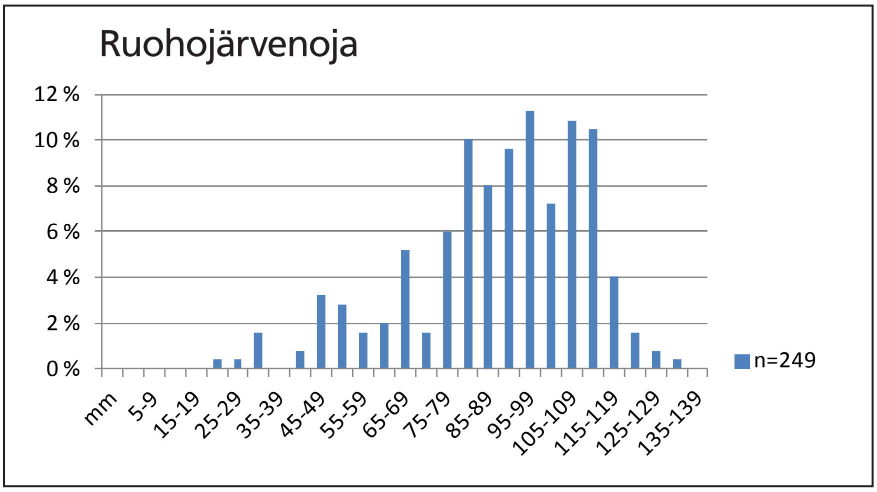


Figure 42. Size distribution of the mussels in the Ruohojärvenoja. No specific recruitment site could be distinguished, and therefore the samples from random transects and from an "optimal site" were combined.

inaccuracies of the estimates. Compared to the many other rivers in our study, Ruohojärvenoja has a better recruitment rate of young mussels (Fig. 42). Nevertheless, the viability status of the population falls into class *non-viable*, although the smallest observed mussels were only 20 mm in length (Table 8 p. 125). The conservation status of the population is *high* (Table 9 p. 126).

The redox potential was measured at two sites, one containing juvenile mussels and the other only adults. The redox values were higher at the juvenile site (Fig. 43). Due to a malfunction of the redox meter, the results of the redox measurements from Ruohojärvenoja are a little unreliable, however.

Water samples in the autumn of 2013 showed good water quality, but comparison with national monitoring data from years 1992–1993 shows that nutrient levels have risen during last 10 years (Finnish Environmental Database Hertta). The detailed results of the water analyses are given in Annex C.

The average coverage of filamentous algae during the field surveys in 28.6.–3.7.2012 was 23.7%.

Brown trout densities have been studied in Ruohojärvenoja in 2004 by Geist *et al.* (2006). The average density at two electrofishing sites was 0.27 0+ brown trout and 2.67 1++ brown trout/100 m^2. These are really low figures, but, as suggested by Geist *et al.* (2006), the low host density may be compensated in the Ruohojärvenoja type of oligotrophic streams with low post-parasitic mortality of the mussels.

River Hanhioja

The Hanhioja is ca. 3.4 km long stream in the Lutto catchment. It rises in Lake Hanhijärvi and runs down to River Kivijoki. The Kivijoki flows further across the Finnish-Russian border to Lake Moosesjärvi in Russia. The outlet river from Lake Moosesjärvi joins the main channel of the Lutto in Russian territory (Fig. 44). The

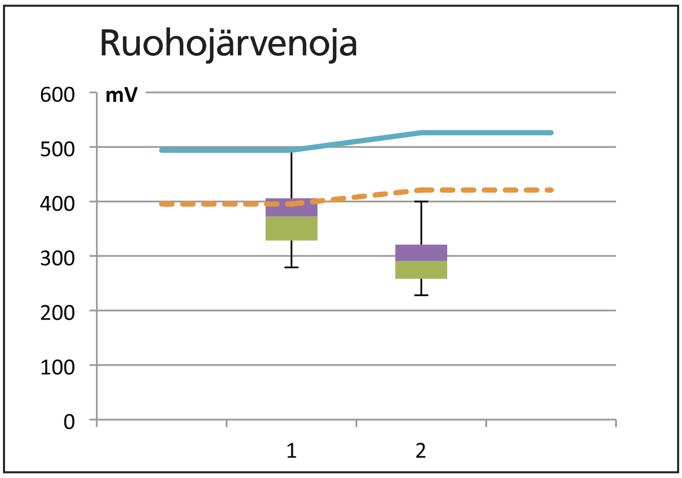


Figure 43. Redox potential measurements in Ruohojärvenoja. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Site 1 is situated in the area with juvenile mussels, while at site 2 only adult mussels were present.

Hanhioja is on average only 1–3 metres wide and 0.2–0.3 metres deep, the deepest sites being around one metre (Fig. 45). The bottom substrate consists mainly of stones and gravel. The river habitat varies between rapids and riffles with some slow current areas between. In the middle course there is a mire area with narrower channel, deeper water and lot of aquatic plants (Fig. 46).

The upper part of the Hanhioja is relatively untouched by humans. There are, however, old forestry areas nearby. In the lower course, the problems are the forest roads that cross the river. One of the roads has collapsed into the river and lead sand drifting into the stream (Fig. 47).

Freshwater pearl mussel was detected from the Hanhioja in 2004 during the Interreg Kolarctic mapping project (Oulasvirta at al. 2006). The distribution of the mussels extends ca. 2,300 metres down from the Hanhijärvi lake (Fig. 44). At the lower limit of the population the slope of the river gets steeper, which is obviously the reason for the absence of the freshwater pearl mussel there. The field investigations in 2006 revealed that there are also mussels in the tiny stream above Lake Hanhijärvi (Metsähallitus, unpublished data).

In this project, the investigations in the Hanhioja were carried out in 2011 and some complimentary surveys were conducted in 2012. The estimated population size in the Hanhioja was ca. 15,700 mussels (Table 7 p. 124). The figure matches quite well with the earlier estimate from 2004, 13,200 mussels (Oulasvirta *et al.* 2006). In 2004, the entire river was investigated and all the observed mussels counted.

The Hanhioja was the only river in our study that showed good recruitment of juvenile mussels. The freshwater pearl mussel population in the Hanhioja can be classified as *viable* in all of the criteria used (Table 8 p. 125). However, the best recruitment in the Hanhioja seems to take place in specific areas favourable for young mussels. The difference in size classes is remarkable between the samples taken from the random transects, from the dense adult site, and from the best juvenile site (Fig. 48). It is notable, that juvenile mussels were not found below the point where the forest road had collapsed into

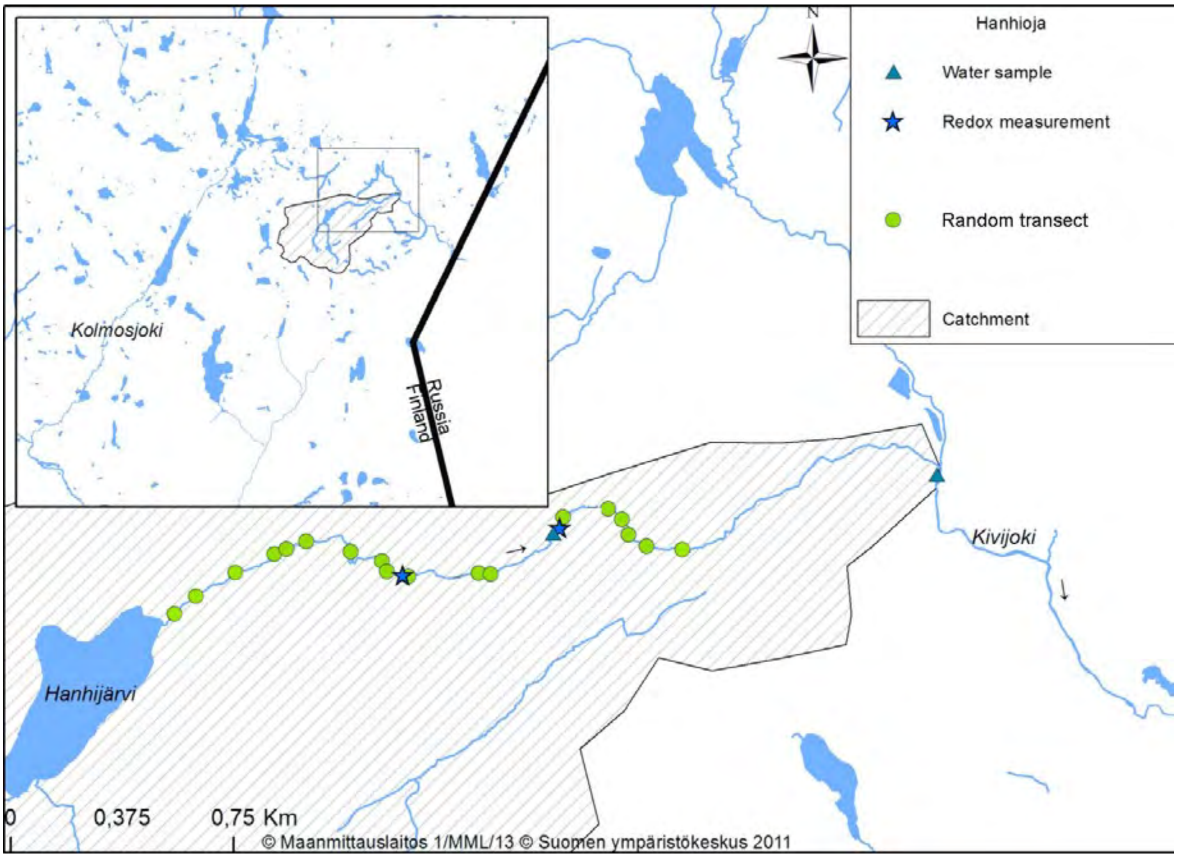
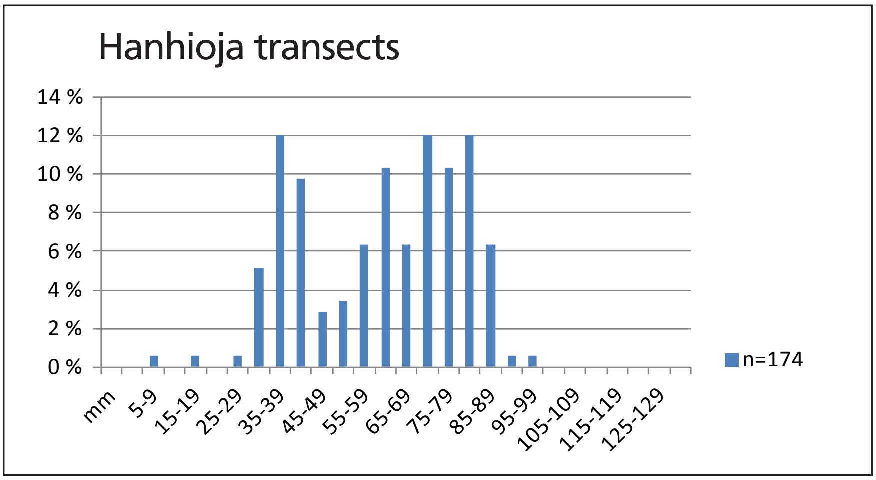


Figure 44. Study sites in River Hanhioja. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

Figure 45. River Hanhioja is a tiny stream flowing to River Kivijoki and further down to Lake Moosesjärvi in Russia. Photo Panu Oulasvirta, Metsähallitus.

Figure 46. In its middle course the Hanhioja runs through a mire area. Here the channel is narrow, the stream is deeper and aquatic plants are abundant. Freshwater pearl mussel can be found even from the roots of the plants. Photo Panu Oulasvirta, Metsähallitus.

Figure 47. Forest road has collapsed into the river at River Hanhioja. Juvenile mussels were not detected below this site although they were abundant just above. Photo Panu Oulasvirta, Metsähallitus.



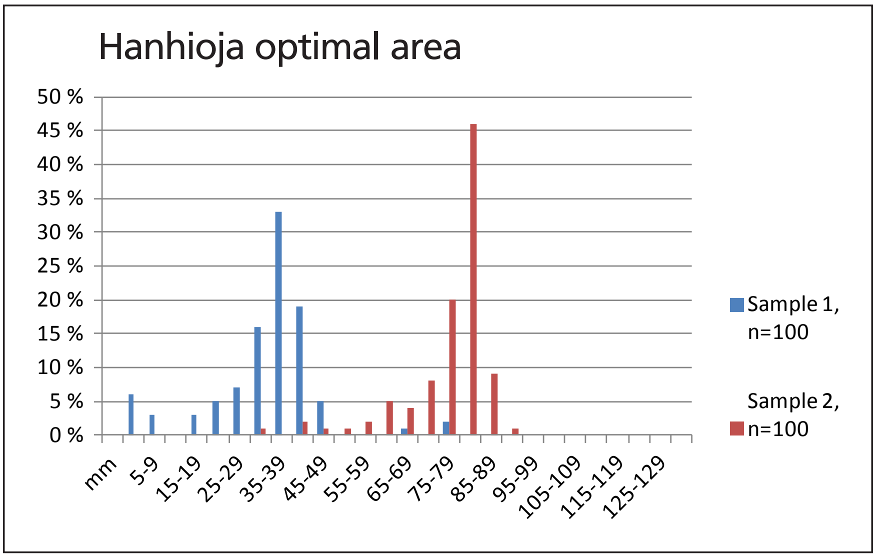


Figure 48. Size distribution of the mussels in the samples taken from River Hanhioja random transects (above), from the optimal recruitment site (below, sample 1) and from an area with the densest population of adult mussels but with only few juvenile mussels present (below, sample 2).

the river. The conservation status of the population is *very high* (Table 9 p. 126).

Redox potential was measured at the mire area and at the best recruitment site. The difference between the sites was clear, the latter having higher redox values and only a small difference between the free flowing water and interstitial water (Fig. 49). These results agree quite well with Geist & Auerswald´s (2006) findings.

Water samples in the autumn of 2013 showed elevated phosphate levels (7 µg/l). Earlier water quality data from River Hanhioja is available from 1992 (Finnish Environmental Database Hertta). Compared to the autumn of 1992, all nutrient levels had risen in 2013. The detailed results of the water analyses are given in Annex C.

The average coverage of filamentous algae was 65.7% at the end of August 2011.

The host fish for the freshwater pearl mussel in the Hanhioja is the brown trout, densities of which have been investigated by the Fisheries Research Institute in 1991–93 (Niemelä et al 1992, Kylmäaho *et al.* 1993, Kylmäaho & Niemelä 1994). The mean densities of 0+ and 1+ brown trout were almost 80 fish/100m^2, which is far above the densities in most of the rivers in the same region. In 2010 the mean density was still relatively high, 20 fish/100 m^2 (Ranta 2010).

River Kiertämäoja

River Kiertämäoja is a ca 10.5 km long tributary of River Lutto (Fig. 50). The whole catchment, 128 km^2, belongs to the Urho Kekkonen National Park, and consists of several small and two bigger lakes, the Upper and Lower Kiertämäjärvi lakes (Note that the river stretch below Lower Kiertämäjärvi lake is called the Kiertämäjoki. To simplify, we have used only the name Kiertämäoja, which hereinafter means also the lower part of the river). The Kiertämäjoja is also included into the UK-Park-Sompio-Kemihaara Natura 2000 area (FI1301701).

The previous data on the freshwater pearl mussel from the Kiertämäoja was rather limited. The known distribution range consisted of the river stretch below Upper Kiertämäjärvi lake (Sakari Kankaanpää, Urho Kekkonen National Park, pers. comm.). The distribution above Upper Kiertämäjärvi lake is unknown.

In this study, the 21 random transects were chosen in the known distribution area between Upper Kiertämäjärvi lake and River Lutto. Freshwater pearl mussel was found from 18 of the transects, and the mean density of the mussels was 1.15 specimens/m^2. The estimated population size was 111,400 mussels, i.e. one of the biggest in our study (Table 7 p. 124).

Although the population is relatively big and the river is situated in the national park outside all forestry activities, for instance, it seems that the mussels are not reproducing very well. The

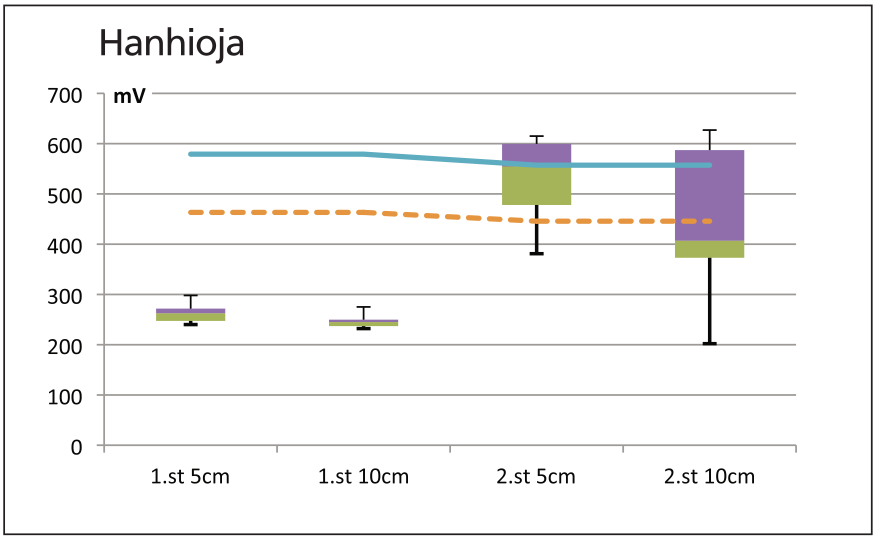


Figure 49. Redox potential measurements in the Hanhioja in the interstitial water 5 cm and 10 cm deep in the sediment. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Site 1 is situated in the mire area in the middle course where only adult mussels were found. Site 2 is in the best recruitment area downstream from Site 1.

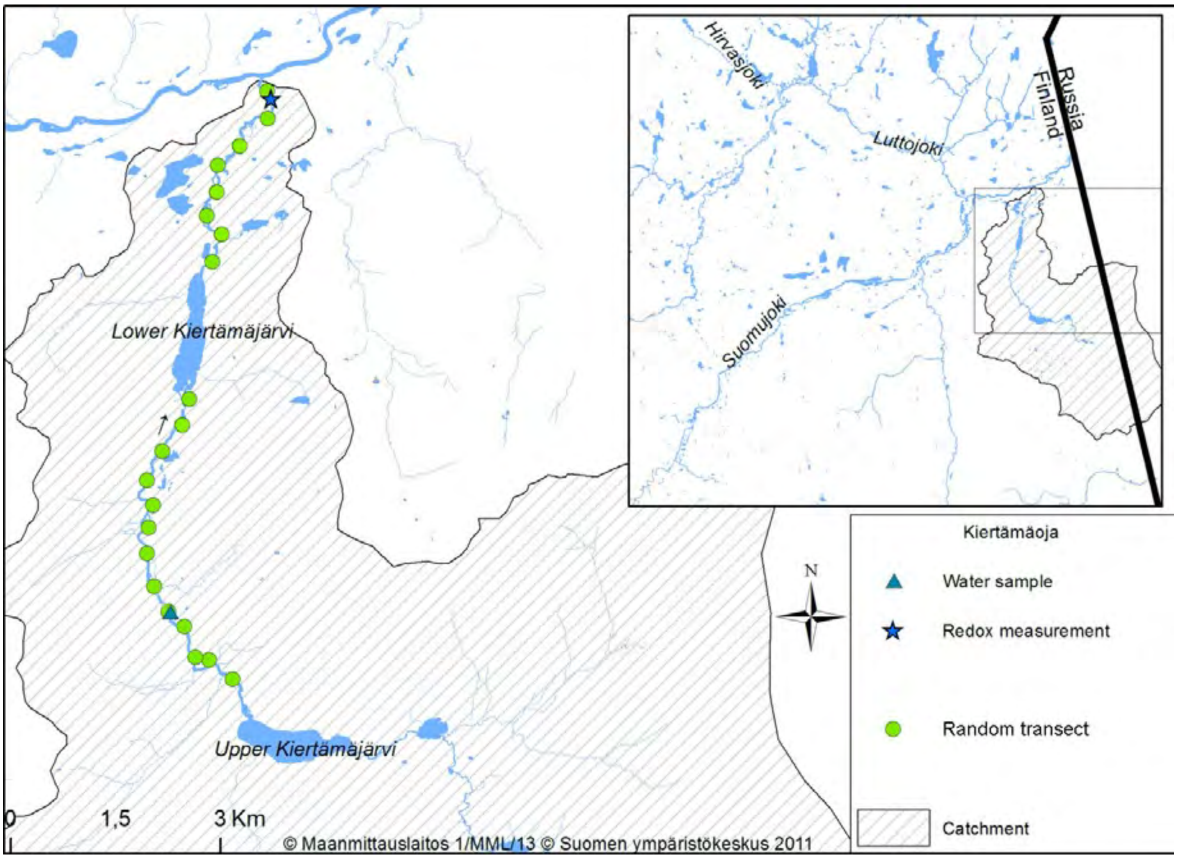
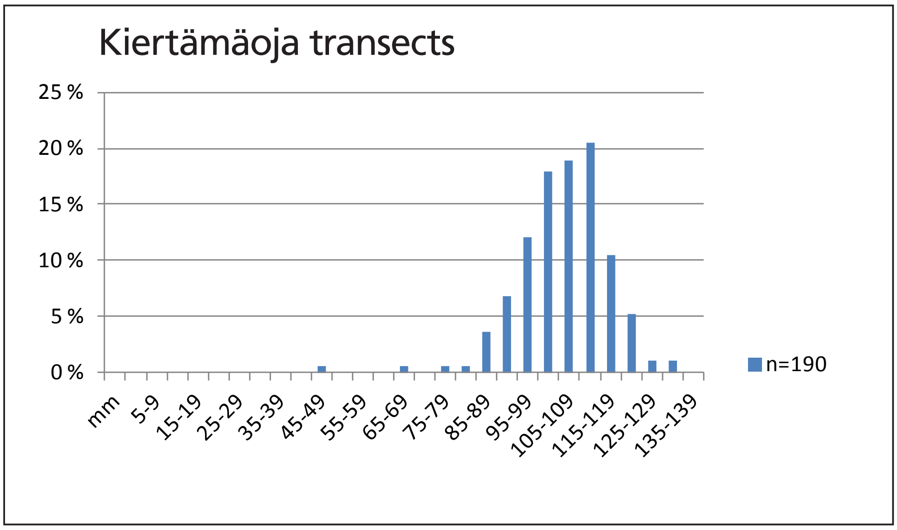


Figure 50. Study sites in River Kiertämäoja. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

Figure 51. Kiertämäoja belongs to the Urho Kekkonen National Park. Photo Aune Veersalu, Metsähallitus.



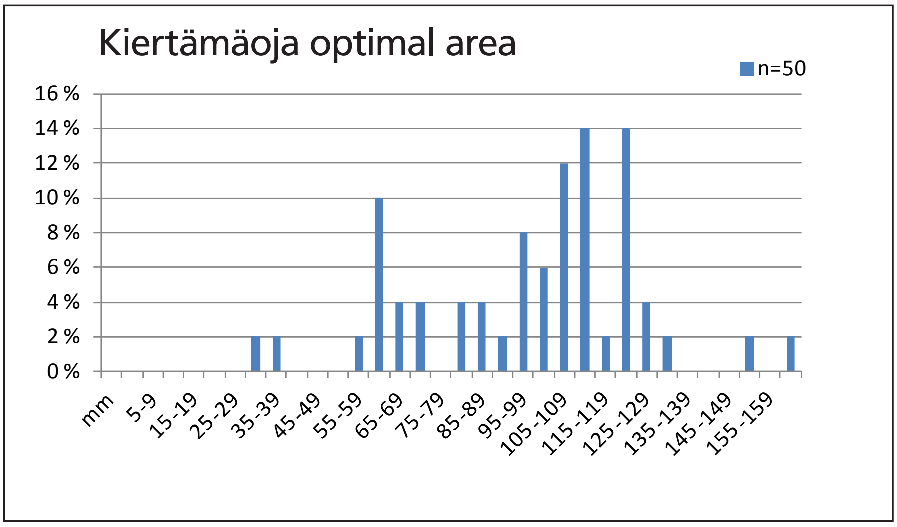


Figure 52. Size distribution of the mussels in Kiertämäoja random transects (above) and from the optimal recruitment site (below).

size distribution shows that majority of the mussels are aged adults (Fig. 52). Indeed, the biggest individual mussel in our project, 165 mm in length, was detected from the Kiertämäoja (Fig. 53) in 2013. Although the juvenile mussels were rare in random transects, in a search for small mussels several mussels under 20 mm were found, suggesting that in places the degree of recruitment is good (Fig. 52). However, because of the small proportion of juveniles in the random samples, the status class of the population became *non-viable* (Table 8 p. 125). The conservation status of the population is *high* (Table 9 p. 126). However, if the mussels are salmon-dependent in their reproduction, the conservation status would be *very high* (Table 9).

There was no recent electrofishing data available from Kiertämäoja. The results from 1991–93 fishing showed, that the mean density of 0+ and 1++ brown trout was only 0.2 fish/100 m^2 (Niemelä et al 1992, Kylmäaho *et al.* 1993, Kylmäaho & Niemelä 1994). The small densities of host fish could at least partly explain the low recruitment rate of freshwater pearl mussel in the river. It is also possible that the primary host for the Kiertämäoja mussels is the Atlantic salmon, since the lower and middle courses of the river have obviously served as a nursery areas for migrating juvenile salmon before the construction of Upper-Tuuloma dam in Russia in the early 1960's (Erkinaro *et al.* 2001).

Redox potential was measured only at one site on the Kiertämäoja (Fig. 50). The figures indicate a well oxygenated environment for juvenile mussels in the interstitial water (Fig. 54). The average coverage of filamentous algae during the field surveys in July 2012 was 22.8%.

Two water samples were taken from the Kiertämäoja in October 2013. The sample

Figure 53. The biggest mussel found in the whole project was found from the River Kiertämäoja. Photo Juho Vuolteenaho, Metsähallitus.

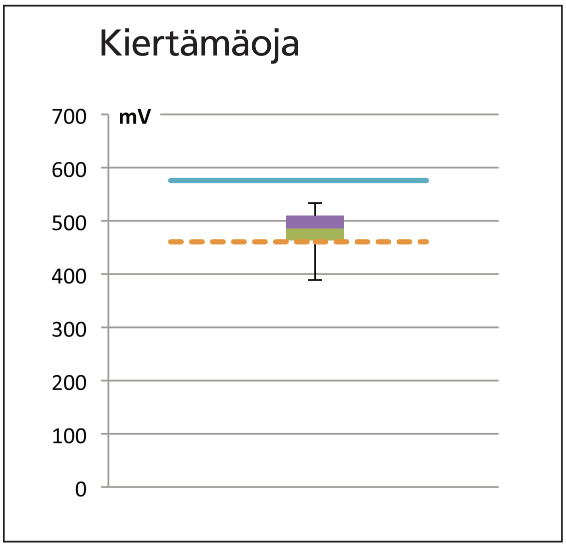


Figure 54. Redox potential measurements in Kiertämäoja. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values.

from the upper course indicated good water quality, although the phosphate level was slightly elevated. In the sample taken from the lower course, all nutrient levels were alarmingly elevated, however. Especially high was the level of ammonium (NH_4) 115 µg N/l. There are mainly two potential sources for the ammonium in the national park, people (hikers) or reindeer. The toilets in the park are, however, designed so that the nutrient flow into the river or lakes should not be possible (Sakari Kankaanpää, pers. comm.). Older water quality data from Kiertämäoja was quite limited. In 1992–1993, the water quality was good on the lower course also, although alkalinity was low (0.022 mmol/l) and high ammonium (24 µg/l) values were detected from Lake Kiertämäjärvi in 1990–1991. The detailed results of the water analyses are given in Annex C.

River Torkojoki

The Torkojoki is a part of the Nahkimaoja catchment in Lutto drainage system. The Torkojoki receives its water from several lakes in the upper part of the catchment. The freshwater pearl mussel distribution range consists of the lower part of the river between the Lower-Torkojärvi lake and River Nahkimaoja (Fig. 55) (Oulasvirta 2006). The forestry activities in the vicinity of the river are an obvious threat to the River Torkojoki mussel population.

The 18 random transects were chosen in the known distribution area. The estimated population size was 7,200 mussels (Table 7 p. 124), which is in line with the previous counts in 2005 (Oulasvirta *et al.* 2006, Oulasvirta, unpublished data). The field investigations in the Torkojoki were carried out mainly in

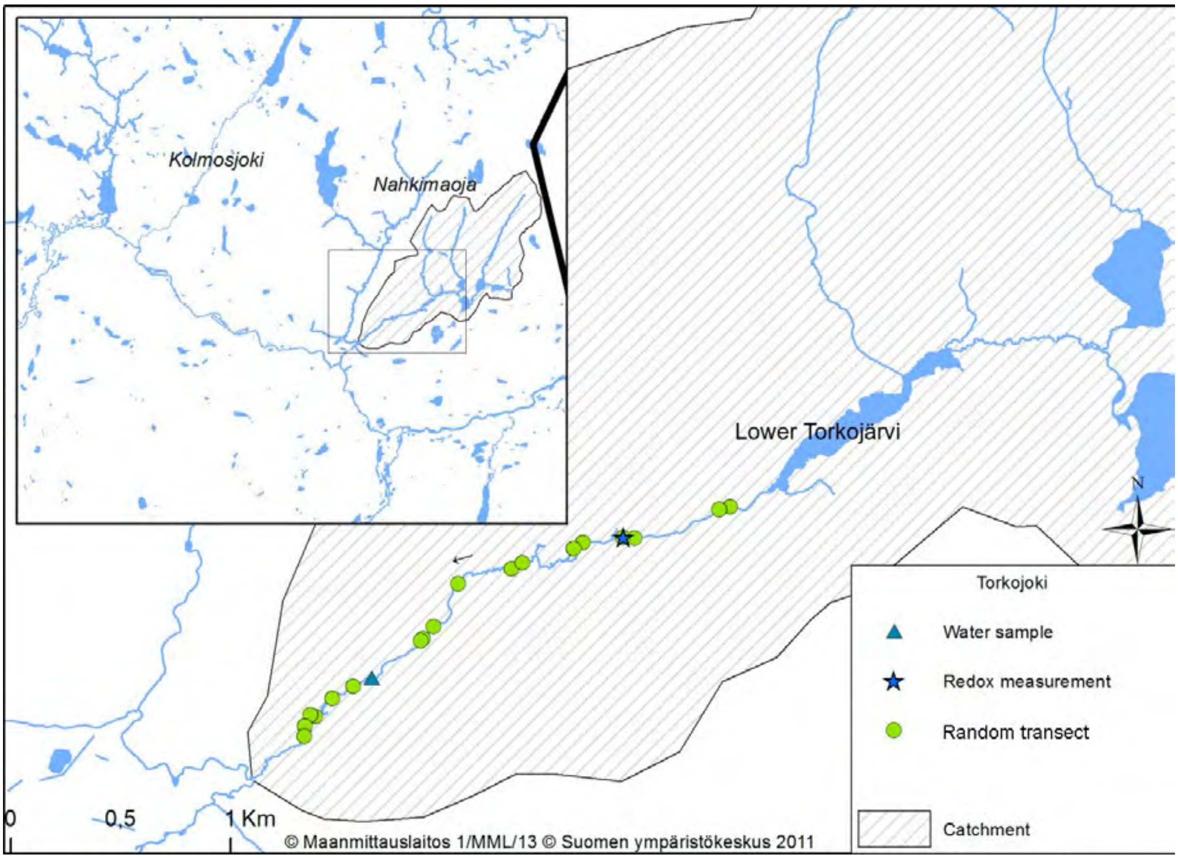


Figure 55. Study sites in River Torkojoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/ MML/15.

September 2011. At the time of the surveys, the river was over-flooding due to the heavy rains. The high and turbid water combined with a strong current have most probably affected to the results obtained from River Torkojoki. For example, juvenile mussels were not detected during the random transect surveys and therefore the viability class for the Torkojoki population became *non-viable* (Table 8 p. 125). This may be an incorrect conclusion, however, since juveniles were found quite frequently in a search conducted in 2013. At optimal sites, approximately 20% of the mussels were under 50 mm, and smallest ones were 20 mm in length. Juvenile mussels have also been detected before, in the 2003–2005 project (Oulasvirta *et al.* 2006, Oulasvirta, unpublished data). The size distribution of the mussels from the Torkojoki is shown in Fig. 56. The conservation status of the population is *high* (Table 9 p. 126).

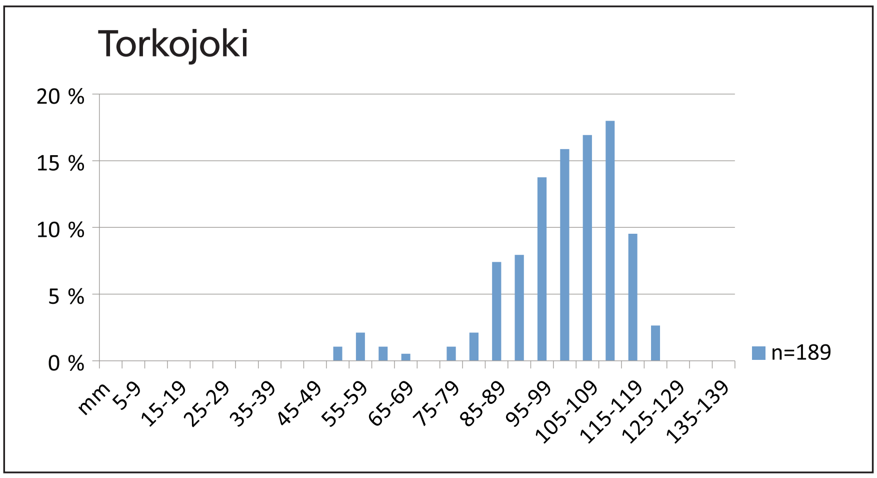


Figure 56. Size distribution of the mussels in the Torkojoki. The samples from random transects and from the "optimal site" were combined.

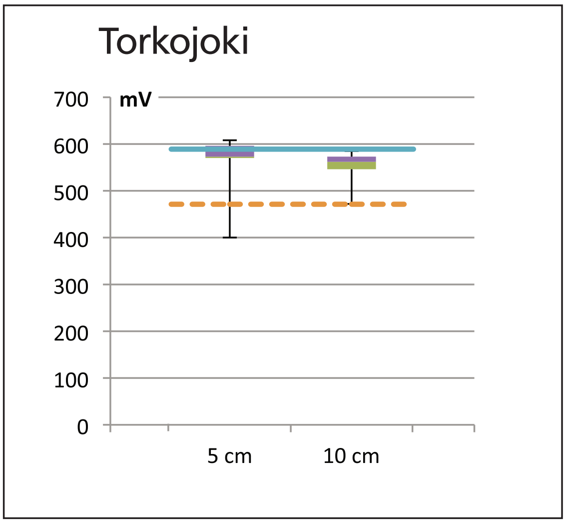


Figure 57. Redox potential measurements in River Torkojoki in the interstitial water 5 cm and 10 cm deep in the sediment. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values.

The redox potential was measured at one site. Both 5 cm and 10 cm deep interstitial water was recorded. The values were good and did not show any significant difference between the free water and the interstitial water (Fig. 57). This result also emphasizes the assumption, that the river is at least in some places would offer a favourable environment for juvenile mussels.

Electrofishing was conducted in the Torkojoki in August 2013. The density of 0+ and 1+ brown trout was approximately 30 fish/100 m^2 (Metsähallitus, unpublished data), which should be adequate for freshwater pearl mussel recruitment.

A water sample from October 2013 revealed elevated nutrient contents. Especially ammonium and phosphate levels were high. Earlier water quality data is available from 1992 (Finnish Environmental Institute Hertta database). Compared to that, the nutrient and mineral levels were no higher. The detailed results of the water analyses are given in Annex C.

During the field surveys in September 2011, the average coverage of filamentous algae was 9.6%.

Tornionjoki catchment

The description of the River Tornionjoki (Swedish Torneälven) catchment is given in Chapter 4.1. The two known freshwater pearl mussel rivers on the Finnish side of the catchment are Rivers Koutusjoki and Luomalanjoki. The Koutusjoki was selected as a target river for population status assessments.

River Koutusjoki

River Koutusjoki rises in Lake Koutusjärvi (Fig. 58) and runs down to Lake Miekojärvi (Fig. 59). The total length of the river is ca. 6.3 km, and the catchment area covers 24.32 km^2 (Ekholm 1993). Koutusjoki is surrounded mainly by spruce forests (Fig. 60). Forestry works and old ditches in the catchment area are an obvious threat to the mussel population in the Koutusjoki.

The 18 random transects and redox potential in the Koutusjoki were studied in August 2011. Some complementary surveys were done in September 2012. The estimated population size was ca. 131,500 mussels, i.e. almost as much as in the much bigger River Suomujoki. The average density of the mussels in random transects was almost 8 specimens/m^2. In certain areas the mussel densities were very high. Since none of the random transects hit these areas, it is possible that the real population size is even bigger than that obtained from the census. Thus, although River Koutusjoki is small, its freshwater pearl mussel population is one of the largest in Finland, and its conservation value is the highest possible i.e. *very high* (Table 9 p. 126). The conservation value of the Koutusjoki freshwater pearl mussel population is increased even more by the fact that there are only three known populations of freshwater pearl mussels in the entire Tornionjoki river basin.

The more downstream one goes in Koutusjoki the influence of the forestry works and ditches become more obvious. Indeed, although Koutusjoki contains one of the biggest freshwater pearl mussel populations in Finland, it is seriously threatened. The influence of the ditches and logging are visible in the lower course in a form of siltation and eutrophication. Also the contents of aluminium and iron are high (Annex C). Alka-

Figure 58. Lake Koutusjärvi September 2014. Photo Panu Oulasvirta, Metsähallitus.

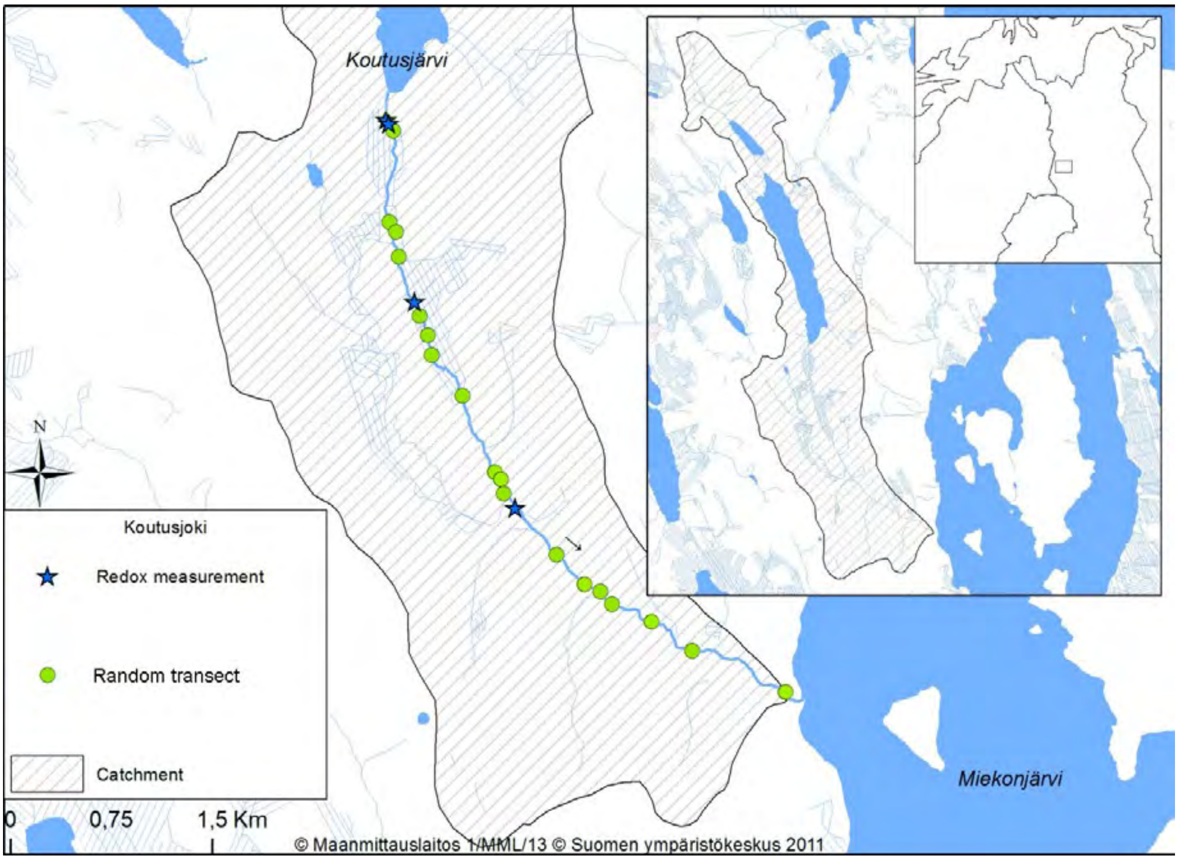


Figure 59. Study sites in River Koutusjoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/ MML/15.

linity and pH are reduced especially in spring, which, together with high Fe and Al levels, can be dangerous for biota. Also, levels of turbidity, suspended solids and nutrients, especially total phosphorus, are often elevated. As a consequence, adequate recruitment of the freshwater pearl mussel takes place almost entirely at the upper end of the population. Elsewhere, the population consists mainly of adult mussels only, which can be seen from the size distribution in the samples taken from random transects (Fig. 61). Even in the recruitment area it is possible to distinguish

Figure 60. Spruce forests along River Koutusjoki. Photo Panu Oulasvirta, Metsähallitus.

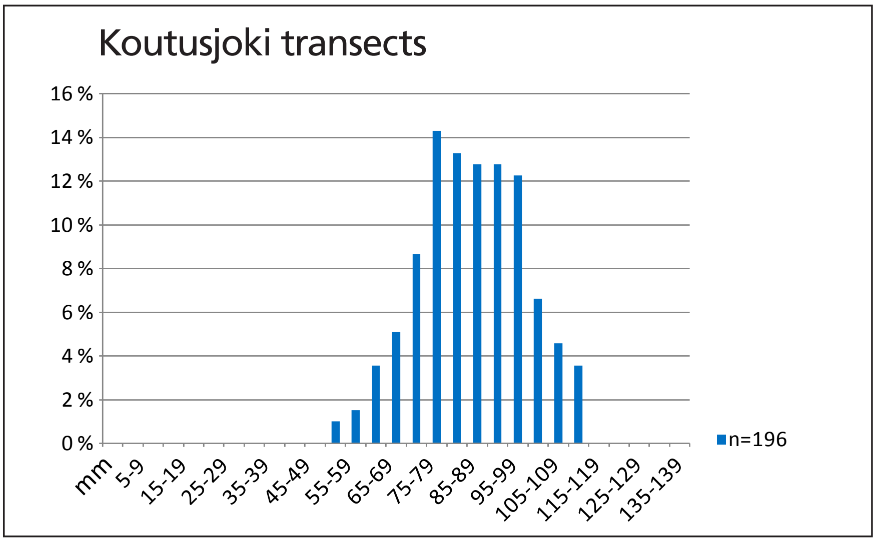


Figure 61. Size distribution of the mussels in the samples taken from random transects in River Koutusjoki.

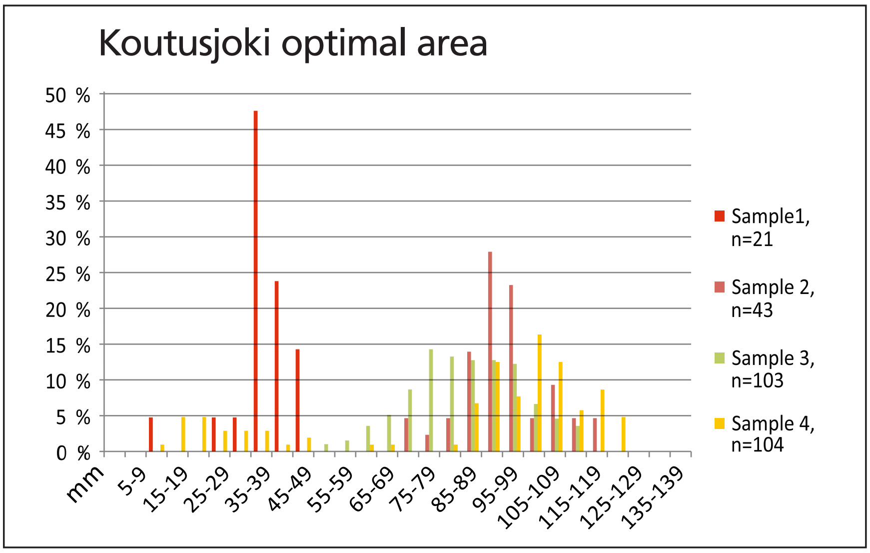


Figure 62. Size distributions of mussels in the samples taken from the recruitment area in River Koutusjoki's upper course. All samples have been taken within the same 10 metre-long stretch of the river. Sample 1: 0.2 x 0.2 metre frame micro-habitat with plenty of juveniles; Sample 2: 0.2 x 0.2 metre frame only 0.5 metre distance from the previous sample, but only adult mussels; Sample 3: 0.5 x 0.5 metre frame, micro-habitat with mainly adult mussels; Sample 4: 0.5 x 0.5 metre frame, micro-habitat with both juveniles and adults;. The 0.5 x 0.5 frame samples were taken during the previous Interreg project in 2007. The difference between the samples shows that, even in a short stretch of the river the juvenile mussels may have their own micro-habitats.

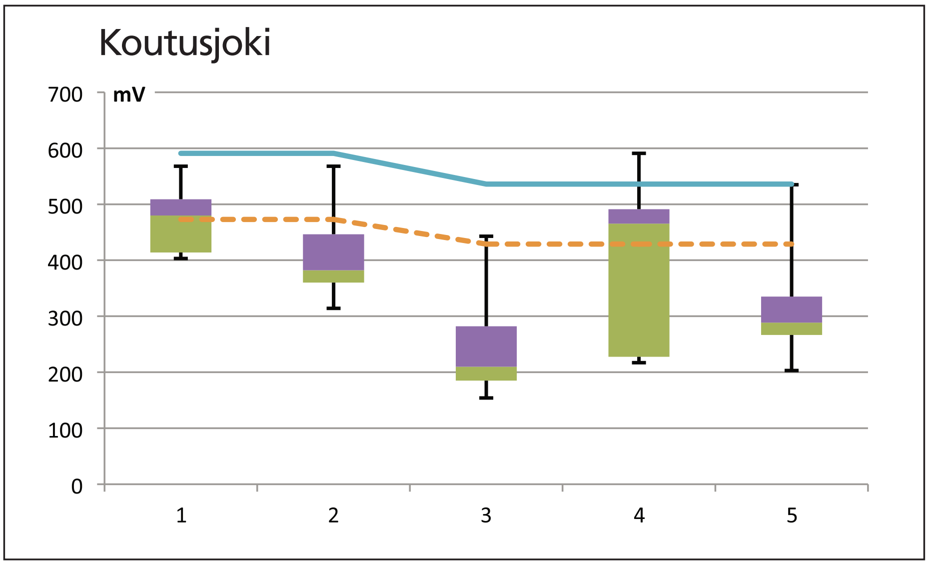


Figure 63. Redox potential measurements in the Koutusjoki. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the free water values. Horizontal axis: 1. Recruitment site on the upper course on 19.9.2012; 2. Close to site 1 but below a forest ditch, juvenile mussels are still present, measurements taken on 19.9.2012; 3. Same area as site 2, but measurements taken on 30.8.2011; 4. Rapids in the middle course on 31.8.2011, high adult densities but no < 50 mm mussels, 5. Lower course site in 31.8.2011, adult mussels, but no juveniles.

micro-scale habitats for juveniles (Fig. 62). Thus, estimating the recruitment rate in the Koutusjoki is extremely difficult – the proportion of juvenile mussels in the sample is totally dependent on which small-scale spot the sample is taken from. Examples of this are shown in Fig. 62. Nevertheless, it is predictable, that the population will be decreasing in future because of the lack of recruitment in the lower course. The status class of the population is *non-viable* (Table 8a p. 125). In the recruitment area alone in the upper course, the status class would be *viable* (Table 8b p. 125).

The influence of the ditches and forest works can also be seen from the results of the redox measurements. Redox was measured at four sites. One area was studied both in 2011 and 2012 (Fig. 63). The best redox values were recorded from the juvenile site at the upper end of the population and in a rapids area in the middle course. Very close to the upper course site, but below a ditch leading to the river, the values were already much worse. Low redox values were also measured from the lower course (Fig. 63).

The average coverage of the filamentous algae was 2.15% during the field surveys at the end of August 2011.

River Iijoki catchment

Iijoki catchment is situated in the North-Ostrabothnia province, in the south of Lapland (Fig. 64). The outlet of the River Iijoki is in the Bothnian Bay. The area of the whole catchment is 14,190 km^2 (Ekholm 1993). The main tributaries of the Iijoki are the Livojoki, Siuruanjoki, Kostonjoki and Korpijoki rivers. Five hydropower plants have been built into the main channel of the Iijoki, and they have prevented salmon and sea trout migrations into the river since 1961, when the first dam was built. The genetic strains of the native salmon and sea trout populations have been kept alive in fish farms, however. This enabled the host fish experiments with different hosts and mussel populations in our project (see Annex E).

Together with the Lutto and Kemijoki catchments, the Iijoki with its 28 known freshwater pearl mussel populations is the key area for the freshwater pearl mussel in Finland. Most of the Iijoki freshwater pearl mussel populations are found from small streams, but River Livojoki, for instance, is one of the few representatives of a former salmon river in Finland that still contains freshwater pearl mussels. Three Iijoki catchment rivers, the Livojoki, Haukioja and Norssipuro, were chosen for the population status assessments in our study.

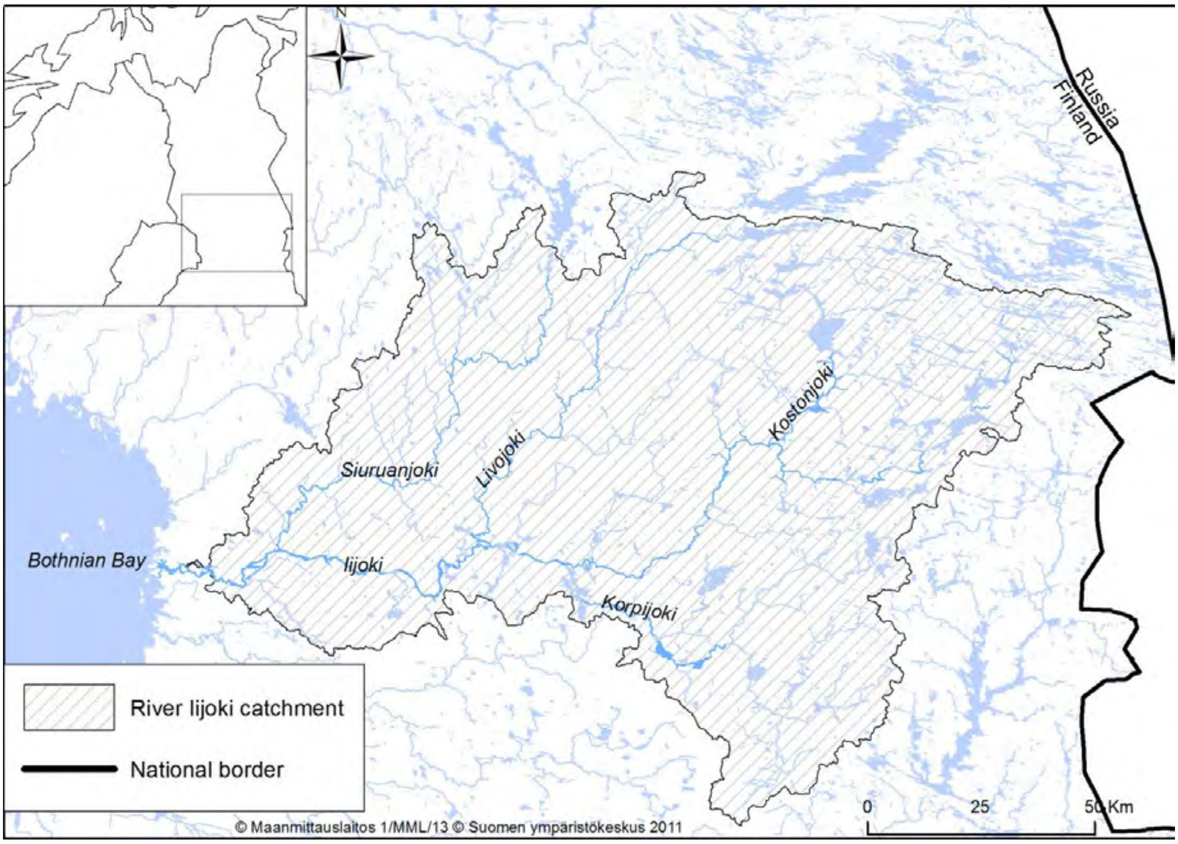


Figure 64. Iijoki catchment area. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

River Livojoki

As said, River Livojoki is one of the main tributaries of the Iijoki river and a former salmon river. Previously, the Livojoki freshwater pearl mussel population has been investigated in 1989–1992 (Valovirta 1990d, Valovirta 1993). Investigations showed that the Livojoki contains a ca. 8,700 mussel population with a majority of the mussels in the upper course. In the lower course only individual mussels were found, and these were presumed to be the remains of the former abundant mussel population when the river was in a natural state (Valovirta 1993). There is also evidence of pearl fishing in the lower course of the river in the 1950's (Paavo Vääräniemi, pers. comm). Recent studies in River Livojoki include the study of the population status in the key population area in the upper course (Porkka 2011). The conclusion of the study was that the recruitment of the population ceased 50–60 years ago. River Livojoki was cleared for timber floating in the 1950s (Fig. 65). The same rapids were restored in the 1990's.

In this study, the population census was carried out only in the key distribution area. 14 cross-transects were established into the Louhikosket rapids area and six transects down from the Raakunkosket rapids (freshwater pearl mussel rapids) (Fig. 66). Due to great depth and poor visibility under water, transects were studied by SCUBA-diving.

The estimated number of mussels in the Louhikoski rapids area was 5,100 and only 225 mussels in the Raakunkosket rapids area (Table 7 p. 124). Since all the observed mussels were big, the measurements were taken only from 18 mussels (Fig. 67). The average length of the mussels was 105 mm. The smallest observed mussel was 88 mm in length. These results support the fact that the River Livojoki mussel population is not recruiting. The status class of the population is d*ying-out* (Table 8 p. 125), but the conservation status is *very high* due to the salmon-dependent mussel population and unique haplotypes (Table 9 p. 126).

The non-recruitment is probably caused by two main factors: (1) The lack of suitable host fish, Atlantic salmon, and (2) the heavy land use in the drainage area, with several forest ditches

Figure 65. Clearing of River Livojoki for timber floating in 1950s. Photo Uittoteho ry (1957).

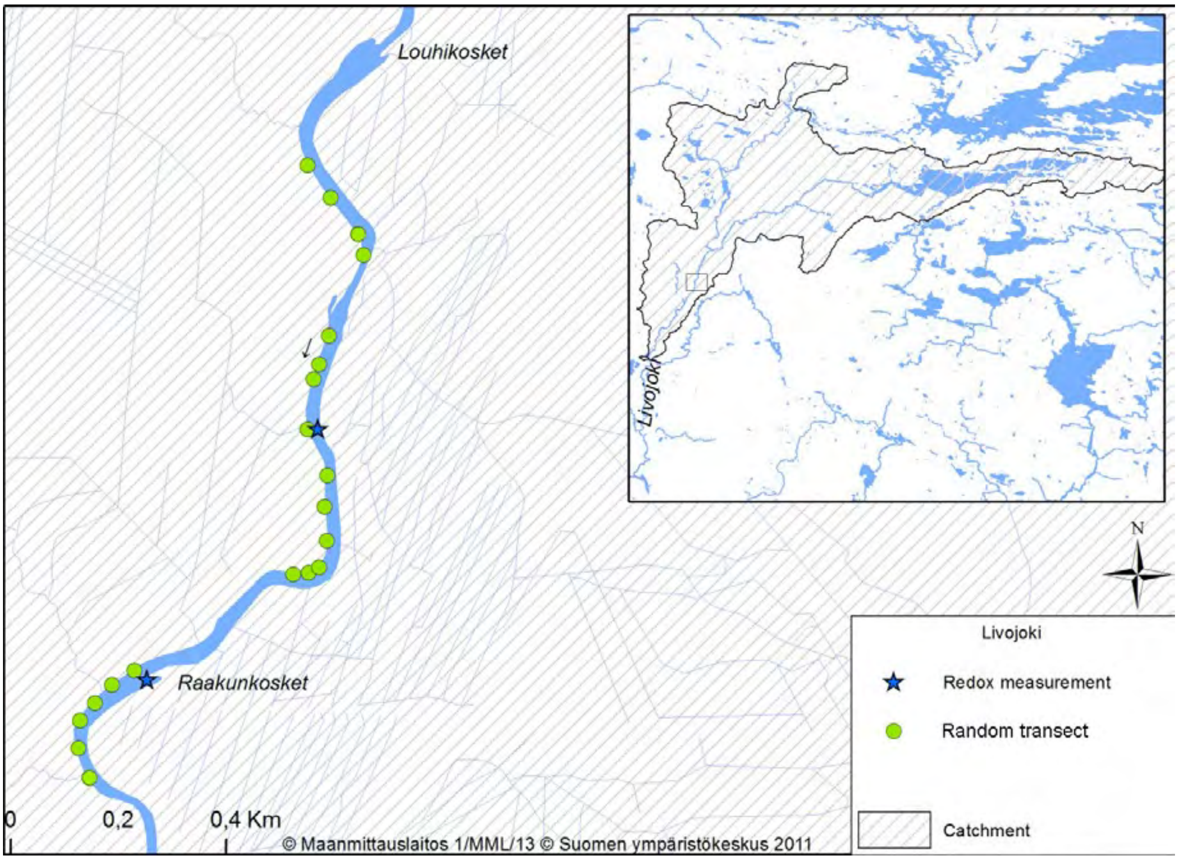


Figure 66. Location of the cross-transects and redox measuring sites in River Livojoki. The numerous ditches on both sides of the river are examples of the heavy land use in the catchment area. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

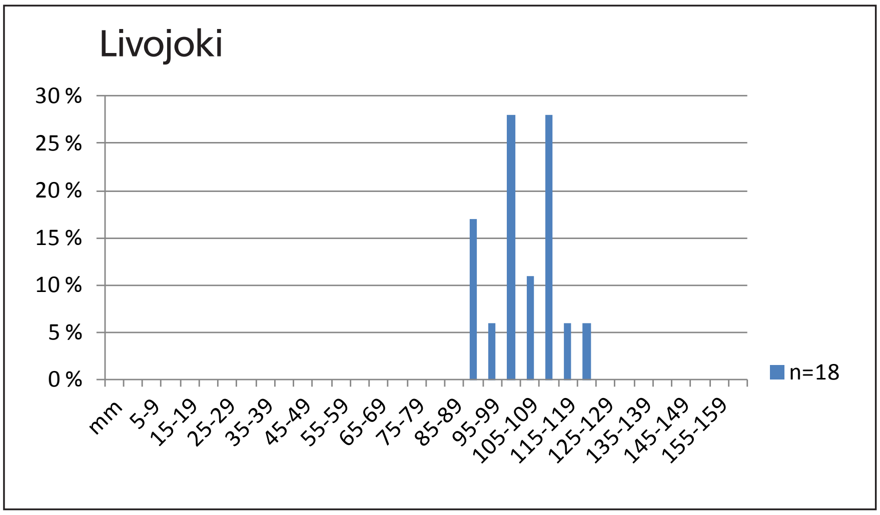


Figure 67. Size distribution of the mussels in the sample taken from River Livojoki.

leading directly into the river (Fig. 68). The host fish experiments carried out in our project showed that the primary host for the Livojoki freshwater pearl mussel is the Atlantic salmon (Annex E). Brown trout can only seldom if at all serve as a host for the Livojoki freshwater pearl mussel. Re-starting the natural recruitment of the Livojoki freshwater pearl mussel would, therefore, require the return of the salmon to the river. Since the native salmon strain is alive in fish farms, this would be possible. Actually, this work has been already started – hundreds of thousands of salmon and sea trout fry have been restocked in River Livojoki since 2007. In the long run, the only sustainable solution would, however, be the construction of the fish ways into the hydro power dams on River Iijoki, which would enable the natural migrations of salmon to the river.

The other problem, siltation and eutrophication of the river, can be seen in the Livojoki in the form of loose sand and organic sediments

Figure 68. With heavy rains the ditches carry siltation to River Livojoki. Photo Panu Oulasvirta, Metsähallitus.

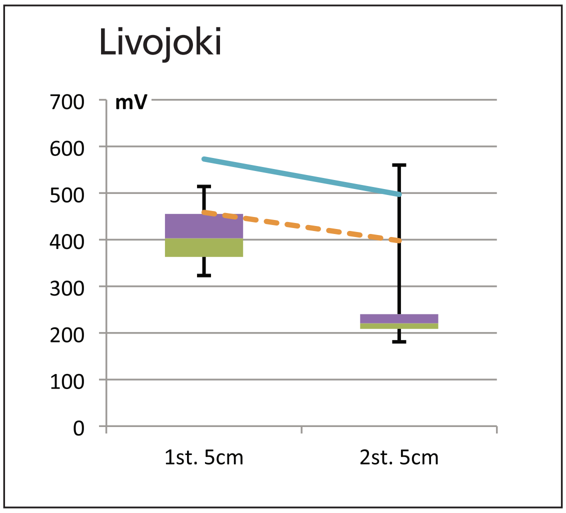


Figure 69. Redox potential measurements in the Livojoki. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Site 1 is in the Louhikosket rapids area and site 2 in the Raakunkosket rapids area.

in many places. Also, the redox readings from Louhikoski and especially from Raakunkoski area showed poor quality of the interstitial environment (Fig. 69). The ditches do not only carry sediments and nutrients to the river but also acid water – a pH value of 4.7 was measured from one of the ditches leading to the Livojoki (Fig. 70). Also, water quality data in Finnish national monitoring show strong fluctuations of pH (pH 5.7–7.7) and occasionally low alkalinity values (Finnish Environmental Institute Hertta-database). Low pH can be dangerous in River Livojoki, since the median iron level is high, 870 µg/l, and also quite high, 386 µg/l aluminium peaks have been measured. Nutrient levels are permanently elevated, the median phosphate level being 7.5 µg/l, median total phosphorus 18 µg/l and median nitrogen 285 µg/l. Several ammonium peaks up to 57 µg/l have been detected, while nitrate peaks (up to 230 µg/l) are not so common. Also, turbidity is chronically high 2.05 FNU (median). Quite often also water colour (max 200 mg PT/l) and suspended solid (up to 6,7 mg/l) values have been high and oxygen saturation below 90 S% in many samples (Annex C). All these figures stress the unsuitability of the Livojoki for juvenile freshwater pearl mussel at the moment. In order to return the river back into its natural

Figure 70. pH 4.7 was measured from the water running into River Livojoki after rain. Photo Panu Oulasvirta, Metsähallitus.

state, considerable restoration efforts would be required in the drainage area.

The average coverage of the algae during the field surveys in 29.6.–4.7.2013 was 0.5%. The low coverage of algae is caused by the depth and turbid water – most of the transects were so deep that algae growth was not possible.

River Haukioja

The Haukioja is a small stream that rises in Lake Pieni-Haukijärvi and has its outlet in the main river of the Iijoki (Fig. 71). The area of the catchment covers 50.64 km^2. The upper part of the river is shallow and stony, but in the lower course sand and gravel substrates prevail. The Haukioja has been used for timber floating previously, and for that purpose the river channel has been cleared and straightened in many places.

Preliminary information on freshwater pearl mussels in the Haukioja was obtained from the investigations made by Metsähallitus Natural Heritage Services Ostrabothnia (Metsähallitus, unpublished data).

The 18 random transects were chosen in the previously known mussel distribution area. During the survey it emerged that the distribution extends further upstream than had been thought, and therefore six more transects were established in that area, making the total number of transects 24. The investigations in Haukioja were carried out in June-July 2013.

The estimated population size for the Haukioja freshwater pearl mussel population was 21,300 specimens with a mean density of 1.96 mussels/m^2 (Table 7 p. 124). Juvenile mussels were found regularly. According to the different criteria, the population can be classified as *viable?* (Table 8 p. 125). Mussels smaller than 20 mm in length were not found, however. Most probably they do exist, but without digging the sediment the smallest mussels often stay invisible. The size distribution of the mussels is presented in Fig. 72. There was not any significant difference in the

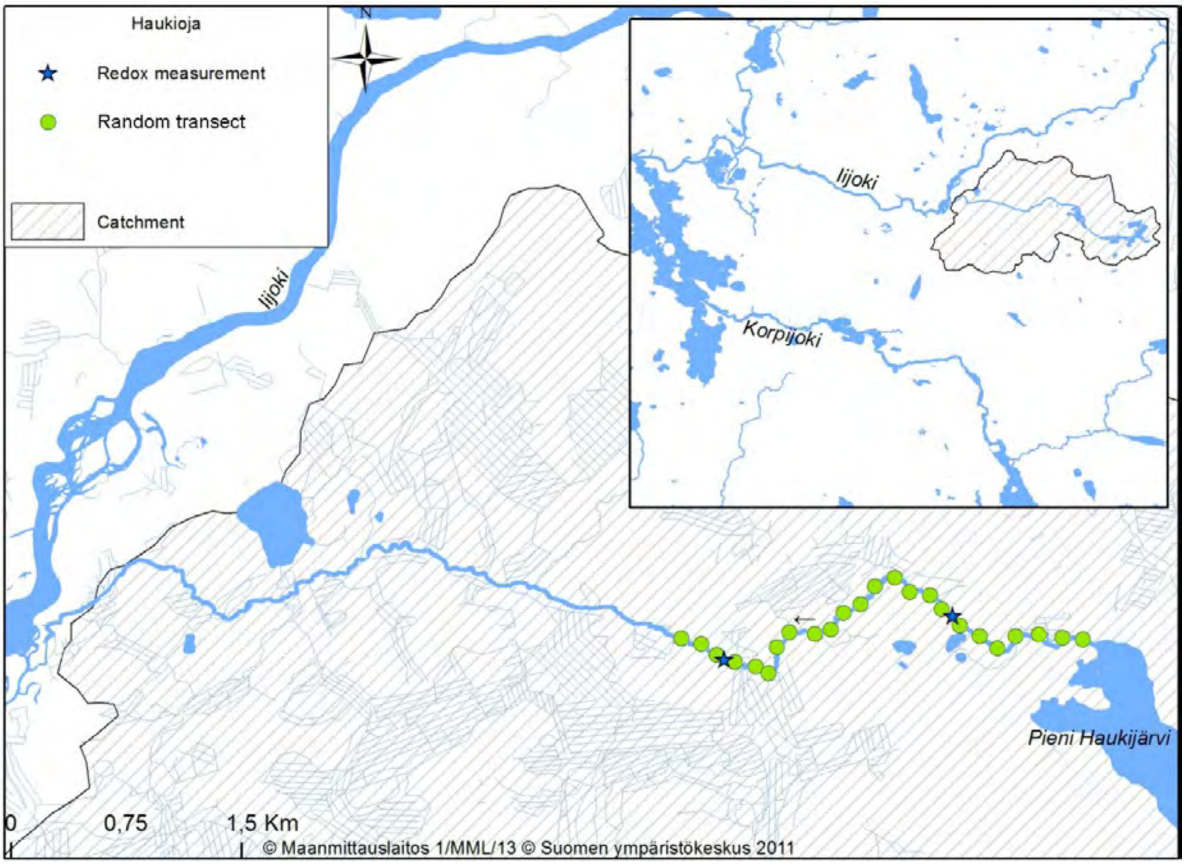


Figure 71. Random transects and redox measuring sites in River Haukioja. The map shows the dense network of ditches in the catchment. Most of the ditches were opened in the 1960s to 1970s, i.e. at the same time that there was a drop in freshwater pearl mussel recruitment (see Figure 72). © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

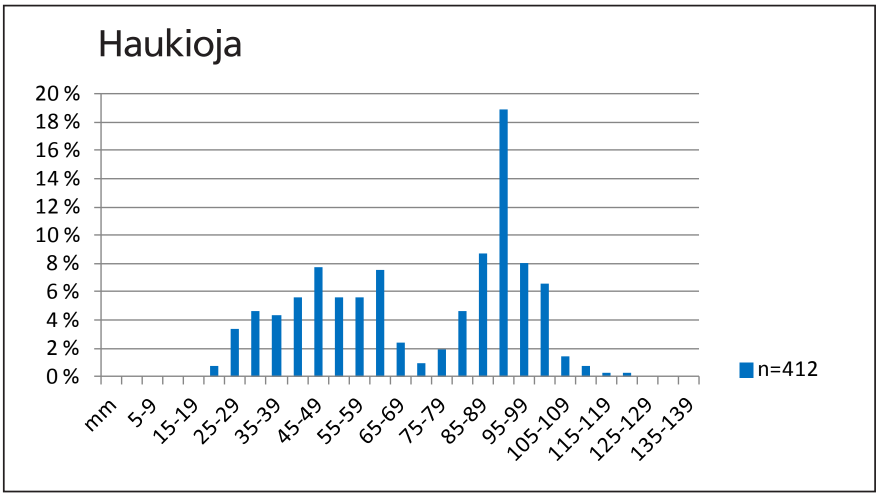


Figure 72. Size distribution of the mussels in the samples taken from the Haukioja. Since no specific recruitment site could be distinguished, therefore the samples from random transects and from the "optimal site" were combined.

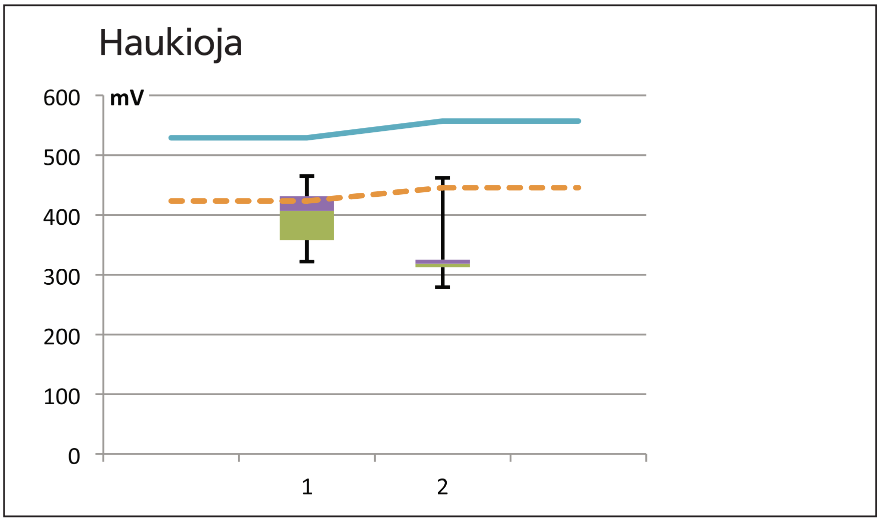


Figure 73. Redox readings from Haukioja. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Site 1 is situated in the upper course and Site 2 in the lower course of the river. Young mussels were found from both sites, but they were more common at Site 1.

size distribution between the samples taken from transects or the "optimal" recruitment area, and therefore the data of these two was combined. Notable in the size distribution is the small proportion of middle size 65–80 mm mussels, indicating problems in recruitment ca. 30–50 years ago. The low recruitment period coincides with intensive ditching operations in the catchment area (see Fig. 71). The conservation status of the population is *high* (Table 9 p. 126).

Redox potential was measured from two sites in the Haukioja (Fig. 71). Better recordings were obtained from the upper course at a site where juvenile mussels were common. At the downstream site, the redox values were worse and also the loss from the free flowing water value to the sediment value was quite big (Fig. 73). Although the redox values would indicate a poor environment for the juveniles in the lower course, those were still present there.

No recent water quality data was available from River Haukioja. The water plants in the Haukioja were in stony areas water moss and in sandy areas vascular plants. Filamentous algae were not detected during the field surveys at the end of June – beginning of July 2013.

River Norssipuro

The Norssipuro is a tiny stream in the Iijoki catchment. It rises in Lake Norssilampi and runs to River Lukkarinoja, which flows further down to Lake Korpinen (Fig. 74). The stream is only 1–2 metres wide and 0.1–0.3 metre deep. The maximum depths, around one metre, are often found in the hollows under the river bank in slowly flowing stretches. The drainage area covers 23.24 km^2 (Ekholm 1993). The freshwater pearl mussel population in the Norssipuro was found during this project in 2012 (see Annex E).

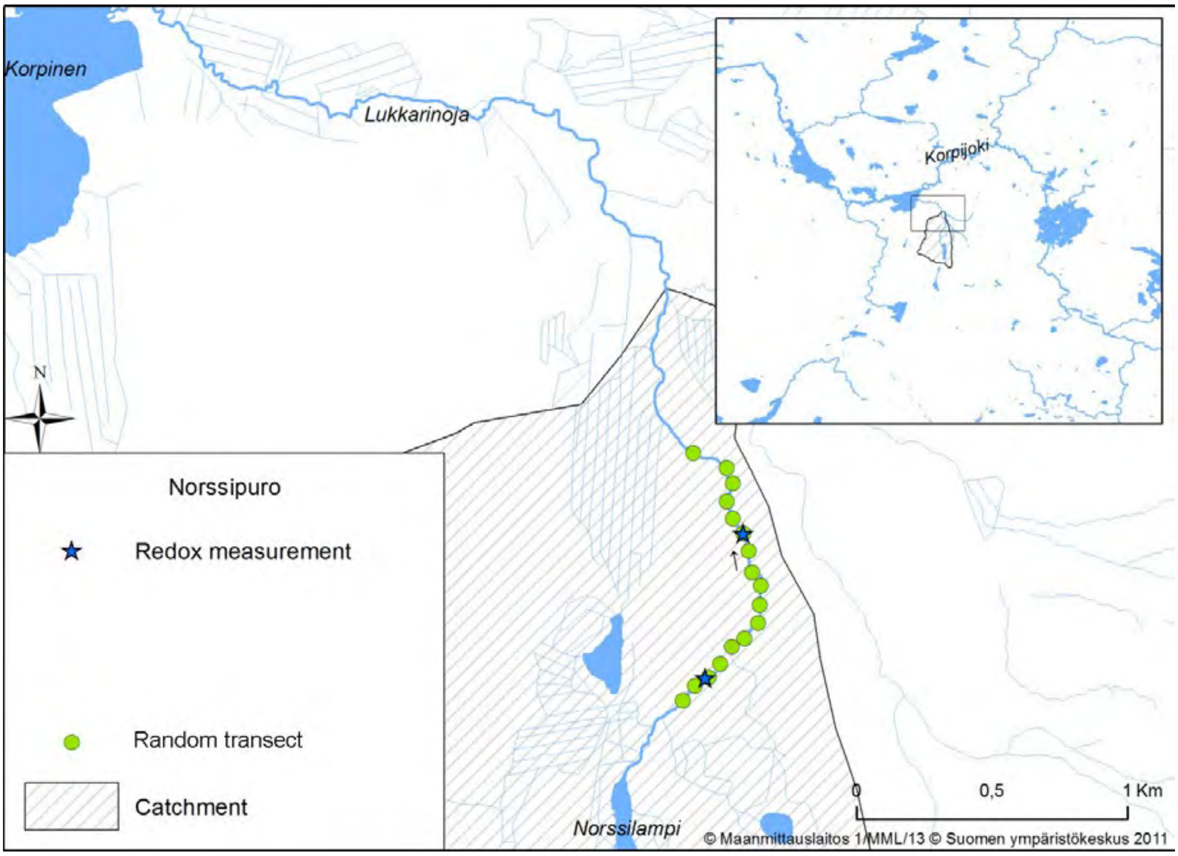


Figure 74. Study sites in River Norssipuro. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

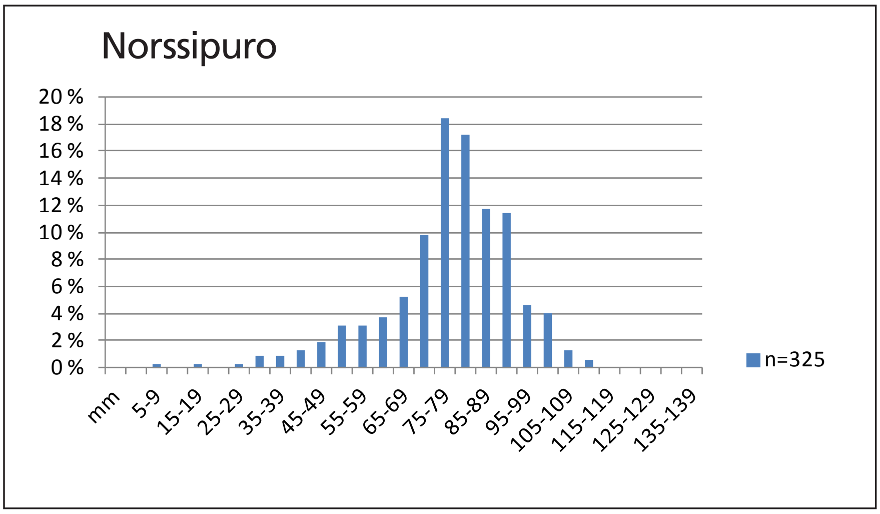


Figure 75. Size distribution of the mussels in the samples taken from the Norssipuro. No specific recruitment site could be distinguished, and therefore the samples from random transects and from the "optimal site" were combined.

The 18 random transects were investigated during June–July 2013. The estimated population size was 20,181 mussels with the highest mean density in our study, 12.26 mussels/m^2 (Table 7 p. 124). Young mussels were detected regularly, but not in very high percentages (Table 8 p. 125, Fig. 75). The smallest observed specimen was 9 mm. A special feature in the Norssipuro was that mussels were found also on the vertical walls of the hollows under the river bank (Fig. 76). Although juvenile mussels were found, the status class of the population still falls into the class *non-viable* (Table 8 p. 125). The conservation status of the population is *high* (Table 9 p. 126).

The redox potential was measured at two sites. Apart from 5 cm, also the 10 cm inside sediment value was recorded. This was done because at

Figure 76. Mussels on the vertical walls of the hollows under the river bank of River Norssipuro. Photo Panu Oulasvirta, Metsähallitus.

one site the redox potential 10 cm down in the sediment was higher than at 5 cm indicating the ground water influence (Fig. 77). In general, the loss in the redox potential from the free water to the interstitial sediment was bigger than was considered favourable for juveniles. Norssipuro is mostly a quite slow flowing stream with soft sediments prevailing on the bottom, which may explain the result.

The average coverage of filamentous algae during the field surveys in 28.6.–1.7.2013 was 3.75%. The low percentage of the algae is at least partly explained by the rareness of stony substrate in River Norssipuro.

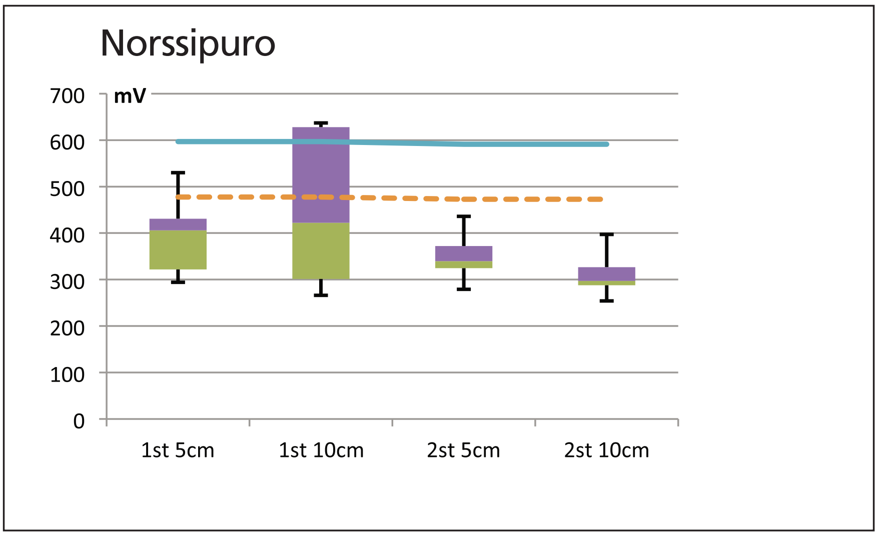


Figure 77. Redox potential in Norssipuro. Measurements from the free flowing water and from the interstitial water 5 cm and 10 cm deep in the sediment. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Site 1 is downstream from site 2. The higher values at Site 1 in 10 cm measurements are probably caused by the ground water effect.

The Koutajoki catchment

The Koutajoki river catchment has its upper parts in Finland and lower parts in Russia, where River Koutajoki runs into the White Sea. The catchment area on the Finnish side is 4,915 km^2 (Ekholm 1993). The main river in Finland is called River Oulankajoki, which has two main tributaries, the Kitkajoki and Kuusinkijoki rivers (Fig. 78). River Oulankajoki runs partly inside the Oulanka National Park. Concerning the freshwater pearl mussel, the Koutajoki catchment is mostly uninvestigated and presumably there are still unknown populations to be found. The known freshwater pearl mussel populations in the Koutajoki catchment are in Rivers Juumajoki and its nameless tributary, in River Porontimajoki and River Oulankajoki. Records from River Oulankajoki are old though, from the 1970s (Valovirta & Huttunen 1997). River Juumajoki was chosen as a target river for this study.

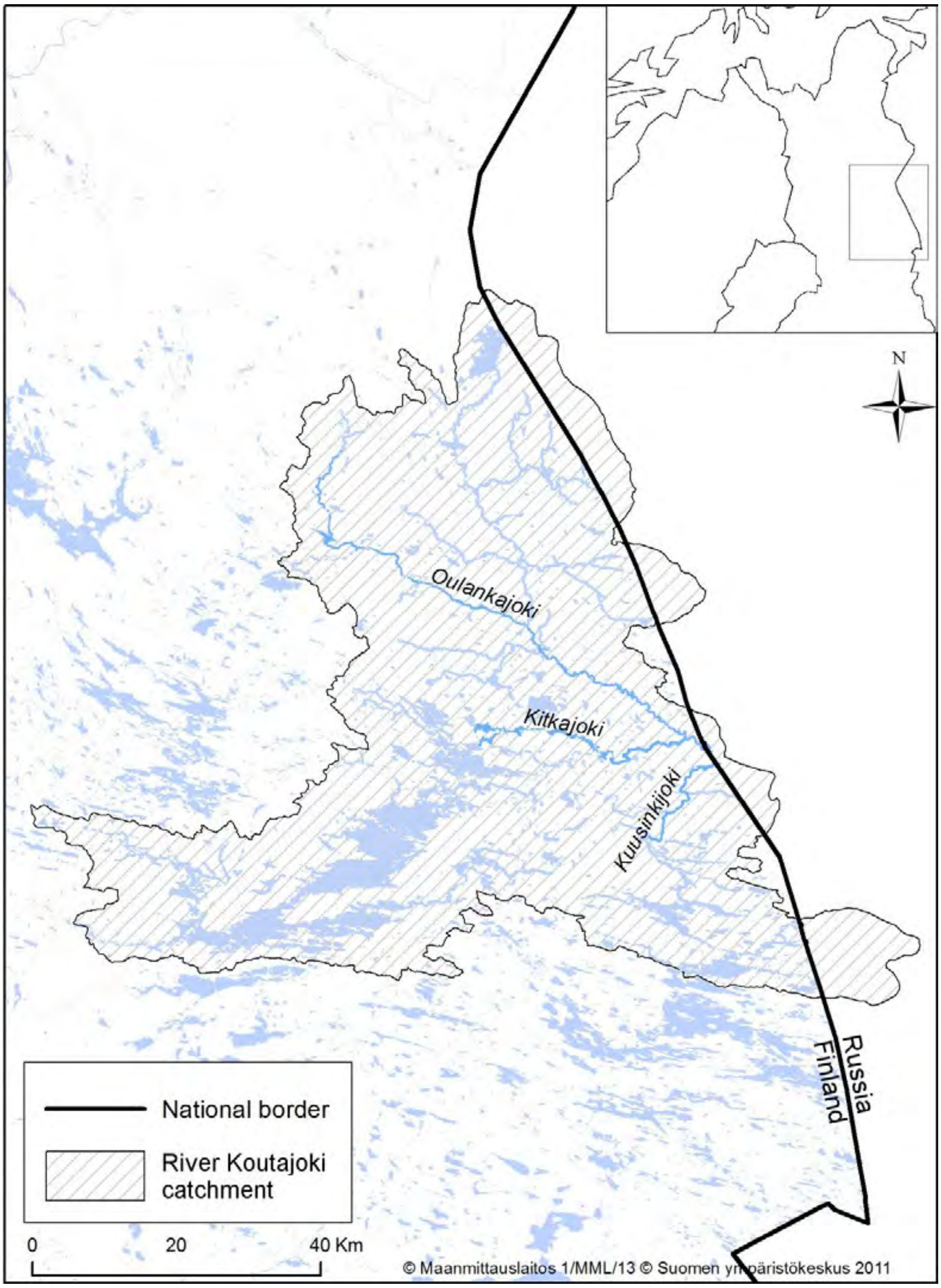


Figure 78. Koutajoki catchment area and the main tributaries Oulankajoki, Kitkajoki and Kuusinkijoki in Finnish side. Koutajoki has its outlet in the White Sea, Russia. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

River Juumajoki

River Juumajoki rises in Lake Juumajärvi, which is a border lake between Russia and Finland (Fig. 79). Around nine kilometres downstream it joins to river Kuusinkijoki, which further down runs back to Russian territory. The lower parts of the Juumajoki belong to a Natura 2000 area (FI1101631). Despite the Natura 2000 status, in the surroundings there are quite heavy forestry activities going on, which certainly affects the river.

Freshwater pearl mussel was found from the Juumajoki during this project in 2011. Besides the Juumajoki river itself, freshwater pearl mussel was also found from one of its tributaries. The population assessment surveys in the Juumajoki were carried out in July 2013. We had no exact information on the distribution range of the mussels in the river beforehand, and therefore the 21 random transects were at first chosen for the entire river stretch from Lake Juumajärvi down to river Kuusinkijoki. During the survey, it was discovered that the there are no freshwater pearl mussels in the lower course. Therefore, nine extra transects were established in the mussel distribution area.

The estimated population size in Juumajoki was 25,800 mussels with a mean density of 1.57 mussels/m^2 (Table 7 p. 124). Juvenile mussels were found from the upper part of the distribution, but in general the recruitment rate was low (Table 8 p. 125). The size distribution of the measured mussels is shown in Figure 80. The status class of the population in general is *non-viable* (Table 8a), but juvenile mussels were met in places in the upper course. The conservation status of the population is *high* (Table 9 p. 126).

Redox potential was measured at two sites. The redox values were much higher in the upper course (recruitment area) than in the lower course, where no recruitment took place (Fig. 81). The difference may be explained by the forestry activities in the vicinity of the river, which have probably affected to the lower part of the river. An example of the harmful forestry activities is shown in Fig. 82, where forestry machines have been driven across the mussel bed. Also the fish farm in the lower course may have affected the water quality.

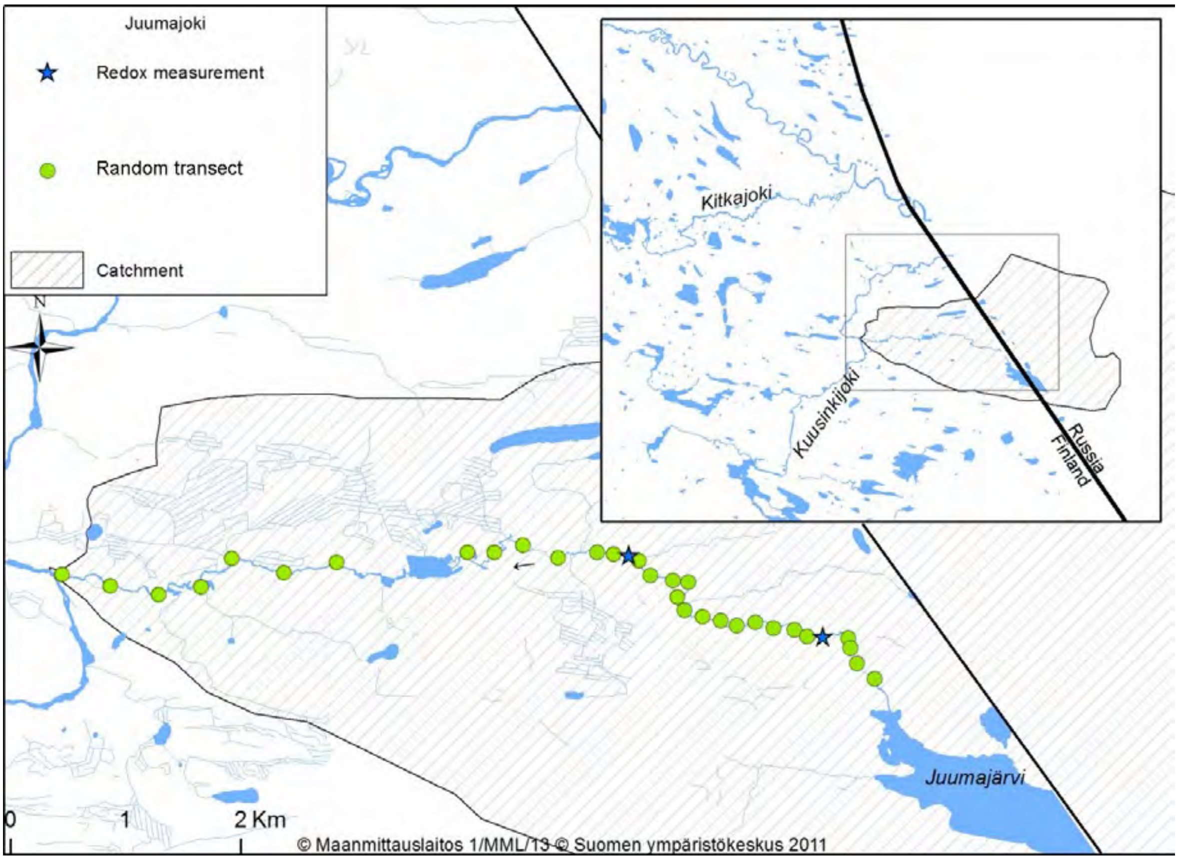


Figure 79. Study sites in River Juumajoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

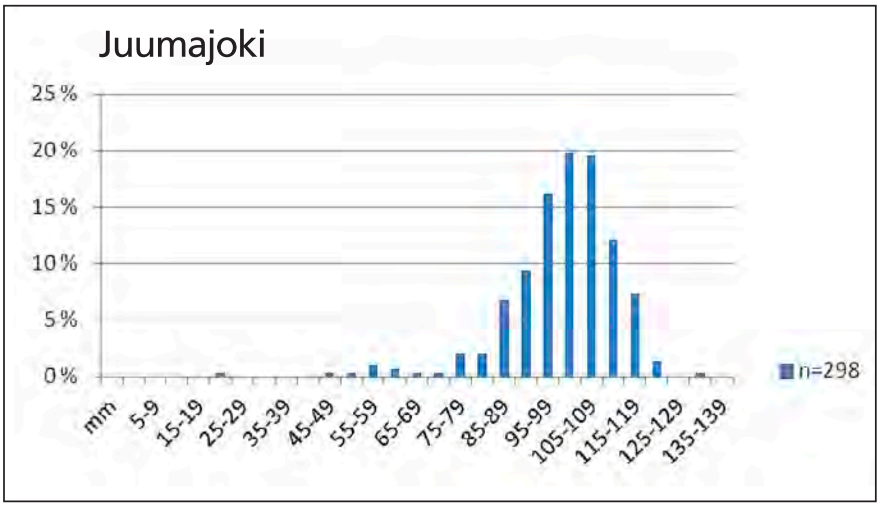


Figure 80. Size distribution of the mussels in the River Juumajoki. Samples from random transects and from the "optimal site" were combined.

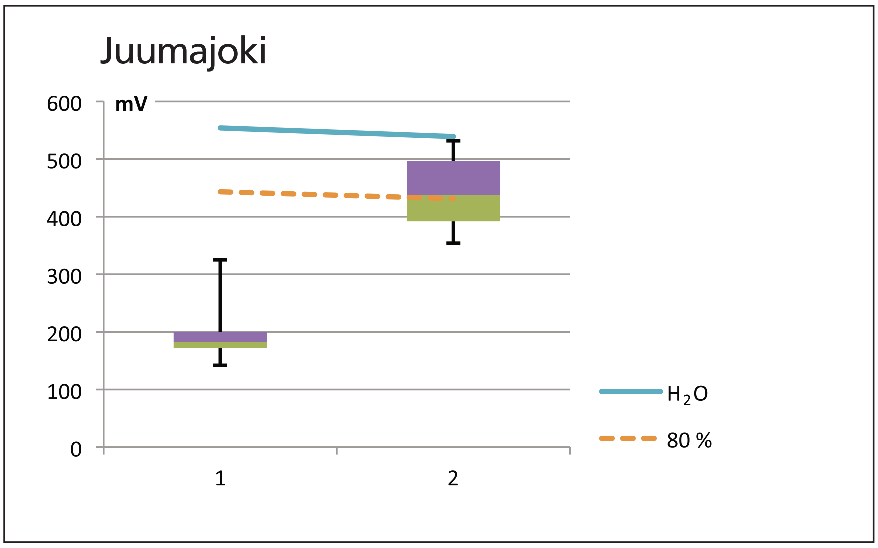


Figure 81. Redox potential in River Juumajoki. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Site number 1 is in the lower course on non-recruitment site area and site number 2 in the upper course, where also juvenile mussels were detected.

Figure 82. Forestry machines have been driven across the river and over the freshwater pearl mussel in River Juumajoki. Photo Panu Oulasvirta, Metsähallitus.

The average coverage of the filamentous algae was 41% during the surveys in mid-July 2013. The algae as well as the vascular plants were more abundant in the lower course down from the mussel distribution range.

River Kemijoki catchment

The Kemijoki river basin, with its 51,127 km^2 is the second largest river catchment in Finland and covers a major part of Lapland. Some of the upper tributaries have their origin in Norway or Russia (Fig. 83). The freshwater pearl mussel is currently known from 31 rivers in the Kemijoki drainage (Metsähallitus, unpublished data). Six of them were chosen as target rivers in our study. Those are the Toramojoki and Onnasjoki rivers in the Ounasjoki sub-catchment, the Kopsusjoki in the Luiro sub-catchment, the Saukko-oja in the Tenniöjoki river sub-catchment and

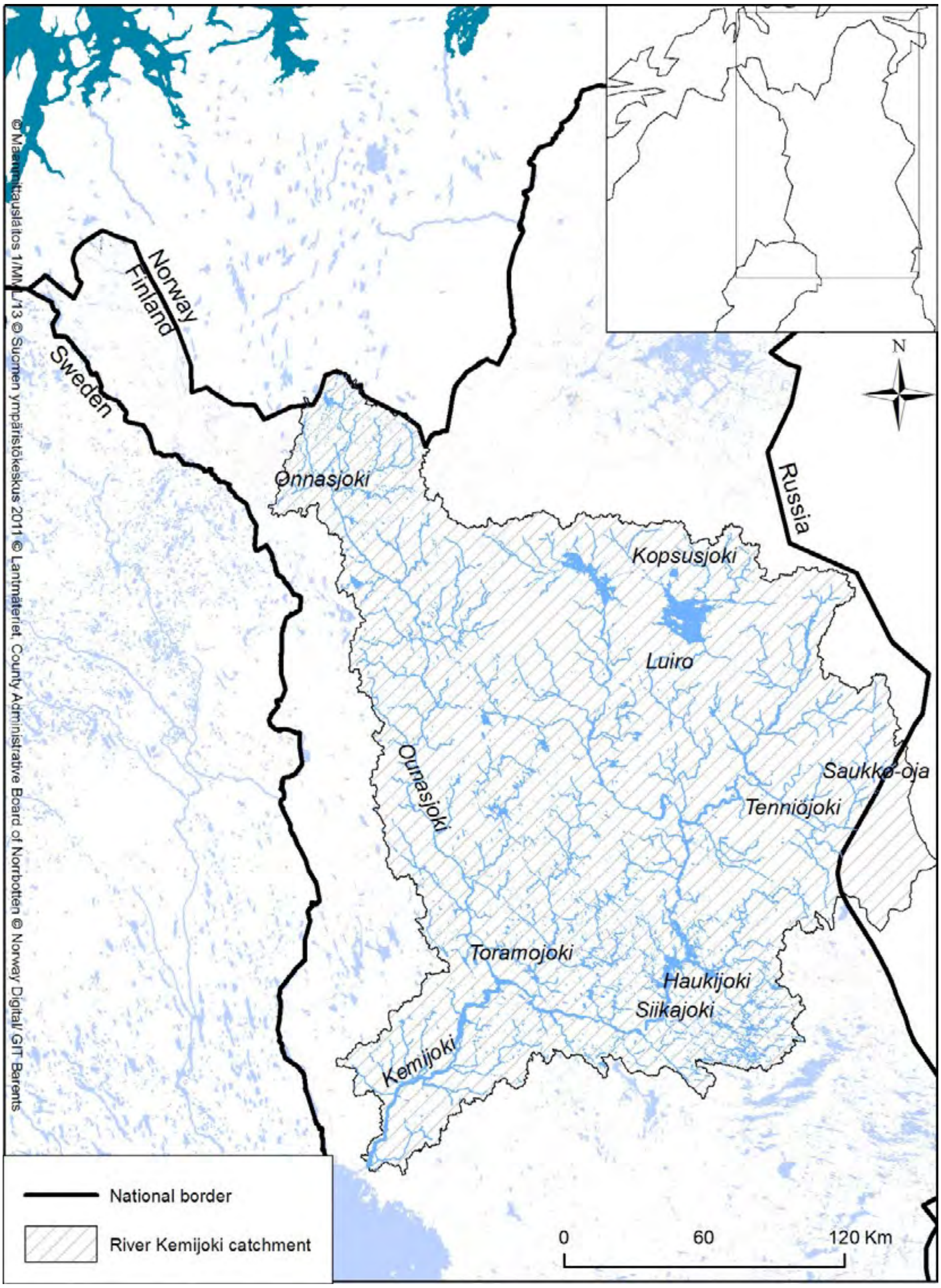


Figure 83. Kemijoki catchment area. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15, © Läntmäriet, County Administrative Board of Norrbotten, © Norway Digital / GIT Barents.

the Siikajoki and Haukijoki rivers in the main catchment of the Kemijoki.

River Onnasjoki

Onnasjoki is a small tributary of River Ounasjoki (Fig. 84). It rises in Lake Onnasjärvi, which together with the River Onnasjoki belongs to the Pallas-Ounastunturi National Park, which is also protected as a Natura 2000 area (FI1300101). The freshwater pearl mussel was detected from River Onnasjoki in the early 1980s by the WWF Finland mussel team (Valovirta & Huttunen 1997).

In Onnasjoki, the 18 random transects were chosen over a one kilometre-long stretch, which was known to contain freshwater pearl mussel (Fig. 84). Transects were investigated in 2012. Redox measurements were done at two sites in 2013.

The estimated population size was ca. 15,000 mussels. Considering the short stretch and

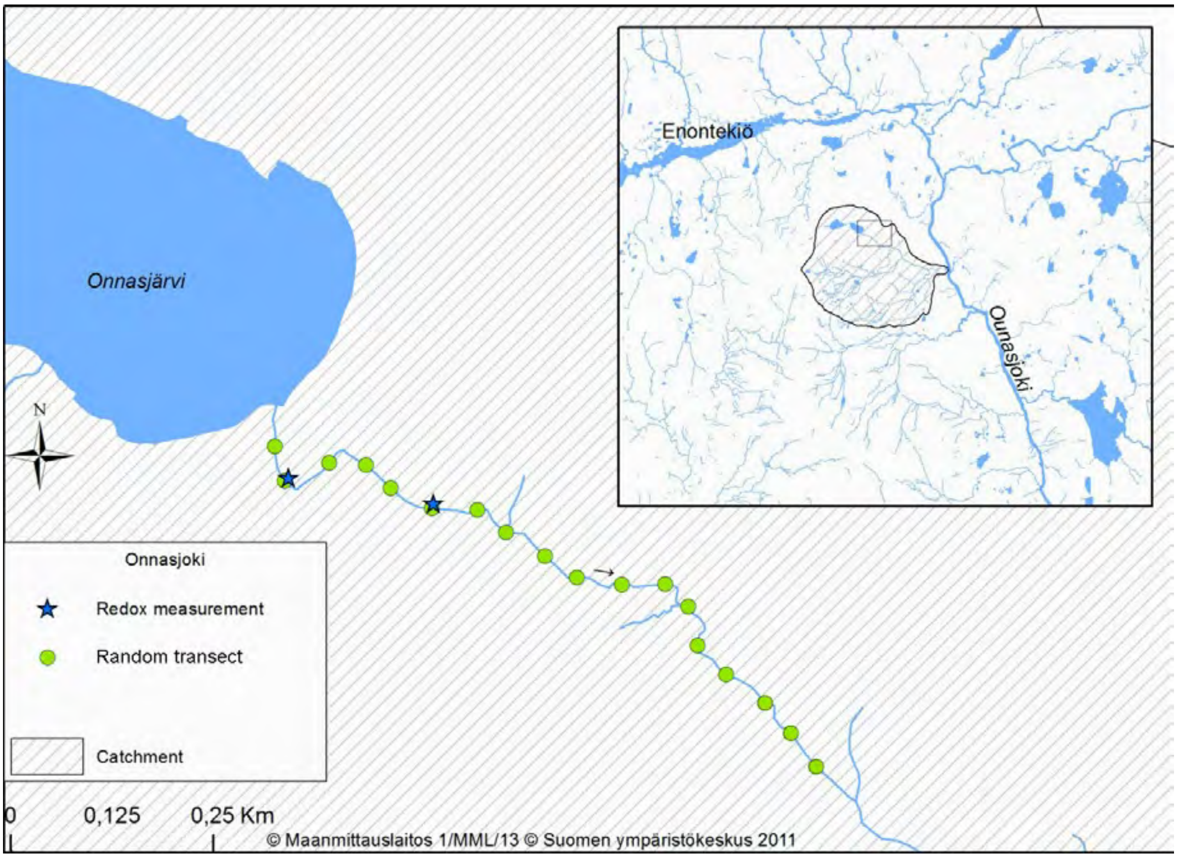


Figure 84. Study sites in River Onnasjoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

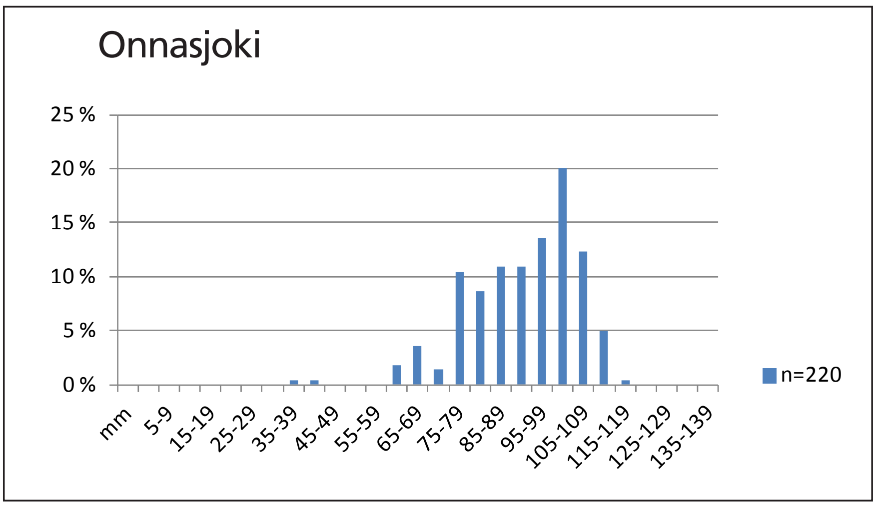


Figure 85. Size distribution of the mussels in the samples taken from the Onnasjoki. Since no specific recruitment site could be distinguished, the samples from random transects and from an "optimal site" were combined.

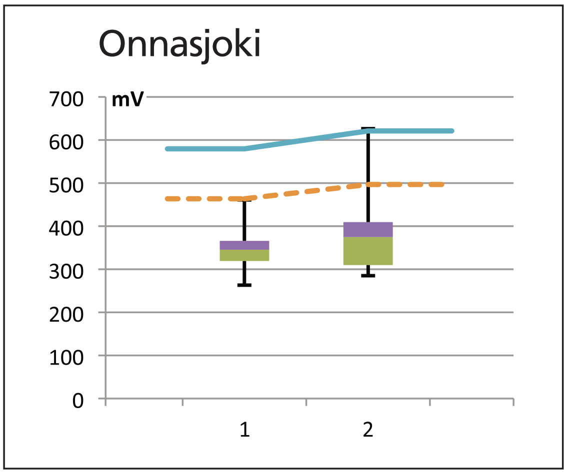


Figure 86. Redox potential measurements in river Onnasjoki at two sites. Site 1 is upstream from site 2. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values.

narrowness of the stream the population is quite big. The mean density of the mussels, 9.6 specimens/m^2, was the second highest in our study.

Although the Onnasjoki mussel population was expected to be recruiting well, the juvenile mussels were sparse (Fig. 85). This is a little surprising, since the river is quite well protected against anthropogenic pressures. Also the redox potential measurements showed quite a large difference between the free water value and interstitial water (Fig. 86). The status class of the population is *non-viable* (Table 8 p. 125). The average coverage of the filamentous algae in the Onnasjoki was 1.39% in July 2012. The conservation status of the population is *high* (Table 9 p. 126).

No data was available about brown trout densities in River Onnasjoki. Also, the water quality data was old, from the 1980s. At that time the water quality was good.

River Toramojoki

River Toramojoki is another freshwater pearl mussel river in the vast Ounasjoki sub-basin in the Kemijoki catchment. The river rises in Lake Iso-Toramojärvi and runs towards west to River Kätkäjoki, which flows further down to River Ounasjoki (Fig. 87). The freshwater pearl mussel population in the Toramojoki was found and investigated by WWF Finland in 1981 (Valovirta & Huttunen 1997). Because of its freshwater pearl mussel population, the Toramo-

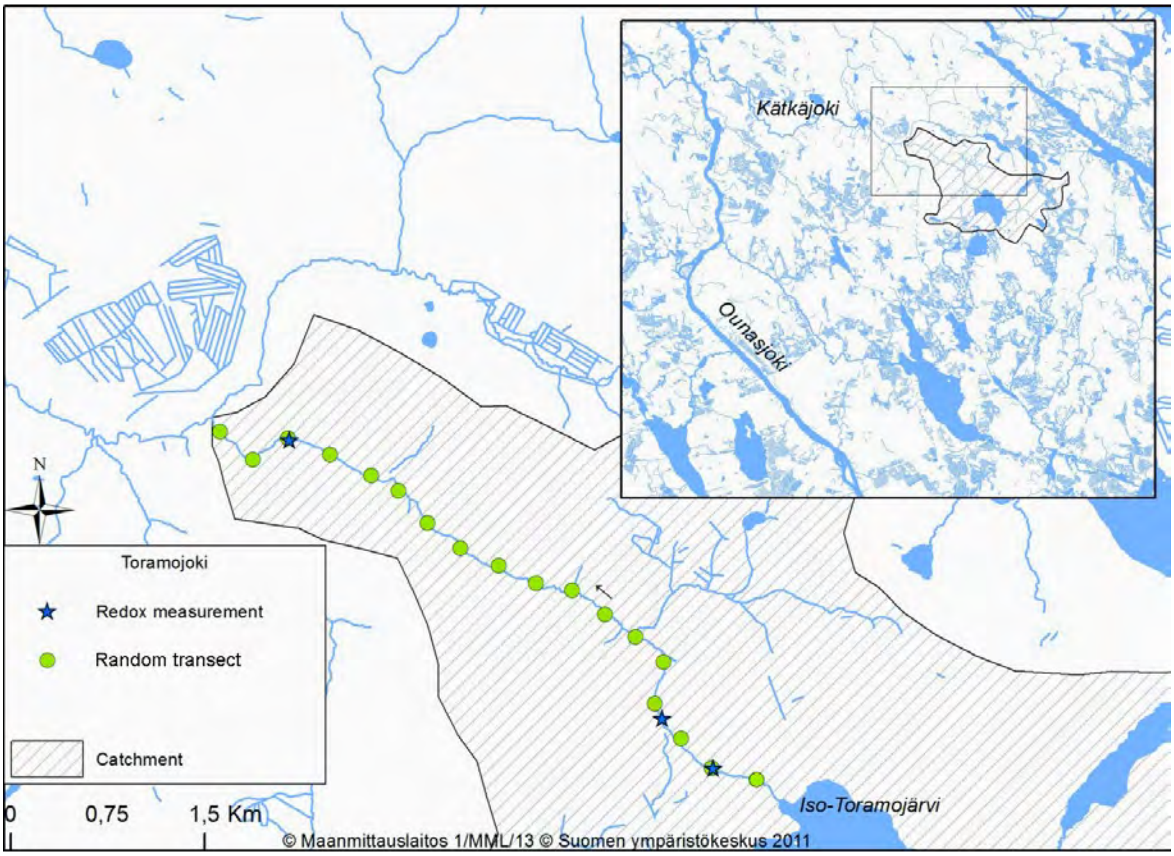


Figure 87. Study sites in River Toramojoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

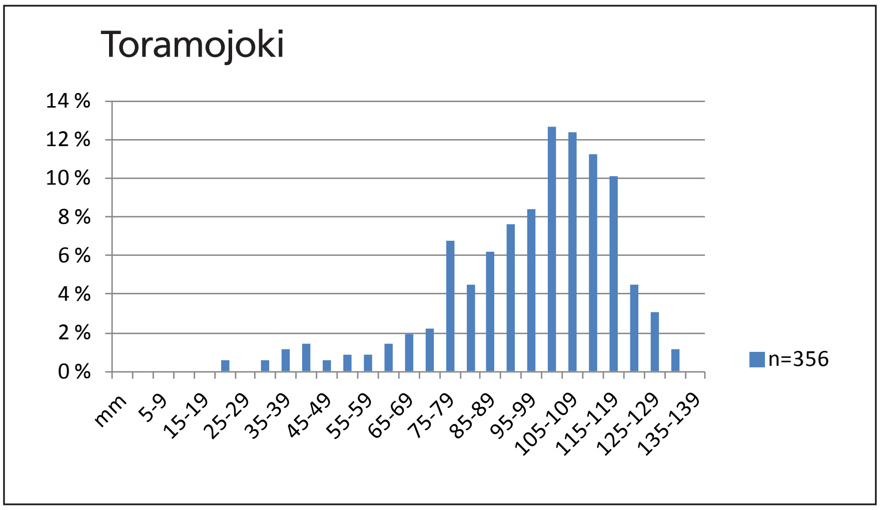


Figure 88. Size distribution of the mussels in the samples taken from River Toramojoki. No specific recruitment site could be distinguished; the samples from random transects and from the "optimal site" were combined.

joki has been protected as a Natura 2000 area (FI1301319).

In River Toramojoki, the 18 random transects were chosen on a stretch of the river downstream ca. 5 km from Lake Iso-Toramojärvi, i.e. in the area where we had previous information on the distribution. The estimated population size was 108,300 mussels, which is one of the biggest observed in our project (Table 7 p. 124). The mean density of the mussels was 6.48 mussels/m^2.

Juvenile mussels were found all over the distribution range, although young mussels were more common in the upper course. However, the proportion of juveniles was nowhere very big (Fig. 88), and therefore the viability class of the population still became *non-viable* (Table 8 p. 125). On the other hand, the smallest observed mussel was 19 mm, which also tells about recent recruitment. Considering all the factors, the conservation value of the Toramojoki freshwater pearl mussel population is *very high* (Table 9 p. 126).

The redox measurements showed a good interstitial sediment environment in the upper courses of the river, which were also the best juvenile habitats. Still, some smaller mussels could also be found from the lower course where the redox readings were much worse (Fig. 89). The average coverage of the filamentous algae during the field surveys in July 2013 was 4.83%.

River Kopsusjoki

The Kopsusjoki is ca. 30 km long river, which rises in Lake Kopsusjärvi and flows into the Lokka reservoir (Fig. 90). Lake Kopsusjärvi and the upper parts of River Kopsusjoki belong to the Urho Kekkonen National Park. The terrain around the river is mostly spruce forests and large boggy areas, especially in the lower parts

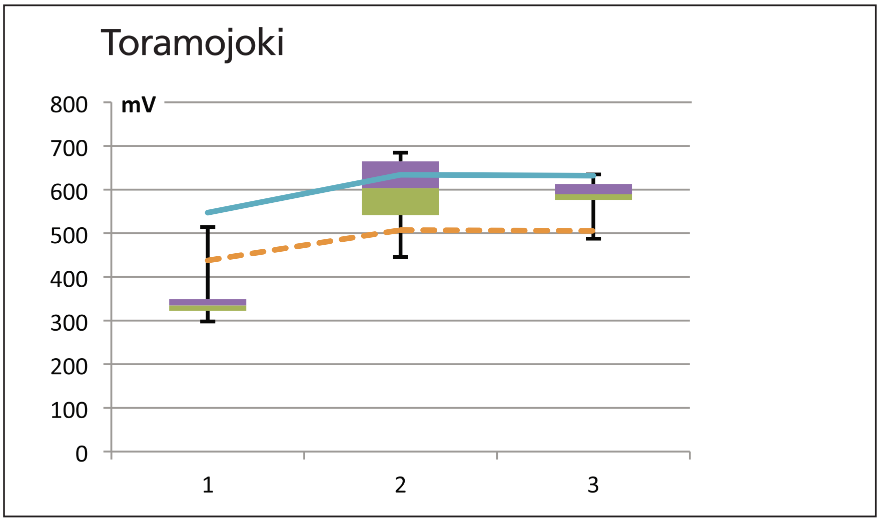


Figure 89. Redox potential in River Toramojoki. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Site 1 is in the lower course with more sediment than the two other upper course sites, which are very oligotrophic and contained young mussels.

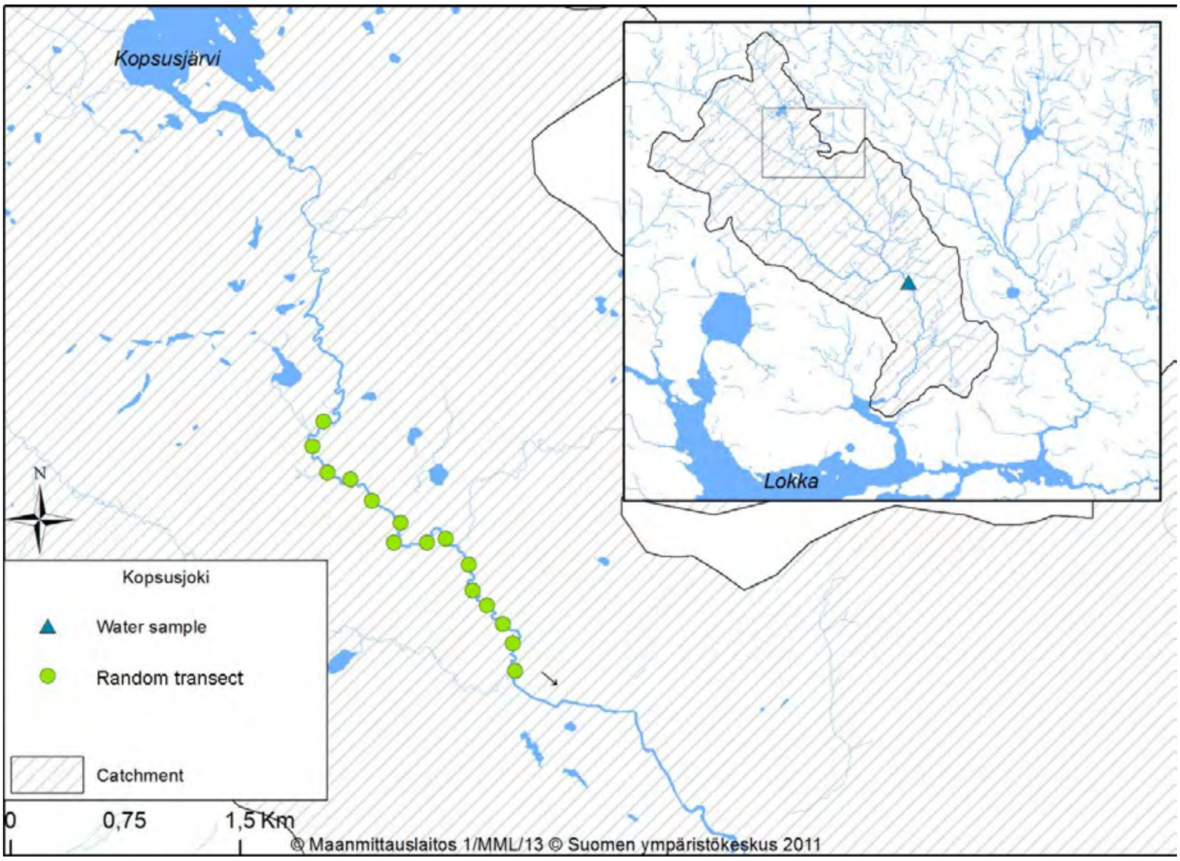


Figure 90. Study sites in River Kopsusjoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

Figure 91. The Kopsusjoki in its upper course. Photo Panu Oulasvirta, Metsähallitus.

the catchment. The area of the catchment is 303 km^2 (Ekholm 1993).

In the upper course the Kopsusjoki is a narrow sharply winding stream (Fig. 91). Gradually downstream the channel gets wider and deeper. Freshwater pearl mussel was previously documented from the upper parts of the Kopsusjoki by Valovirta (1996). The lower parts of the river are still uninvestigated.

In the Kopsusjoki, 15 random transects were chosen in the 3.8 km long, previously known distribution area in the upper part of the river. Investigations were carried out in August 2013. The census of transects showed that, although the Kopsusjoki is a small stream in its upper parts, the freshwater pearl mussel population was remarkable, 30,100 specimens (Table 7 p. 124), and much bigger than estimated earlier by Valovirta (1996). Moreover, it is obvious that the result obtained from the mussel counts is a clear underestimate for two reasons. Firstly, during the study it emerged that the distribution of the mussels extends further upstream than known before. This upper part of the population is not included in the result. Secondly, it is obvious that a major part of the mussels were undetectable in the Kopsusjoki because of the very dense vegetation on the river bottom. In places the thick cover of aquatic vegetation covered 100% of the bottom, but the freshwater pearl mussel was still found in high densities under the plants. Compared to many other freshwater pearl mussel streams, this is untypical. Because of these sources of error, the real population size in the Kopsusjoki was estimated to be at least double (> 60,000 specimens) compared to the results obtained directly from the mussel counts. The middle and lower parts of the Kopsusjoki have not been investigated. Valovirta (1994) estimated, that the whole river might contain up to 100,000 mussels. The aquatic plants in the Kopsusjoki consisted mainly of *Fontinalis antipyretica* in the rapids areas and *Caltha palustris* ssp. *radicans* and *Sparganium* sp. in the slow current areas (Fig. 92). The average coverage of filamentous algae was only 1.7% during the study in August 2013, but the coverage of vascular plants and moss in transects was 80–100%. Redox potential was not measured in the Kopsusjoki due to a malfunction of the meter.

The size distribution of the mussels shows that the Kopsusjoki freshwater pearl mussel population is recruiting relatively well (Fig. 93).

Figure 92. Dense *Caltha palustris* ssp. *radicans* vegetation in River Kopsusjoki. Photo Panu Oulasvirta, Metsähallitus

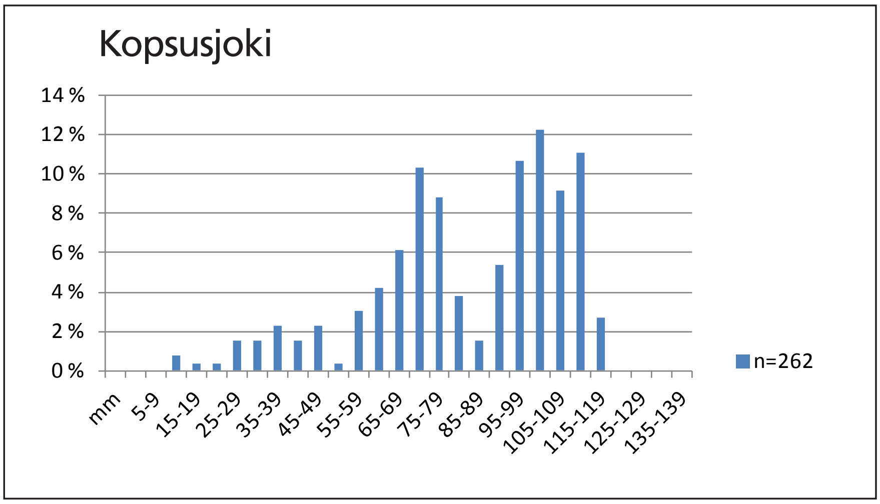


Figure 93. Size distribution of the mussels in the samples taken from River Kopsusjoki. Since no specific recruitment site could be distinguished, the samples from random transects and from an "optimal site" were combined.

Juvenile mussels were found all over the distribution range, and therefore no "optimal juvenile site" could be distinguished. On the other hand, it is probable that the proportion of the juvenile mussels is even higher in the population, because they were especially difficult to find in the dense vegetation. In the size distribution, a cap in the middle size mussels 80–90 mm could be distinguished (Fig. 93). The status class of the population is *viable?* (Table 8 p. 125). The conservation status of the population is *high* (Table 9 p. 126).

A water sample from Kopsusjoki was taken in October 2013. In general, the water quality was good except slightly elevated phosphate value (PO_4P 6 µg/l). The detailed results of the water analyses are given in Annex C.

River Saukko-oja

Saukko-oja (Fig. 94) is situated in eastern Lapland in Salla municipality. It rises in Lake Saukkojärvi and runs approximately 15 km down to a point where it joins River Naruskajoki (Fig. 95). River Naruskajoki runs further down to River Tenniöjoki, which combines with the River Kemijoki main channel. The area of the whole Saukko-oja catchment is 63.89 km^2 out

Figure 94. Field surveys in River Saukko-oja, July 2012. Photo Terho Myyryläinen, Metsähallitus.

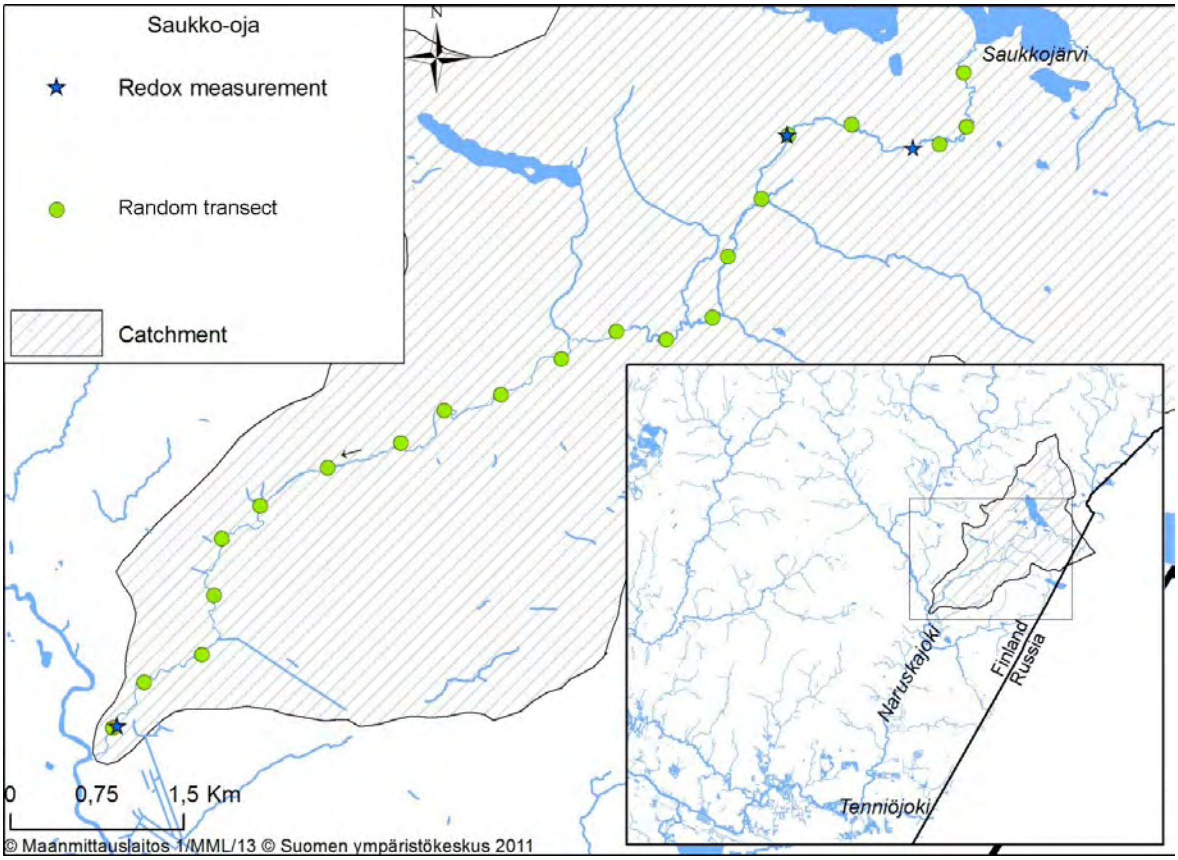


Figure 95. Study sites in River Saukko-oja. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/ MML/15.

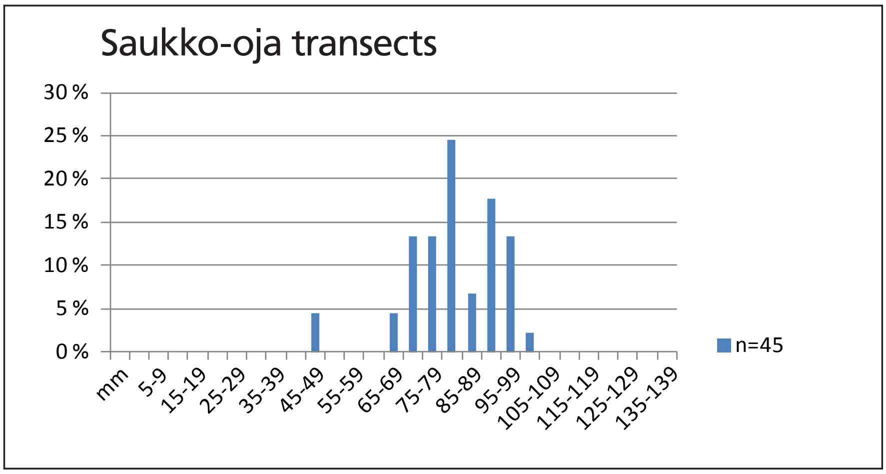
of which the upper part, 1.68 km^2, is on Russian territory (Ekholm 1993).

There was no exact information available on the distribution range of the freshwater pearl mussel in Saukko-oja. Therefore, the 21 random transects were chosen for the entire stretch between Lake Saukkojärvi and River Naruska-joki. Freshwater pearl mussel was detected only from eight transects. Both the uppermost and the lowest transects were empty, but there were also empty transects in between. The estimated size of the population was 27,200 mussels and the mean population density 0.47 mussels/m^2 (Table 7 p. 124).

Recruitment in River Saukko-oja takes place mainly in the upper part of the population. From the random transects no mussels under 20 mm were found. Also, the percentage of mussels smaller than 50 mm was only 4%. Thus, the viability class for the entire population would be *non-viable* (Table 8a p. 125). However, at the best recruitment sites in the upper course 1% of the mussels were smaller than 20 mm and 11% smaller than 50 mm. For this area, the viability class would be *viable?* (Table 8b p. 125). The smallest observed mussel was 14 mm. The size distribution of the mussel samples are shown in Fig. 96. The conservation status of the population is *high* (Table 9 p. 126).

Redox potential was measured from three sites (Fig. 95). The two sites in the upstream recruitment area showed higher redox values than the site downstream below the mussel area (Fig. 97). The main pressure affecting to the river in Saukko-oja is the clear cuttings in the catchment.

Water quality in River Saukko-oja has been monitored occasionally between 1986 and 2002. The results from those years show high nutrient levels – nitrogen peaks up to 710 µg/l (median 210 µg/l) and total phosphorus 13 µg/l (median). Also, ammonium levels have been high, on average 27 µg/l and maximum 120 µg/l. Moreover, average turbidity has been high, > 1 FNU, and average oxygen saturation low, 72 S%. (see Annex C). No water quality data is available after 2002. Because of the massive on-going forest clear cuts on surrounding land, it is evitable that the water quality has not improved, especially in the lower course. An



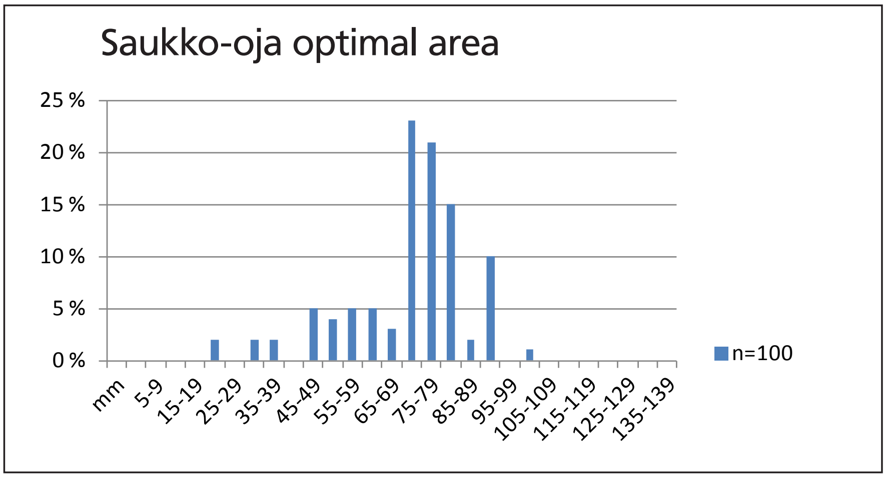


Figure 96. Size distribution of the mussels in the samples taken from random transects (above) and from the optimal recruitment site in the upper course (below).

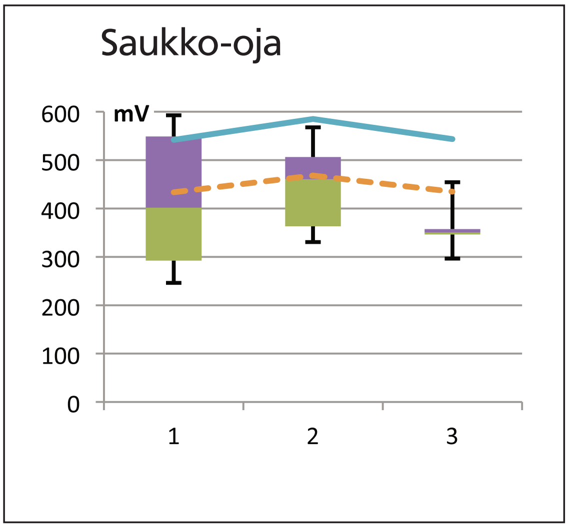


Figure 97. Redox potential in River Saukko-oja. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Sites 1 and 2 are located into the upper part of the river and especially Site 1 contained several juvenile mussels. Site 3 is situated in the lower course, below the mussel area.

unusual greyish-greenish opacity of water was observed in the upper course of the river during our fieldtrip in July 2013. Still no filamentous algae were observed in River Saukko-oja during our surveys in 2012 and 2013. On the other hand, water moss and vascular plants were abundant in places.

River Haukijoki

The Haukijoki is a small stream situated in Kemijärvi municipality. It rises in Lake Iso-Haukijärvi lake and runs through Pikku-Haukijärvi and Kämppälampi lakes down to Lake Ala-Askanjärvi, which further flows to River Iso-Askanjoki and Lake Kemijärvi (Fig. 98).

There was no exact knowledge of the freshwater pearl mussel distribution in the Haukijoki beforehand. Therefore, the 18 random transects were chosen for the entire 5.2 km-long stretch between Kämppälampi and Ala-Askanjärvi lakes. Freshwater pearl mussel was found only from the uppermost transects, however (Fig. 98). The esti-

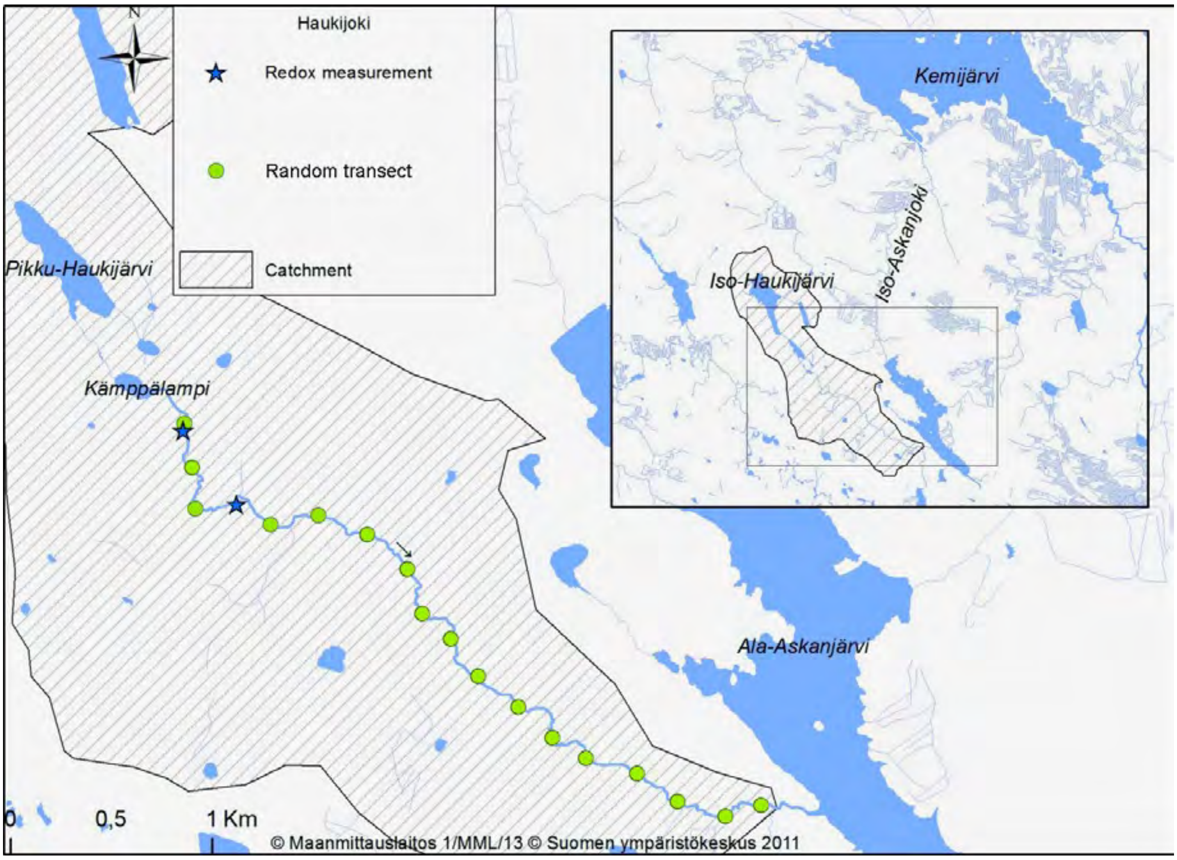


Figure 98. Study sites in River Haukijoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/ MML/15.

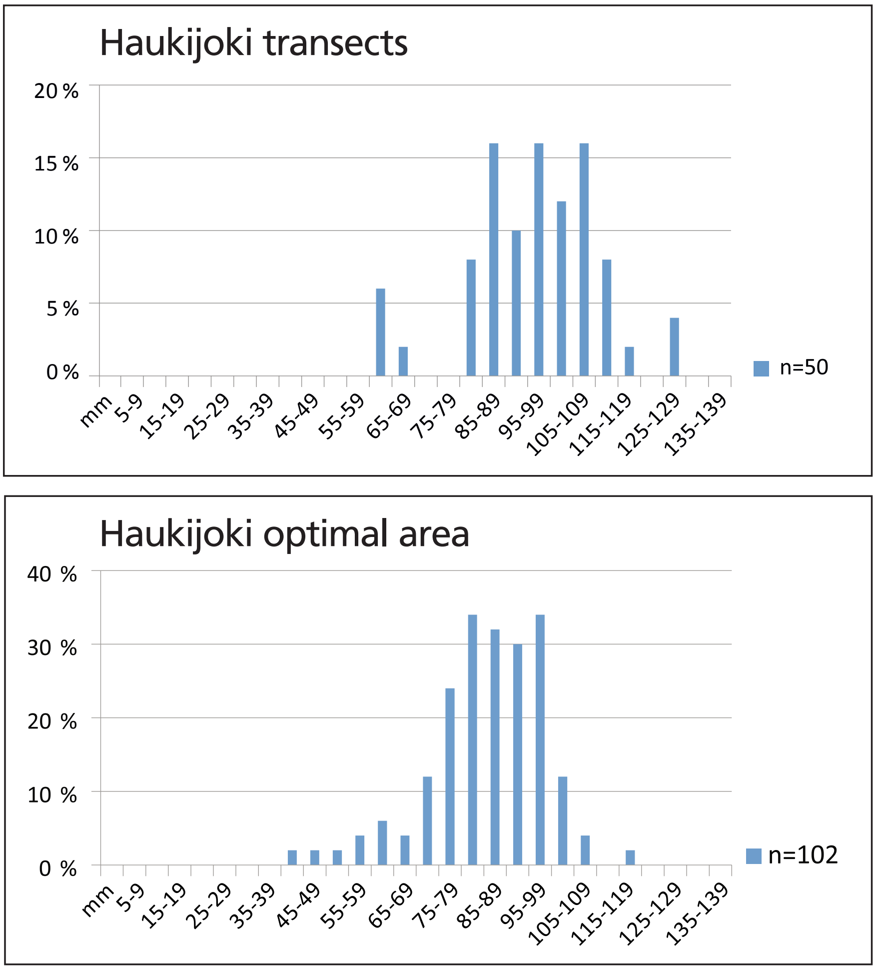


Figure 99. Size distribution of the mussels in the samples taken from random transects (above) and from the optimal recruitment site (below).

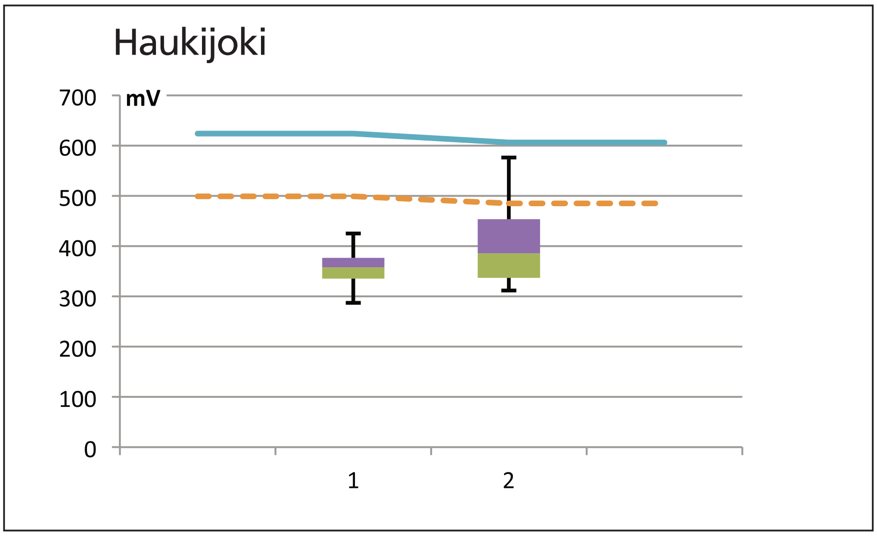


Figure 100. Redox potential measurements in River Haukijoki. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Site 1 is upstream from site 2, where also juvenile mussels were detected in spite of the abundant sediment and thick layer of vegetation. Measuring Site 2 was also observed to be influenced by the ground water.

mated population size was 12,200 mussels and the mean density 4.2 mussels/m^2 (Table 7 p. 124).

Few juvenile mussels were found, but in general those were rare, indicating a low recruitment rate. In the random transects all the measured mussels were over 50 mm in length (Table 8a p. 125). In the optimal juvenile area the proportion of < 50 mm mussels was 2% (Table 8b p. 125). The smallest observed mussel was 24 mm. The status class of the population is *non-viable* (Table 8). The conservation status of the population is *high* (Table 9 p. 126).

Redox potential was measured at two sites (Fig. 98). The temperature-corrected mean values were above 300 mV, but the difference in the redox potential between the free-flowing water and interstitial water was greater than 20% (Fig. 100).

The River Haukijoki drainage area is heavily utilized by forestry. In the vicinity of the river clear cuttings, ditching and ploughing have taken place in many areas. Some of the ditches lead directly into the river. These actions may explain the absence of freshwater pearl mussel in the lower course. Also, the mussel area in the upper course is affected, which may explain the low recruitment rate. The average coverage of filamentous algae was 4.3% during the surveys in 31.7.–1.8.2012.

River Siikajoki

Siikajoki is situated in Kemijärvi municipality and forms its own sub-catchment which, together with the main tributary, River Juujoki, covers 143.61 km^2 (Ekholm 1993). The outlet of the Siikajoki is in Lake Juujärvi, which is a part of the main channel of River Kemijoki. Several lakes cut the water flow in River Siikajoki (Fig. 101). Altogether, lakes cover 6.9% of the Siikajoki catchment (Ekholm 1993).

Freshwater pearl mussel was found from Siikajoki and its tributary Juujoki rivers in 1998, in connection with river restoration planning (Oikarinen & Sihvonen 2004). According to the investigation conducted in 1999–2000, the Juujoki-Siikajoki freshwater pearl mussel population was estimated to be ca. 100,000 specimens (Oikarinen & Sihvonen 2004). The population in the Siikajoki alone, was estimated to be 65,300 mussels (Lapin ympäristökeskus 2003). Because of their freshwater pearl mussel population, Rivers Siika-Juujoki are protected as a Natura 2000 site (FI1300407).

River Siikajoki and many of its tributaries had been cleared for timber floating in 1920–1930. In order to return the rivers to their natural state, the river restoration works in the Siika-Juujoki areas were started in 2004. In the Siikajoki, the restoration works were carried out in 12 areas which altogether covered a 2,750 metre-long river stretch and 8,300 m^2 (Oikarinen & Sihvonen 2004). The main restoration activities were returning the stones and boulders back to the rapids and removing some of the wooden structures built for the timber floating. As a consequence, the width of the river channel was expanded and the area of the channel increased by ca. 2 ha (Oikarinen & Sihvonen 2004).

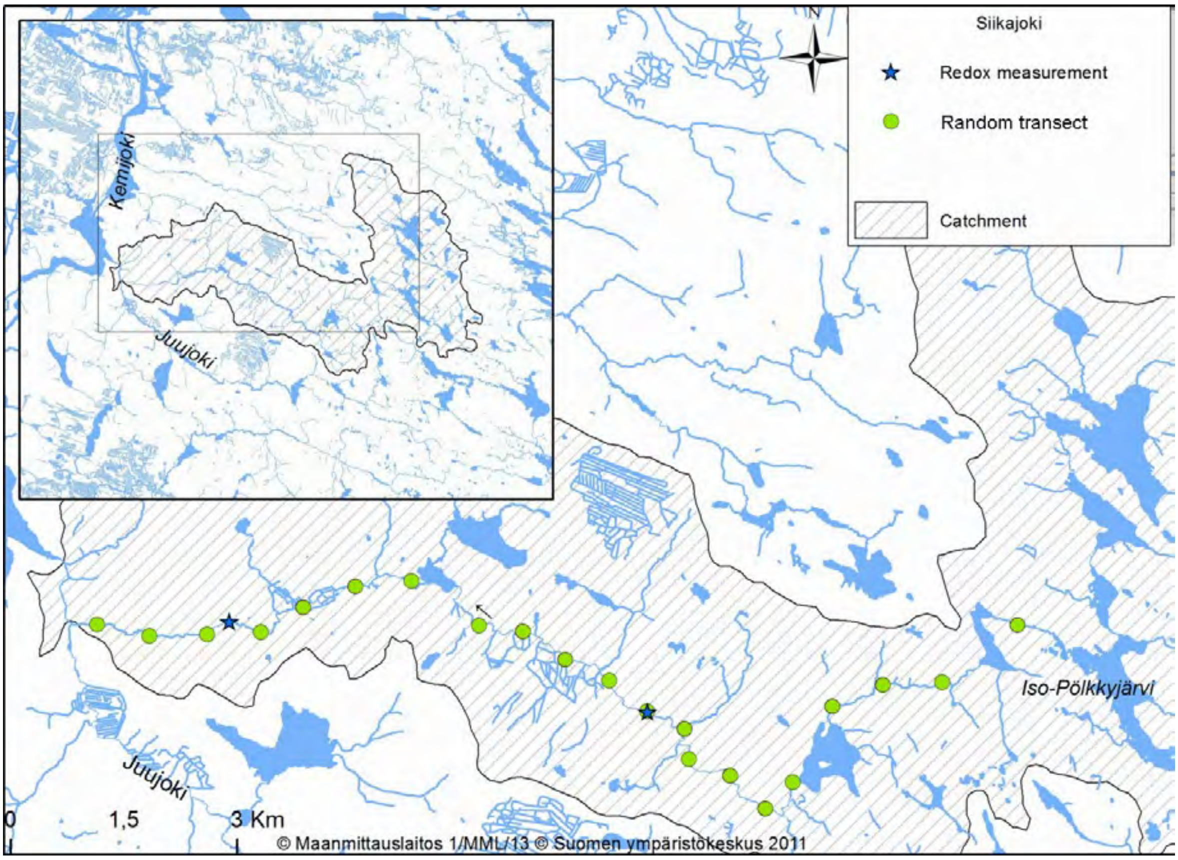


Figure 101. Study sites in River Siikajoki. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

Figure 102. Forestry activities close to River Siikajoki. Photo Marko Kangas, Lapland ELY-Centre.

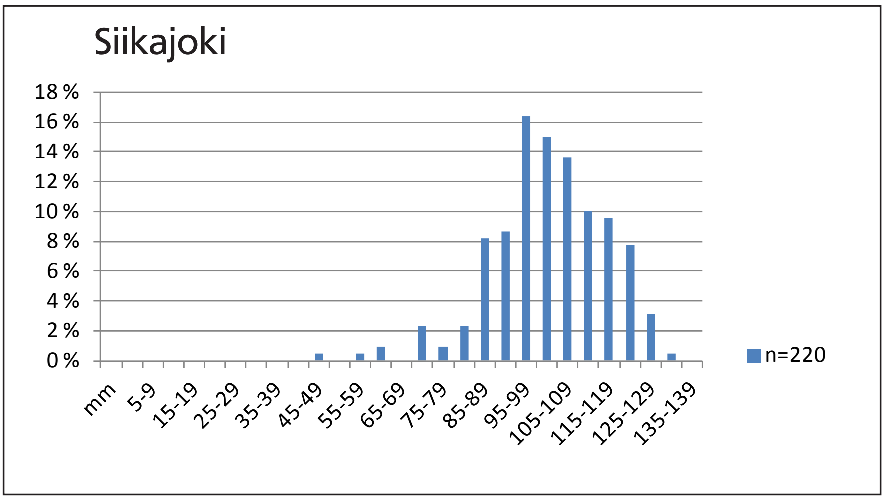


Figure 103. Size distribution of the mussels in the samples taken from River Siikajoki. Since no specific recruitment site could be distinguished, the samples from random transects and from the "optimal site" were combined.

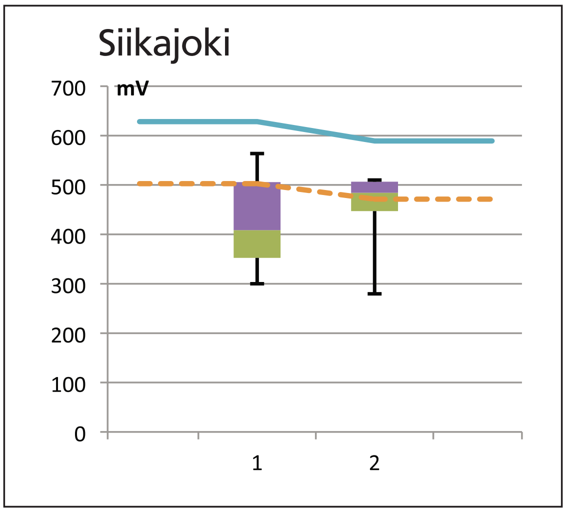


Figure 104. Redox potential measurements in River Siikajoki. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Site 1 is in the middle course and Site 2 in the lower course of the river.

Besides altering the river channel itself, the on-going anthropogenic pressure in River Siikajoki is caused by the intense forestry activities on the surrounding areas (Fig. 102).

In this study, the 21 random transects were chosen on a stretch of the river between Lake Iso-Pölkkyjärvi and a point where River Juujoki joins with River Siikajoki (Fig. 101). Excluding lakes, the total length of this river stretch is 26.7 km. Freshwater pearl mussel was found from 11 out of 21 transects. The estimated population size was 42,800 specimens and the mean density of the mussels 0.39 mussels/m^2 (Table 7 p. 124).

According to the size distribution of the mussels, the population is aged, only 1% of the mussels were less than 50 mm in length and the smallest observed mussel was 35 mm. No specific recruitment area could be found; the size distribution in transects and "optimal" area were quite similar and were thus combined in the data (Fig. 103). The status class of the population is *non-viable* (Table 8 p. 125). The conservation status of the population is *high* (Table 9 p. 126).

The redox potential was recorded at two sites, one in the lower course and the other one in the middle part of the river (Fig. 101). The temperature-corrected mean redox value in the interstitial water was at both sites above 400 mV, but only in the lower site, where moving sand was also observed, was the loss of the value inside the critical 20% (Fig. 104).

The average coverage of the filamentous algae in river Siikajoki was 13.8% during the field work at the end of July 2013.

The results obtained from River Siikajoki do not show that the river restoration works would have been beneficial to the freshwater pearl mussel population. On the contrary, the estimated population size was now smaller than before restoration. Moreover, the proportion of small mussels was low, indicating that the recruitment rate has not improved. Quite many mussels that had recently died were observed downstream from one of the restoration sites. Our field team also reported on a changed flow regime in the river resulting from eroding river banks and moving sand on the bottom (Fig. 105).

Figure 105. Eroding river banks has resulted in trees falling into the river. Photo Juho Vuolteenaho, Metsähallitus.

So, it seems that the environment is in places still unstable and unfavourable for freshwater pearl mussel. However, we cannot say for sure that the decrease in the population size is real or caused by the methodological differences in the investigations now and in 1999–2000. Worth noting are also the investigations carried out by the Lapland ELY-Centre later in the summer, in which also mussels smaller than 20 mm were detected, indicating recent recruitment (Kangas 2013). After all, even if the restoration works had been beneficial to the freshwater pearl mussel in the long term, the results will be seen only after a couple of years, when the juvenile mussels have grown to a size in which they are easier to detect. For that, a regular monitoring of the mussel population in River Siikajoki is a prerequisite. At the same time, the on-going forestry activities in the vicinity of River Siikajoki are a serious threat to the freshwater pearl mussel population and may also overturn the potential positive effects of the river restoration.

The average brown trout density in the electrofishing conducted in River Siikajoki in 2011 was 8.27 fish /100 m^2 (< 8 cm size class) and 2.61 fish/100 m^2 (8–15 cm size class) (Lapin vesitutkimus 2011). According to Kangas (2013), the densities of 0+ year class brown trout have increased after the river restoration.

We did not conduct our own water quality analyses in River Siikajoki. Finnish national monitoring in the river has been occasional. The latest, 2011, samples showed quite good water quality (see Annex C). Earlier, between 1998 and 2003, elevated ammonium levels had been detected in some of the samples, max 180 µg N/l in 2003. Elevated values were measured also during the winter of 2000–2001. The level of total phosphorus has been low, median values being 5µg/l. Alkalinity in the river is generally quite low, with a median value of 0.07 mmol/l, and occasionally < 0.05 mmol/l. The lowest alkalinity values do not, however, coincide with the minimum 6.1 pH values. The turbidity of the water is generally low (median 0.5 FNU), but can be high in flooding conditions (maximum 4 FNU). The iron content (median 210 µg/l with peaks up to 620 µg/l) is not very high, but may be harmful in low pH situations. Very high iron concentrations (max. 3,300 µg/l) and turbidity values (15 FNU) were measured in August 2004 during the restoration work (Oikarinen & Sihvonen 2004). No data was available after the restoration in 2005–2010.

The Teno catchment

River Teno (Norwegian Tana) is a border river between Norway and Finland. The main tributaries of the Teno are River Inarijoki on the border between Norway and Finland, River Karasjok in Norway and River Utsjoki in Finland (Fig. 106). The drainage area of River Tenojoki is 14,891 km^2, out of which 5,123 km^2 is in Finland and 9,768 km^2 in Norway (Ekholm 1993). The outlet of the Tenojoki is in Norway at the bottom of the Tanafjorden. Teno is an important salmon river with an annual catch of 60,000–250,000 kg salmon (Erkinaro *et al.* 2012).

Freshwater pearl mussel is known only from a couple of streams in the Teno catchment. On the other hand, River Teno and its tributaries are mostly uninvestigated, which makes it likely that there are still populations to be discovered. For example, freshwater pearl mussel was detected from River Utsjoki, a tributary of the Teno in Finland, in 2009 (Juho Vuolteenaho,

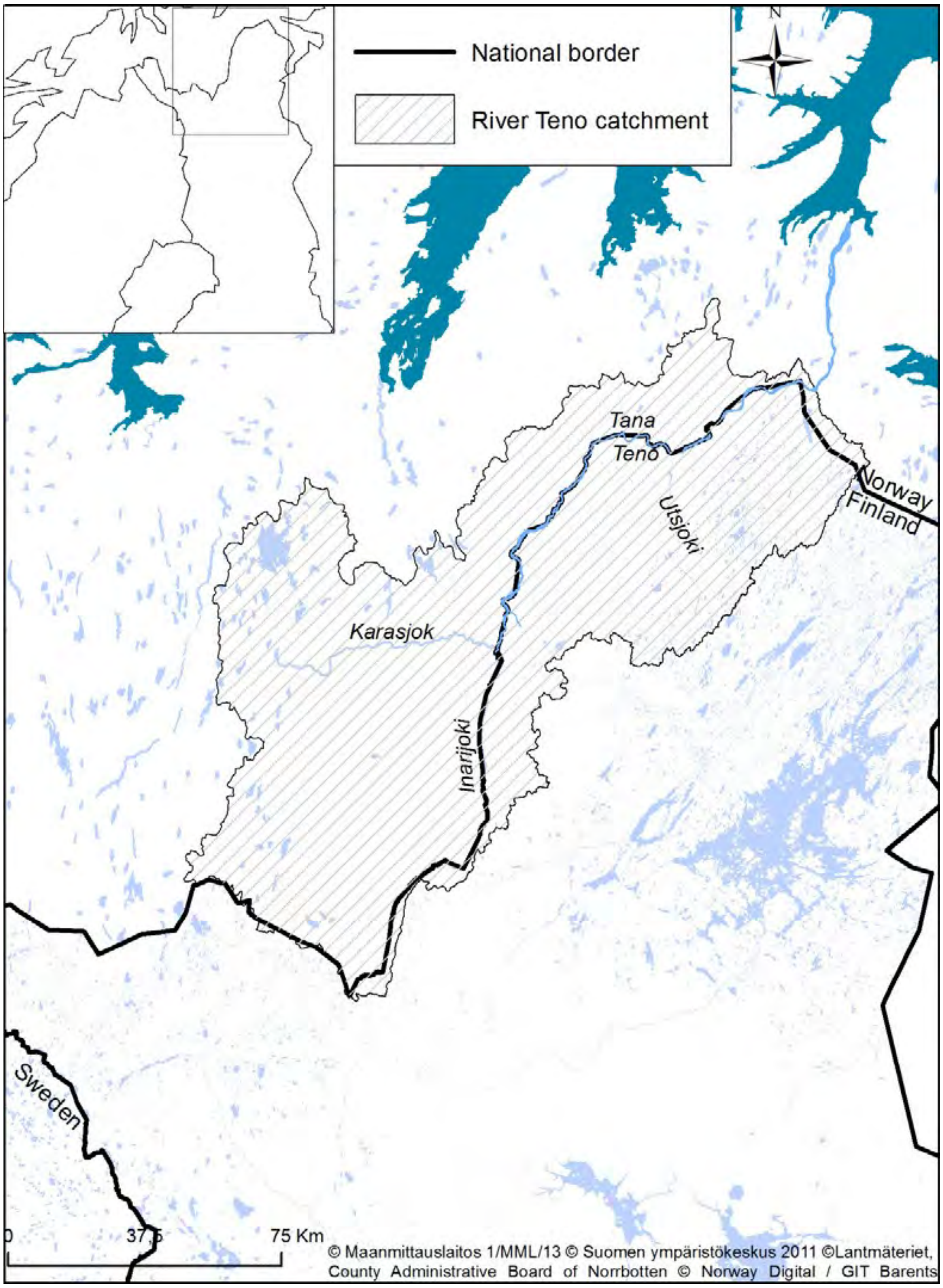


Figure 106. Teno (In Norwegian Tana) catchment area. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15, © Läntmäriet, County Administrative Board of Norrbotten, © Norway Digital / GIT Barents.

pers. comm). In this study, the presence of freshwater pearl mussel in River Utsjoki was verified at a couple of sites, but most of the river and its tributaries are still unmapped. Considering the large size of River Utsjoki, it is possible that there may be a remarkable population of freshwater pearl mussels. An even bigger river is River Karasjok in Norway, where freshwater pearl mussel was detected during our study in 2012 (Paul Aspholm, pers. comm). The other rivers where freshwater pearl mussel has been found are the Lovttajohka-Kalddasjohka. From River Inarijoki there is historical evidence of pearl fishing, but according to the latest surveys in 1998 the population has probably gone extinct (Oulasvirta *et al.* 2006). River Lovttajohjka was chosen as a target river for the population status assessment in our study.

River Lovttajohka

River Lovttajohka is the main tributary of River Kalddasjohka, which is located in northernmost Finland in Utsjoki municipality. The Kalddasjohka runs down to Lake Pulmankijärvi, whose outlet river, the Pulmankijoki, is a tributary of River Teno (Fig. 107). The Lovttajohka rises in the small Lovttajavri lake ca. 233 metres above sea level west from Lake Pulmankijärvi, 13 metres above sea level. The terrain in the drainage area is very barren, with the Arctic downy birch (*Betula pubescens* subsp. *tortuosa*) prevailing, while pine and spruce forests are totally missing (Fig. 108). Rivers Lovttajohka-Kalddasjohka are inside the Kaldoaivi wilderness Natura 2000 area (FI1302002).

Freshwater pearl mussel was found from Lovttjohka and Kalddasjohka in 2004 during the investigations in the Interreg Kolarctic project (Oulasvirta *et al.* 2006). It is the northernmost freshwater pearl mussel population in Finland, and also one of the northernmost populations globally.

In this study, the 18 random transects were chosen in River Lovttajohka in the area between Lake Lovttajavri and the junction of River Kalddasjohka (Fig. 107). Transects were investigated in August 2012. Freshwater pearl mussel was found from nine transects. The estimated population size was 3,800 specimens (Table 7 p. 124).

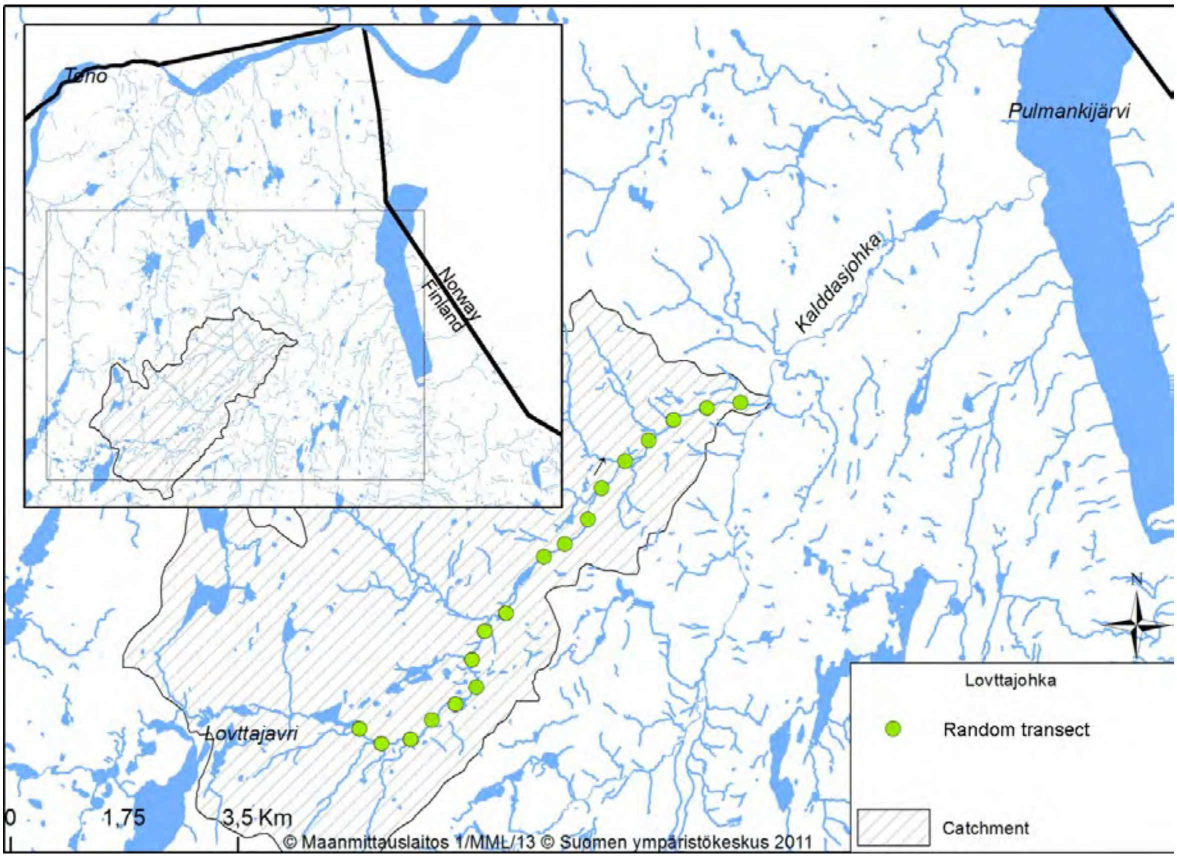


Figure 107. Study sites in River Lovttajohka. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

Figure 108. Birch trees along River Lovttajohka. Pine and spruce forest do not survive here. Birch forests were killed on vast areas by the Autumnal moth (*Epirrita autumnata*) mass occurrence in 1990s. Photo Aune Veersalu, Metsähallitus.

The mean density was only 0.07 mussels/m^2 due to the many zero transects.

According to the mussel samples, the recruitment rate seems to be low in the Lovttajohka. The smallest observed mussel was 46 mm. From the random samples no < 50 mm mussels were found. No specific juvenile area could be identified. The size distribution of the measured mussels are shown in Fig. 109. The status class of the population is *non-viable* (Table 8 p. 125). The conservation status of the population is *high* (Table 9 p. 126).

It is somewhat surprising that juveniles were not found any more, because the Lovttajohka is situated in the untouched wilderness area with no specific human impact present other than reindeer herding. On the other hand, the potential impact of the airborne pollution from the Nikel industrial combine in Russia is unknown. Unclear is also the impact of the large birch devastation caused by the Autumnal moth (*Epirrita autumnata*) in 1990s (Fig. 108).

The coverage of filamentous algae was 34.76% during the study in August 2012. Redox potential was not measured, and no water quality data is available from River Lovttajohka.

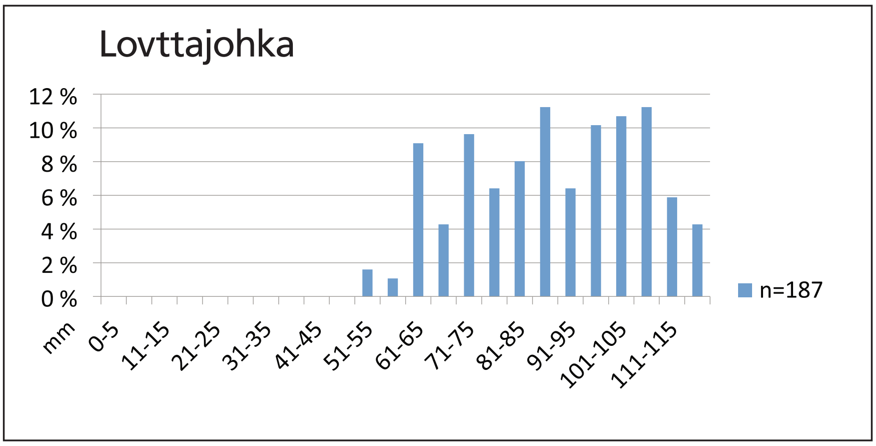


Figure 109. Size distribution of the mussels in River Lovttajohka. No specific recruitment site could be identified and therefore the samples from random transects and from an "optimal site" were combined.

The Näätämö catchment

River Näätämö (Norwegian Neiden elva) is a cross-border river between Finland and Norway. Its upper parts are in Finland and its outlet in Varangen fjorden, Norway (Fig. 110). In Finland River Näätämö rises in Lake Iijärvi. The main tributaries of River Näätämö are Rivers Silisjoki, Avlijohka and Kallojoki. The whole catchment covers 2,962 km^2, out of which 2,354 km^2 is in Finland. River Näätämö is included in the Kaldoaivi Wilderness Natura 2000 area (FI1302002).

In the past, River Näätämö and some of its tributaries (e.g. River Silisjoki) were known as pearl fishing areas (Oulasvirta *et al.* 2006). After the pearl fishing era, searching for freshwater pearl mussel has been conducted by the Metsähallitus diving team in the main channel of the Näätämö in 1998 and again in 2004–2005 during the Interreg Kolarctic project (Oulasvirta *et al.* 2006). In 2004–2005, the investigations

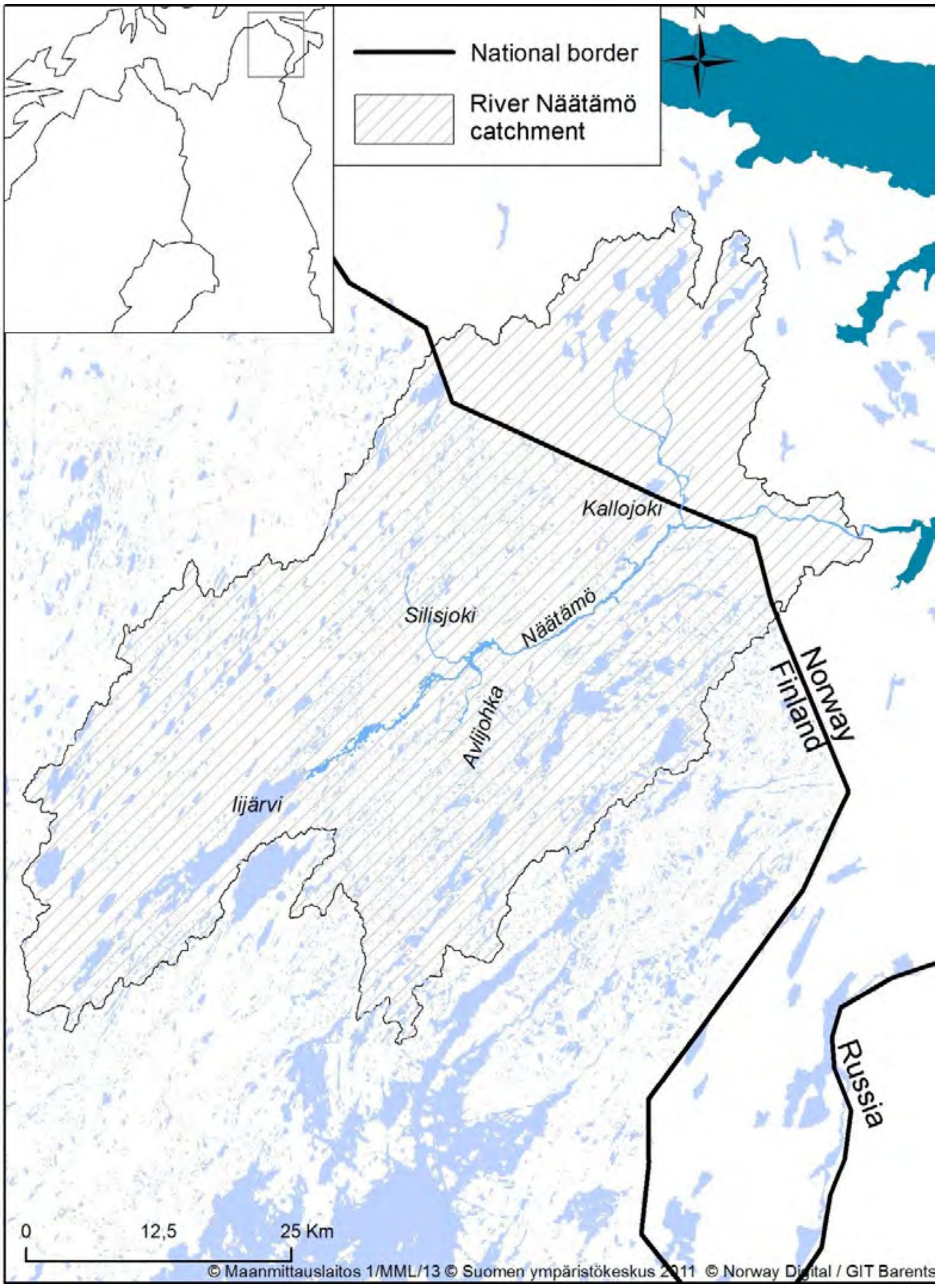


Figure 110. Näätämö (In Norwegian Neiden) catchment area. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15, © Norway Digital / GIT Barents.

were carried also out in many of the tributaries. The result of these investigations was that the only individual living mussels were detected in the main channel and none in the tributaries. On the other hand, the river channel of the Näätämö is wide and deep, which makes it likely that many mussels were not observed. Anyway, there is no doubt that the freshwater pearl mussel is rapidly disappearing from River Näätämö and its status class is *almost extinct* (Table 8 p. 125). However, since the population is the only one known in the whole catchment, the conservation status of the population is *very high* (Table 9 p. 126). Most probably the mussels are also salmon-dependent, but there is no scientific evidence of that yet.

The reason for the bad state of the freshwater pearl mussel in the Näätämö catchment is a little mysterious, since the river basin is mostly a relatively untouched wilderness area with the main anthropogenic pressure being reindeer herding. On the other hand, the impacts of airborne pollution from the Nikel industrial combine in Russia are unknown. It is also possible, that the intense pearl fishing in the 1950s destroyed some of the populations.

In this study, the activities in the River Näätämö catchment were (1) searching for mussels in those areas which were not mapped during the previous surveys, and (2) gathering the remaining mussels in the main channel into one spot, which would enable them to breed and produce glochidia.

The search for new populations were mostly done by electrofishing in order to detect glochidia-infected host fish. These investigations are described by Annex F. Our diving team conducted a mussel search in River Silisjoki, tributary of River Näätämö, in August 2012 (Fig. 111). No mussels were found.

In River Näätämö, the planned gathering of the known mussels could not be done, because of the low water level during the surveys in August 2012, which prevented us from going down the river with inflatable boats. However, since the low water did not allow us to move down the river, we conducted a more thorough mussel search in a smaller area just below Lake Opukasjärvi (Fig. 112). Altogether, nine freshwater pearl mussels were found, and those were

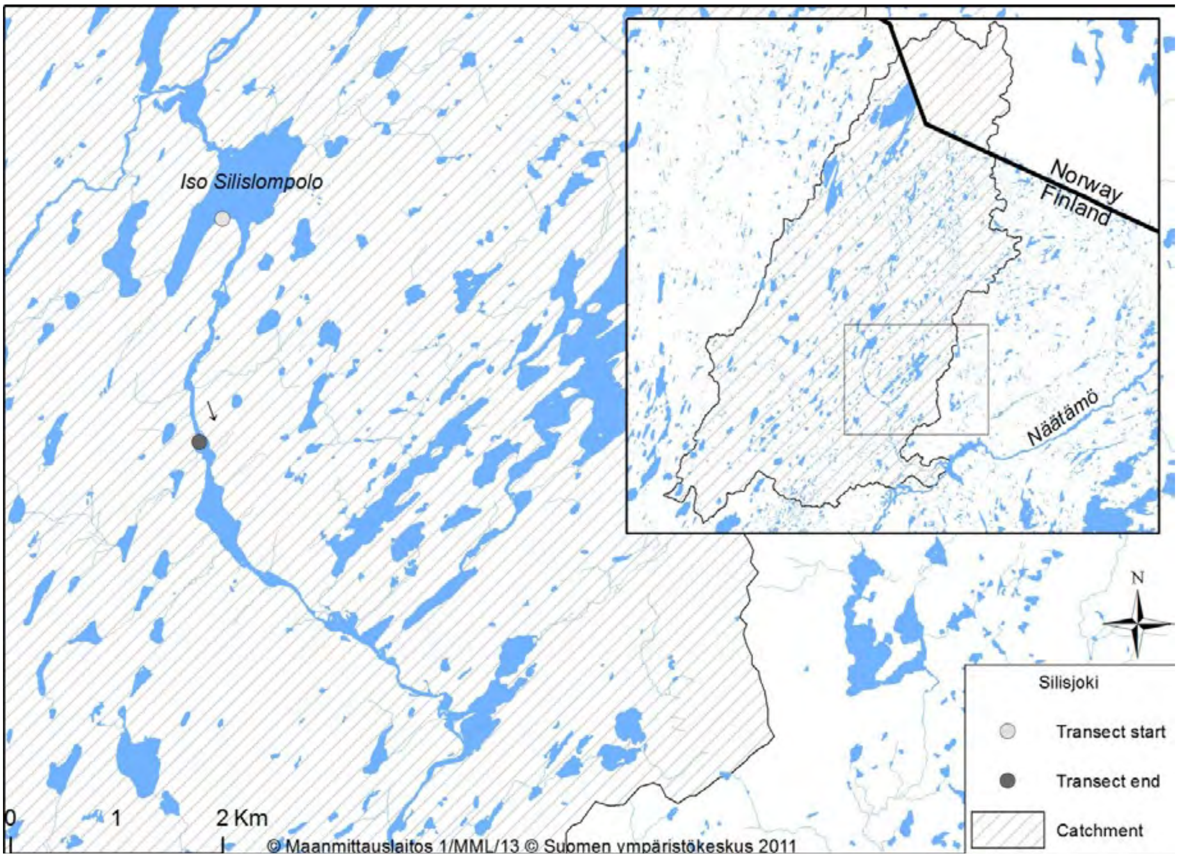


Figure 111. The river stretch surveyed by diving in River Silisjoki, August 2012. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15.

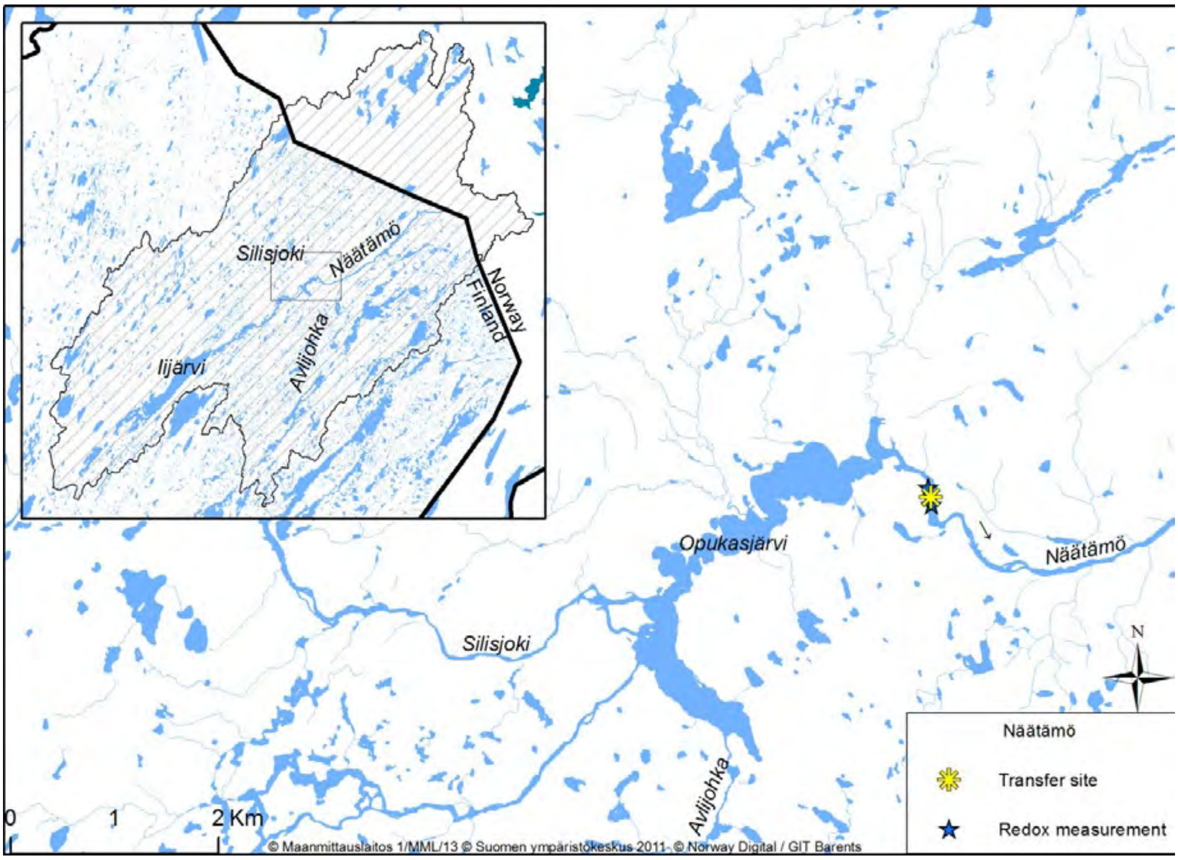


Figure 112. Mussel transfer site and redox potential measuring point in River Näätämö. © Metsähallitus 2015, © SYKE 2015, © National Land Survey of Finland 1/MML/15, © Norway Digital / GIT Barents.

Figure 113. In River Näätämö the mussels were transferred into one spot close to each other in order to enable their glochidia production. Photo Panu Oulasvirta, Metsähallitus.

Figure 114. Abundant filamentous algae and thick layer of organic sediment in River Näätämö (above) and Silisjoki (below) in August 2012. Photos Panu Oulasvirta, Metsähallitus.

gathered into one spot close to each other (Fig. 113).

A year later, in 2013, we inspected the same place. We found two mussels, both of which were ca. 20 metres downstream from the transfer site. Both mussels were in good shape. We believe that the other seven mussels are also still alive, but not detectable because of the great size and depth of the river, and due to the dense algae mat covering the bottom.

The abundance of the filamentous algae and organic sediments were notable both in River Näätämö and in its tributary River Silisjoki (Fig. 114). Abundant filamentous algae indicate nutrient loads, which is in line with the Finnish national water quality monitoring in River Näätämö (Finnish Environmental Database Hertta). High levels of nitrogen (peaks up to 1040 µg/l) and total phosphorus (peaks up to 250 µg/l) have been detected. Also, quite often

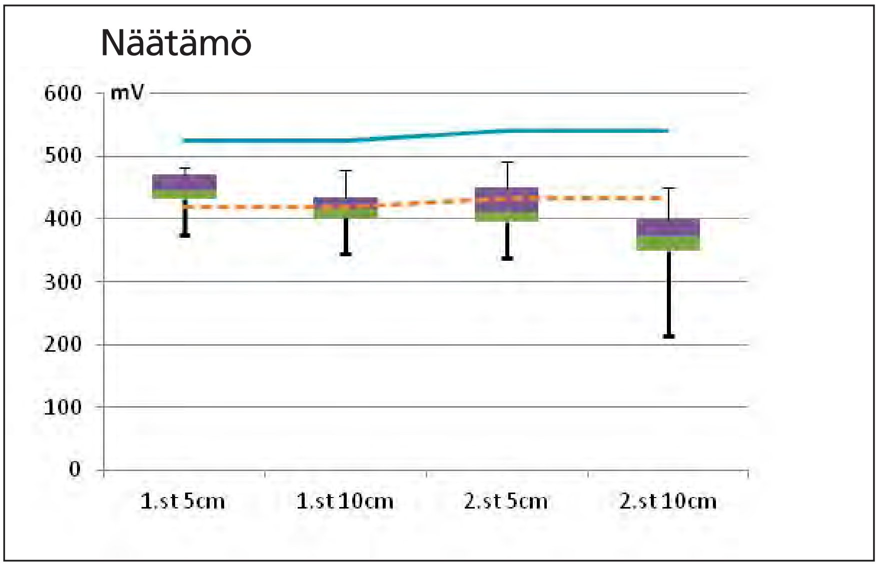


Figure 115. Redox potential measurements in river Näätämö 5 cm and 10 cm down in the sediment. Box-Whisker plots: vertical lines: min-max, boxes: 0.25 quartile, median and 0.75 quartile. Blue line: Redox potential in free flowing water; dotted line: 20% reduction from the water values. Site 1 is in the spot, where the collected mussels were transferred and site 2 ca. 20 metres downstream of it.

during the winter period the ammonium level is high, >10 µg/l (see Annex C). Turbidity of the water has been slightly elevated, the average value being 1 FNU with peaks up to 9 FNU. Lowered alkalinity values are detected especially during flooding conditions, but no alarmingly low pH have been detected from the main river of Näätämö. Probably the acid water comes from acid-sensitive granite bedrock areas and gets mixed with the water from alkaline bedrock areas.

Rivers in the area seem to be recovering from acidification, since the alkalinity trend over the years has been slightly rising (Annex C). Special caution requires the detected high iron (max. 1200 µg/l) and aluminium (max. 512 µg/l) contents in detected River Näätämö, as high values coincide with potential acid peaks during floods, causing Al and Fe to transform into a poisonous form. The Näätämö catchment itself is quite untouched and not affected by the forestry activities, for example. Basically, there are two possible sources of nutrients in the Näätämö river basin – reindeer herding and/or airborne pollution. Reindeer may cause nutrient flows into the river not only due to their excrement, but also by pawing the ground.

Redox potential was measured in two spots in the same areas, where the mussels were planted in River Näätämö. Redox was recorded 5 cm and 10 cm deep in the sediment. The values were good in all except one 10 cm-deep site (Fig. 115).

6 Discussion

The population status was studied altogether in 21 rivers in Finland and 4 rivers in Sweden. According to the criteria applied in Sweden and Norway (see Table 3 p. 47) for determining the viability status of the populations, only one population (River Hanhioja) was given the highest viability status *viable*. Two populations (in Rivers Haukioja and Kopsusjoki) were classified as *viable?* All the rest were classified either *non-viable* (21 populations), *dying-out* (two populations) or *almost extinct* (two populations) (Table 8a).

In some rivers, a special area of juvenile mussels could be distinguished. Often this area was in the upper course of the river, where the anthropogenic pressure from the catchment is usually not so severe. Sometimes adequate recruitment was estimated to take place in these special juvenile areas, although the population as a whole was estimated to be *non-viable* (see Table 8b). Such rivers were, for example, the Saukkooja, Kiertämäoja and Koutusjoki, in which the recruitment took place mainly in the upper part of the mussel distribution range. Optimal areas for juvenile mussels could also be distinguished in River Hanhioja (Table 8b).

Apart from the criteria applied in Sweden and Norway, other criteria for determining the viability of the freshwater pearl mussel population are used in the UK, for instance. There the status of the population is based on the proportion of mussels under 30 mm and 65 mm in length (Table 10). If these criteria are applied to our data, two population, in Rivers Hanhioja and Haukioja, could be considered to be in favourable condition.

Another approach for determining the viability of the population is the criteria suggested by the European Union working group of mussel experts, whose task is to provide guidelines for freshwater pearl mussel monitoring in Europe (CEN working group CEN/TC 230/WG 2/TG 1). Because of the different growth rates of the mussels between different geographical areas, the classification in this system is based on the proportion of ~20 years old mussels (recent recruitment) and 5–10 year old mussels (very recent recruitment). In addition, the proportion of different age-classes is reflected in the maximum life-span of the mussels (see Table 10). If these criteria are applied to our northern populations, where the mussels are supposed to be long-lived, up to 200 years or more, the number of populations showing recent recruitment would be four, Rivers Hanhioja, Haukioja, Kopsusjoki

Table 7. Estimated population size in the rivers investigated. The mussel numbers are based on visually observed mussels in random transects. The real mussel numbers are likely bigger since according to studies carried out in Sweden and Norway on average 20–34% of the mussels are buried in the substrate (Bergengren 2006, Larsen *et al.* 2007).

River	Country	Stretch m	Population size	Mean density/m^2
Hanhioja	Finland	2,300	15,700	5.8
Haukijoki	Finland	1,900	12,200	4.2
Haukioja	Finland	3,500	16,600	1.96
Hirvasjoki[1]	Finland	5,900	4,600	0.02
Juumajoki	Finland	4,000	25,800	1.57
Kiertämäoja[2]	Finland	10,400	111,400	1.14
Kopsusjoki[3]	Finland	3,800	30,500	4.8
Koutusjoki	Finland	6,300	131,500	8
Kuutusoja	Finland	2,300	3,600	0.5
Livojoki[4]	Finland	900	5,300	0.16
Lovttajohka	Finland	10,000	3,800	0.07
Norssipuro[5]	Finland	1,330	20,200	12.26
Onnasjoki[6]	Finland	990	14,500	9.64
Saukko-oja	Finland	12,800	27,200	0.47
Siikajoki[7]	Finland	26,700	42,800	0.39
Suomujoki[8]	Finland	9,000	133,600	0.57
Toramojoki	Finland	6,400	108,310	6.48
Torkojoki	Finland	3,500	7,200	0.82
Ruohojärvenoja	Finland	2,600	4,700	0.92
Harrijaurebäcken	Sweden	3,000	1,900	0.11
Juojoki	Sweden	8,800	39,400	0.9
Kääntöjoki	Sweden	7,000	73	0.001
Silpakbäcken	Sweden	1,300	17,600	4.68

[1] Main population area between road bridge and Hirvaslompolo

[2] Main population area between Upper-Kiertämäjärvi and River Lutto

[3] Kopsujoki population most probably at least double the size shown in the table, since only half of the mussels could be observed due to the dense vegetation and upper parts of the distribution were not investigated

[4] Only the main population area in the Louhikosket and Raakunkosket areas. The whole population in River Livojoki is estimated to be ca. 8,700 individuals by Valovirta (1990a)

[5] Main distribution area, population continues slightly downstream

[6] Main distribution area in the upper course of the river

[7] Between Lake Iso-Pölkkyjärvi and the River Juujoki junction

[8] Between Lotjanankoski rappids and River Lutto. Upper part of the population up above Lake Aittajärvi were not investigated

Table 8a. Proportion of the small mussels in the rivers studied at random transects. Size classes < 20 mm and < 50 mm are used as criteria for determining the state of the population in Sweden and Norway (Bergengren *et al.* 2010, Söderberg *et al.* 2009)

River	Country	% < 20 mm	% < 50 mm	n	Smallest mm	Status
Hanhioja	Finland	1	29	174	4	Viable
Haukijoki	Finland	0	0	50	24	Non-Viable
Haukioja	Finland	0	27	412	24	Viable?
Hirvasjoki	Finland	>0	0	53	15	Non-Viable
Juumajoki	Finland	0	0.6	298	22	Non-Viable
Kiertämäoja	Finland	>0	1	190	14	Non-Viable
Kopsusjoki	Finland	1	11	262	12	Viable?
Koutusjoki	Finland	>0	0	195	12	Non-Viable
Kuutusoja	Finland	0	3	108	29	Non-Viable
Livojoki	Finland	0	0	19	88	Dying-out
Lovttajohka	Finland	0	0	187	46	Non-Viable
Lutto	Finland	0	0	16	113	Dying-out
Norssipuro	Finland	0.4	6	240	9	Non-Viable
Näätämö	Finland	0	0	0*	94	Almost extinct
Onnasjoki	Finland	0	1	220	34	Non-Viable
Saukko-oja	Finland	>0	4	45	14	Non-Viable
Siikajoki	Finland	0	1	220	35	Non-Viable
Suomujoki	Finland	0	1	163	41	Non-Viable
Toramojoki	Finland	>0	4	255	19	Non-Viable
Torkojoki	Finland	0	0	189	20	Non-Viable
Ruohojärvenoja	Finland	0	9	249	20	Non-Viable
Harrijaurebäcken	Sweden	0	10.5	143	27	Non-Viable
Juojoki	Sweden	0	8	160	22	Non-Viable
Kääntöjoki	Sweden	0	0	0*	85	Almost extinct
Silpakbäcken	Sweden	0.7	1.4	138	13	Non-Viable

*Due to very few individuals found, no measurements were taken

Table 8b. Size distribution and status of the population, when the random sample was taken from the optimal area for young mussels. Only those rivers where an "optimal area" could be identified and where the size distribution was significantly different from in random transects are shown.

River	Country	% < 20 mm	% < 50 mm	n	Smallest mm	Status
Hanhioja	Finland	9	92	100	4	Viable
Haukijoki	Finland	0	2	102	24	Non-Viable
Hirvasjoki	Finland	>0	2	100	15	Non-Viable
Kiertämäoja	Finland	>0	4	50	14	Non-Viable
Koutusjoki	Finland	6	24	103	12	Viable
Saukko-oja	Finland	1	11	100	14	Viable?

and Harrijaurebäcken. Very recent recruitment would represent the best juvenile areas in rivers Hanhioja and Koutusjoki.

To summarize, regardless of the criteria used for classification, only a few mussel populations in our project area show sustainable level of recruitment in the long run. Considering the low human population density and vast wilderness areas in northern Fennoscandia, this is a rather unexpected finding. Mostly the reasons for the bad shape of the mussel populations are still obvious. Since the era of pearl fishing, the reasons for the declining populations have included the clearing and straightening of rivers for timber floating, the construction of hydro-power plants, eutrophication, the building of

Table 9. Conservation status of the freshwater pearl mussel population studied. Population in which genetic values data (see Annex D, this volume) was available are marked with **bold** letters. Maximum scores with the genetic data are 43 and without the genetic data 36 (see Table 4 p. 48).

River	Country	Scores/ maximum scores	Conservation status (notes)
Hanhioja	**Finland**	**21/43**	**Very high**
Haukijoki	Finland	11/36	High
Haukioja	Finland	15/36	High
Hirvasjoki	**Finland**	**11/43**	**High**
Juumajoki	Finland	9/36	High
Kiertämäoja	Finland	17/36	High
Kopsusjoki	Finland	16/36	High
Koutusjoki	**Finland**	**24/43**	**Very high (unique haplotypes; ≤ 3 known populations in the main catchment)**
Kuutusoja	Finland	9/36	High
Livojoki	**Finland**	**16/43**	**Very high (Salmon dependent mussels; unique haplotypes)**
Lovttajohka	**Finland**	**14/43**	**High**
Lutto	**Finland**	**23/43**	**Very high (Salmon dependent mussels, high diversity, unique haplotypes)**
Norssipuro	Finland	17/36	High
Näätämö	Finland	9/36	Very high (salmon mussels; ≤ 3 populations in catchment)
Onnasjoki	**Finland**	**12/43**	**High (unique haplotypes)**
Saukko-oja	**Finland**	**18/43**	**High**
Siikajoki	**Finland**	**19/43**	**High**
Suomujoki	**Finland**	**18/43**	**Very high (Salmon mussels)**
Toramojoki	Finland	19/36	Very high
Torkojoki	**Finland**	**13/43**	**High**
Ruohojärvenoja	Finland	13/36	High
Harrijaurebäcken	Sweden	11/36	High
Juojoki	**Sweden**	**16/43**	**Very high (≤ 3 known populations in the main catchment)**
Kääntöjoki	Sweden	7/36	Normal
Silpakbäcken	Sweden	13/36	High

Tab 10. Criteria for assessing whether the freshwater pearl mussel population is in favourable condition. UK criteria have been applied mainly in the UK and Ireland (Young *et al.* 2003). CEN classification is a suggestion made by an expert working group for a guidance standard on monitoring freshwater pearl mussel populations.

Classification	Targets to meet
UK	≥ 20% ≤ 6 5 mm (< 2 0 years old) and > 0% ≤ 30 mm (< 10 years old)
CEN	No recent decline in adult numbers; < 1% dead shells; ≥ 20% ≤2 0 years old (recent recruitment); ≥ 5% ≤ 5* years old (very recent recruitment)**

* If digging for juvenile mussels is not conducted, the limit mussels ≤10 years should be used.

** With a typical life span of ~100 years, individual targets should reflect the maximum age for each population. The size range of mussels under 5–10 and 20 years should be established

forest roads, and other forestry operations such as ploughing and drainage of forest and peat lands, which have led to the silting of rivers. Especially in Finland, where the drainage operations have been extensive, they are probably the major single cause of population extinction or decline. In most of our rivers the damage took place already in the 1970s, when the ditching operations were especially extensive (Figure 116). Indeed, according to Joosten & Clarke (2002) almost 40% of the world´s forest and peat land ditches are in Finland. Although most of the ditching operations took place over 40 years ago, ditching and land ploughing are common methods in present-day forestry actions as well, not to mention the damage caused by

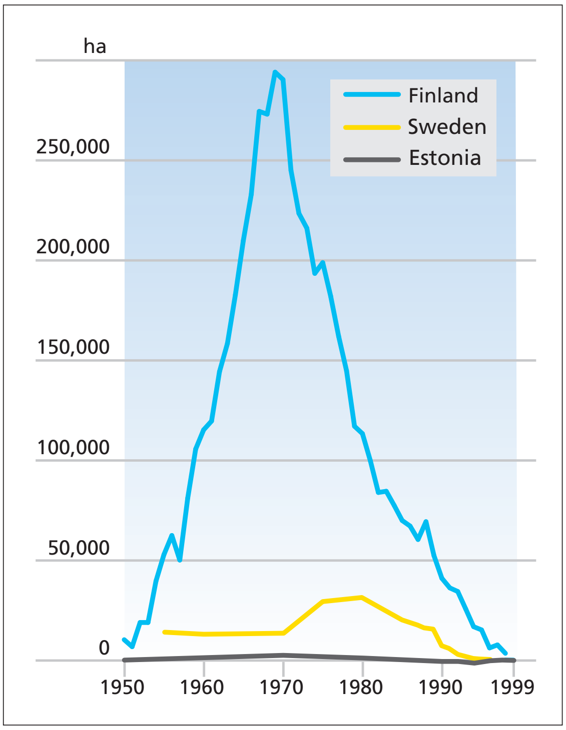


Figure 116. Forest and peat land ditching operations in Finland, Sweden and Estonia (Hallanaro *et al.* 2002).

forest roads or river being crossed with forestry machines (Figures 117–119).

So, although the human population in northern Fennoscandia is sparse, the land use has been and still is extremely intensive. A result of this is seen in the poor water quality in many rivers (see Annex C). The siltation and sedimentation result in colmation of the river bed. This causes oxygen depletion in the interstitial water. This can be verified by redox potential (Eh) measurements. According to Geist & Auerswald (2007), the redox potential in the river beds, which contain functional freshwater pearl mussel populations is usually above 400 mV, and the values below 300 mV represent anoxia, which is impossible for the juvenile mussels to survive. Moreover, there should not be a pronounced difference (typically < 20%) between the open water value and interstitial water at a 5 cm depth. In our data the high redox values correlated quite well with the juvenile sites in the river. Respectively, lower values and > 20% loss from open water value were measured on sites (usually in the lower course) with no recruitment. On the other hand, the temperature-corrected median values were seldom below 300 mV, and sometimes juvenile mussels were also found in the sites where the difference between the free water value and interstitial water value was greater than 20% (see Appendix 2). Thus, the redox potential measurements provide a good tool, but do not always give a reliable picture of the habitats suitable for juvenile mussels. In order to acquire a better result there should be more measurements taken than we were able to do.

Another reason for the low recruitment rate of the freshwater pearl mussel in some rivers is the lack of a suitable host fish. For example, in Rivers Lutto and Suomu, the degree of recruitment is most probably low owing to the hydro power dam on the Tuloma, Russia, which prevents Atlantic salmon from ascending the Finnish parts of the Lutto catchment. Apart from the Lutto catchment, the hydropower plants have also prevented salmon from ascending the Iijoki and Kemijoki catchments. Together these three catchments cover almost the whole of northern Finland (Fig. 1 p. 45).

In northern Sweden the situation is not as bad. From the three main catchments in this study (Torne, Kalix and Lule), the salmon and sea-trout migrations have been prevented by the dams only in River Luleälven main channel, although there is a major problem with migration barriers in the smaller tributaries. Recent figures from the Life+ project – ReMiBar (Removal of Migration Barriers) reveals that in the County of Norrbotten alone 3,000 (probably underestimated) wrongly constructed road culverts act as migration barriers for fish and other aquatic animals. With the current measurement rate it will take 130 years before these barriers are removed. Another problem is the dams that were built when the floating of timber occurred. Many of these old dams, lacking any purpose today, act as migration barriers and have done so for many decades.

The reason for low freshwater pearl mussel recruitment is not always so obvious, however. For instance, Rivers Kiertämäoja, Onnasjoki, Näätämö and Lovttajohka are situated either in the national parks or in wilderness areas far from forestry activities, and still the observed recruitment level of the freshwater pearl mussel was quite low. In Kiertämäoja, the lack of a suitable

Figure 117. Forest ditch leading to freshwater pearl mussel river in Finland. Photo Eero Moilanen, Metsähallitus.

Figure 118. Ditches both side of the road lead to the freshwater pearl mussel river. Photo Panu Oulasvirta, Metsähallitus.

Figure 119. Forest machine trail leading to River Hukkajoki, a freshwater pearl mussel in Iijoki catchment area. Photo Eero Moilanen, Metsähallitus.

host fish, the Atlantic salmon, may at least partly explain the absence of juvenile mussels in the lower course. According to Erkinaro *et al.* (2001) the lower and middle courses of Kiertämäoja may earlier have served as nursery areas for juvenile salmon or occasional spawning areas for spawning fish. This suggests that Kiertämäoja mussels at least in the lower and middle course may be salmon-dependent in their recruitment as in the main river of the Lutto.

In River Näätämö, the freshwater pearl mussel population will soon be extinct without urgent restoration measures. At the moment the population is already so small, that captive breeding is probably the only possible restoration measure to be taken. The reason for the poor shape of the River Näätämö population is still unclear. However, the high contents of iron and aluminium together with the occasionally high nutrient levels and low pH (especially in tributaries) might explain the decline in the population (see Annex C). The high levels of nutrients, especially nitrogen and ammonium apply to many other rivers also in our study area. In this context, the impact of reindeer herding and potential airborne pollution should be studied more closely as a potential source of nitrogen.

The high nutrient levels are linked to eutrophication resulting, for example, in extensive algal growth. Indeed, the percent coverage of the filamentous algae was in many rivers very high. In Ireland, the percent coverages higher than 5% are considered to be harmful to the mussels because of the increased organic sedimentation and oxygen depletion in the substrate (Ireland Government Publications 2009). In our data, the connection between the abundance of the filamentous algae and viability of the mussel population was not always so obvious, however. For example, in river Hanhioja the average coverage of filamentous algae was more than 65%, but still the population is recruiting well. On the other hand, in the best recruitment sites in River Hanhioja the algae were not so abundant. In River Haukioja, where the mussel population was classified as *viable?* the filamentous algae were absent. In the Kopsusjoki, also a *viable?* population, the average coverage of the filamentous algae was 8.3%, but the water moss (*Fontinalis*) and vascular plants were exceptionally abundant. When looking for the abundance of the filamentous algae, one should note that they grow very fast. Therefore, their abundance always depends on the conditions during and just before the survey. Typically, algae are more abundant later in the summer in low water conditions. Also, sunny and warm weather, as in the summer of 2013, accelerate the algal growth.

Apart from the anthropogenic impacts listed above, we cannot exclude the natural and methodological reasons for the low number of juvenile mussels in many rivers. As shown, often the juvenile mussels inhabit their own habitats in the river. In random sampling these special areas are often bypassed. Quite often we did not find small mussels by random sampling, but they were still present and found when searched for especially. For example, the population in Rivers Norssipuro, Torkojoki, Kiertämäoja, Toramojoki and Ruohojärvenoja were classified as *non-viable*, although juvenile mussels were quite common in certain places. It these rivers the result obtained from random transect may have given a wrong picture of the population's viability. Moreover, it is questionable whether we can apply the same criteria for determining the viability in northern freshwater pearl mussel populations as with more southern ones. Many of the populations examined in this study, especially those very northern ones such as the Lovttajohka or Näätämö river populations, certainly are frontier populations living at the extreme climatic limits of the species. In the study carried out in River Hanhioja in 2009 came out that the development time for the glochidia in the host fish gills was ca. 11 months (Taskinen *et al.* 2014). The climatic conditions in River Näätämö and Lovttajohka, for example, are probably even colder than in River Hanhioja. Thus, the parasitic period in these kinds of extreme environments may be even longer, which means that the recruitment of freshwater pearl mussel might take place quite seldom even naturally, only in the most favourable (mild) years, and even then only in some parts of the river. This could explain the absence or small number of the smallest mussels in the random sampling in a given time. Confirming this hypothesis would require regular monitoring of the populations including the monitoring of the glochidia development.

Nevertheless, according to our data we can draw a conclusion that, in general, northern Fennoscandian freshwater pearl mussel populations are seriously threatened, and it is expected that most of the populations will decline in the near future without proper protection. The lack of protection is an obvious problem: In Sweden (figures from 2011), for instance, none of the freshwater pearl mussel rivers in the County of Norrbotten has complete protection (i.e. the whole catchment area protected). Only 0.01% of the freshwater pearl mussel populations are completely within the boundaries of a Nature Reserve (where the purpose for protection is mainly in terrestrial values) and 14.5% of the rivers are partly within the boundaries of a Nature Reserve. 76% of the freshwater pearl mussel rivers are included in the Natura 2000 network in which the water itself is protected, but not the catchment area in the same way as a Nature Reserve. 23.7% of the rivers are totally lacking any form of protection.

In Finland the situation is even worse. Out of the ca. 110 known freshwater pearl mussel rivers in northern Finland, only five rivers (4.5%) are situated in a national park. 18 rivers (16.4%) are included in the Natura 2000 network. In the River Iijoki catchment, which together with the Lutto and Kemijoki catchments, is the key area for freshwater pearl mussel in Finland, only 3 out of 29 known freshwater pearl mussel rivers belongs to the Natura 2000 network. The whole of River Tornionjoki with its tributaries is included in the Natura 2000 network, except for one sub-drainage, River Tengeliönjoki, where the two known freshwater pearl mussel rivers are located! Even worse, the Natura 2000 status does not seem to protect the river against the threats originating from the drainage area. For example, the forestry works, which often have a drastic effect on the river ecosystem, have so far not been obligated to carry out an impact assessment according to the 6th article in the Habitat Directive. In this project, harmful forestry works were documented in almost all forested catchments outside the national parks, including the Natura 2000 rivers Siikajoki, Toramojoki and Juumajoki.

7 Conclusions

7.1 Restoration of the freshwater pearl mussel populations

The freshwater pearl mussel is listed in Annex II of the European Union Habitats Directive as a species whose habitat must be protected for its survival. In addition, the species is protected by national legislation in Sweden, Norway and Finland. Despite the high conservation status, the species is in many ways threatened and the populations in need of urgent restoration efforts. The required restoration measures vary from river to river and actions are needed in different levels: (1) Searching for new populations (2) Status assessment and monitoring of known populations, (3) Restoration of damaged catchment areas, (4) Construction of fish ways to the old salmon rivers and (5) Captive breeding in the most threatened populations.

In many cases only artificial captive breeding (as described in Annex E) is the only possibility to save the genetic strain of a given freshwater pearl mussel population. Captive breeding can at best give an extended time to keep the population alive, but it can never be a final solution for restoring the population. In the long run, the target of the restoration efforts should always be to return the habitat to its natural state, which enables the natural recruitment of the mussels. To accomplish this, large-scale restoration efforts are required on catchment areas. Building of fish ways is a prerequisite especially in old salmon rivers. Especially in River Lutto and Suomu, the returning of Atlantic salmon might alone be a sufficient restoration measure for freshwater pearl mussel population.

At the same time, when the freshwater pearl mussel populations in northern Fennoscandia are in many ways threatened and in many areas already extinct, there are vast areas that are still totally unmapped for freshwater pearl mussel. In Sweden, for instance, basically all the main rivers, which contain freshwater pearl mussel in their tributaries, are un-investigated. In Finland the situation is pretty much the same with the main rivers, but there are also vast un-investigated areas in tributaries. The target areas where the basic mapping project should especially be focused in northern Fennoscandia are shown in Table 11.

7.2 Monitoring programme

Sweden and Norway have their own management plan for the protection of freshwater pearl mussel populations (Naturvårdsverket 2005, Larsen *et al.* 2000, Direktoratet for Naturforvaltning 2006). Estonia has just prepared a draft of the management plan for freshwater pearl mussel in the spring of 2014. In Finland, where the populations are in worse condition than in Norway or Sweden, there is neither management nor monitoring of freshwater pearl mussel populations. Indeed, there is an urgent demand for a freshwater pearl mussel action plan in Finland. One of the aims of this project

Table 11. River basins, in which the searching for new freshwater pearl mussel populations should especially be targeted in Finland, Sweden and Norway.

Country	Main catchment	Target areas/rivers
Finland	Kemijoki	River Ounasjoki sub-basin with the tributaries
		River Luiro sub-basin with the tributaries
		River Tenniö sub-basin with the tributaries
		River Kitinen sub-basin with the tributaries
		River Värriöjoki sub-basin with the tributaries
	Koutajoki	The whole catchment on the Finnish side
	Teno	River Utsjoki with the tributaries
		River Inarijoki with the tributaries
	Tornionjoki	Main channel of River Tornionjoki
	Simojoki	Main channel and the tributaries
Sweden		Main rivers with known mussel populations in their tributaries
Norway		River Tana with the tributaries

was to find suitable rivers for the monitoring programme in Finland. These rivers are listed in Table 12. Apart from the northern rivers, some rivers are also suggested in southern Finland. The criteria for selecting these particular rivers are the following:

1. Geographical representativeness (examples of different main catchment areas).
2. Genetic diversity (based on the genetic studies in this project, see Annex D).
3. Main river salmon-dependent populations (based on the host fish studies in this project, see Annex E).
4. Good background information on the population and its status.
5. Both functional and non-functional populations included.

Table 12. Rivers suggested for a regular freshwater pearl mussel monitoring programme in Finland.

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

* A proper baseline survey of the population required before monitoring

Appendix 1

Parameters recorded during the field work. Fpm = freshwater pearl mussel.

Code of the site	Number of fpm on sub-transect 5–10 m
Date	Number of fpm on sub-transect 10–15 m
Rivername	Number of fpm on sub-transect 15–20 m
Catchment	Number of fpm total
Researchres	Dead shells
River Habitat: Still water, Slow current, Strong current (riffle), Rapids, Water fall	Fpm distribution
Source of Info: Aquascope/Snorkelling/SCUBA	Fpm average density
Human influence in river	Max density
Human influence in transect	Substrate with Fpm
Transect direction: Upstream, Downstream/ Cross-river	Shadowness %
Start LAT	Stones %
Start LON	Stones 2–6 cm %
Remarks	Stones 6–20 cm %
Photo numbers	Stones 20–60 cm %
End LAT	Stones > 60 cm %
End LON	Organic bottom %
Remarks	Gravel %
Photos	Loose sand %
Transect width	Non-loose Sand %
Transect area m^2	Clay %
Transect length	Mud %
River width	Sediment
Profile	Vegetation coverage %
Average depth	Moss %
Max depth	Submerged plants %
Current speed	Algae %
Water level	Halophytes %
Visibility	Fish
Temperature	Sponges
Water quality	Why not fpm?
Fpm present: yes/no	Why not small fpm?
Number of fpm on sub-transect 0–5 m	Notes
	Smallest found fpm

Appendix 2

Redox potential (E_h) values from different rivers. Temperature corrected redox potential values from free flowing water and interstitial water 5 cm down in the sediment (median values of 10–12 repetitive measuring/site). Loss greater than -20% is considered to be harmful for juvenile mussels. Fpm = freshwater pearl mussel.

River	Country	Redox mV Free water	Median 5 cm	Loss H_2O => 5 cm	Notes
Hanhioja 1	Finland	579	262	-55%	Non-recruitment area
Hanhioja 2	Finland	563	555	-1%	Recruitment area
Haukijoki 1	Finland	624	358	-43%	
Haukijoki 2	Finland	606	386	-36%	
Haukioja 1	Finland	529	407	-23%	Upper course; smallest 5-6 cm
Haukioja 2	Finland	557	319	-43%	Lower course, but small still detected
Hirvasjoki	Finland	553	500	-10%	
Juumajoki 1	Finland	554	182	-67%	Non-recruitment area
Juumajoki 2	Finland	539	437	-19%	Recruitment area
Kiertämäoja	Finland	576	486	-16%	Lower limit of the distr.range, where one 40 mm mussel 40 mm
Koutusjoki 1	Finland	591	480	-19%	Optimal recruitment area
Koutusjoki 2	Finland	591	382	-35%	Close to Site 1, but below a ditch. Still juveniles
Koutusjoki 3	Finland	533	207	-61%	Same as Site 2, but measurements 2011
Koutusjoki 4	Finland	534	464	-13%	Middle course, up from site 5, where high density of freshwater pearl mussel but no juveniles
Koutusjoki 5	Finland	536	288	-46%	Lower course
Kuutusoja	Finland	527	490	-7%	Bottom spring
Livo 1	Finland	573	403	-30%	
Livo 2		497	221	-56%	
Lutto	Finland	527	446	-26%	
Norssipuro 1	Finland	598	406	-32%	Above site 13
Norssipuro 2	Finland	591	340	-42%	
Onnasjoki 1	Finland	579	345	-40%	
Onnasjoki 2	Finland	621	375	-40%	
Ruohojärvenoja 1	Finland	494	373	-24%	Lots of Fpm, smallest 21 mm
Ruohojärvenoja 2	Finland	526	290	-45%	Only a few Fpm, no juveniles
Saukko-oja 1	Finland	542	401	-26%	Several juveniles
Saukko-oja 2	Finland	585	460	-21%	Several juveniles
Saukko-oja 3	Finland	544	350	-36%	No Fpm
Siikajoki 1	Finland	682	408	-40%	
Siikajoki 2	Finland	589	484	-18%	Only big Fpm here
Suomujoki	Finland	545	408	-25%	Lower course site 19 below the best freshwater pearl mussel area
Toramojoki 1	Finland	547	335	-39%	Lower course, site 16, organic sediments, not much juveniles, smallest still 39 mm
Toramojoki 2	Finland	634	603	-5%	Upper course, juveniles site 2
Toramojoki 3	Finland	632	589	-7%	Upper course, juveniles sites 3–4
Torkojoki	Finland	589	573	-3%	Site4, smallest 38 mm

River	Country	Redox mV Free water	Median 5 cm	Loss H_2O => 5 cm	Notes
Juojoki 2	Sweden	561	451	+20%	1 large mussel. 5/10 measurements in moving sand (higher values)
Juojoki 7	Sweden	531	269	-49%	3 large mussels
Juojoki 9	Sweden	555	457	+18%	No mussels
Juojoki 10	Sweden	525	569	+8%	80 mussels (smallest 28 mm)
Juojoki 14	Sweden	663	325	-51%	302 mussels (smallest 32 mm)
Juojoki 18	Sweden	452	170	-62%	81 mussels (smallest 36 mm)
Silpakbäcken 3	Sweden	575	299	-48%	161 mussels (smallest 67 mm)
Silpakbäcken 4	Sweden	667	652	-2%	No mussels
Silpakbäcken 12	Sweden	625	544	-13%	52 mussels (smallest 82 mm)
Silpakbäcken 13	Sweden	578	271	-53%	1,206 mussels (smallest 38 mm)
Silpakbäcken 16	Sweden	605	496	-18%	37 mussles (smallest 20 mm)
Silpakbäcken 18	Sweden	585	337	-42%	808 mussels (smallest 16 mm)
Harrijaurebäcken 6	Sweden	668	673	1%	20 mussels (smallest 41 mm)
Harrijaurebäcken 7	Sweden	650	683	5%	1 mussel (105 mm)
Harrijaurebäcken 10	Sweden	568	523	-8%	37 mussels (smallest 50 mm)
Harrijaurebäcken 12	Sweden	597	438	-27%	10 cm depth. 32 mussels (smallest 27 mm)
Harrijaurebäcken 15	Sweden	650	624	-4%	No mussels
Harrijaurebäcken 16	Sweden	734	750	2%	3 mussels (smallest 93 mm)
Kääntöjoki 1	Sweden	585	542	-7%	No mussels
Kääntöjoki 6	Sweden	590	485	-18%	No mussels
Kääntöjoki 10	Sweden	602	587	-2%	1 mussel (85 mm)
Kääntöjoki 12	Sweden	562	557	-1%	1 mussel (97 mm)
Kääntöjoki 15	Sweden	594	492	-17%	No mussels
Kääntöjoki 17	Sweden	565	551	-2%	2 mussels (95 mm)