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Updated Implementation Guidelines

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UPDATED IMPLEMENTATION GUIDELINES

Centre for Economic Development, Transport and the Environment for Lapland

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Jordanfossen. Photo: Helén Andersen

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1 General about the programmes

1.1 Introduction

The Pasvik watercourse is exposed to multiple environmental stressors including pollution, water regulation, resource exploitation and biological invasions, which can influence the robustness of the systems and thus synergistically enhance any degradation effect of climate change. The small lakes are mainly exposed to long-range transboundary air pollution. This affects the ecosystems and can thus enhance any degradation effect of climate change. The closest, main emission sources are the Pechenganikel copper-nickel production plants in the towns of Nikel and Zapolyarny at the Kola Peninsula. The Pechenganikel emissions include sulfur dioxide (SO_2), heavy metals (Ni, Cu, Hg, Cd, Cr, As etc.) and persistent organic pollutants (POPs).

This monitoring programme is an update to the previous monitoring programmes for the Pasvik River and the small lakes and streams near the Pasvik River catchment area. The original programmes were published in 2007 as the main product of the Pasvik Project (Interreg Programme from 2003–2007).

In the Pasvik project it was recommended that the monitoring programme should be evaluated after 6 years. Such an evaluation of the previous programme was done as a part of the ENPI project Trilateral Cooperation on Environmental Challenges in the Joint Border Area (TEC) carried out in 2012–2015.

This evaluation concludes that the previous suggested monitoring programme was not satisfactory for the future monitoring and did not include all the stressors that affect lakes and streams in the border region. Results from the research carried out in the TEC project revealed new stressors that should be taken into account in the future long-term monitoring programme for the Pasvik River and the small lakes. This document presents two monitoring programmes, one appropriate for the Pasvik River and one appropriate for the small lakes.

Multiple environmental stressors, along with climate variability, can synergistically contribute to the degradation of biological diversity at the species, genetic, and/or habitat ecosystem levels (Wrona et al. 2006). The border region is exposed to local pollution, long-range transboundary air pollution and resource exploitation, which can influence the robustness of the systems and thus synergistically enhance any degradation effect of climate change.

Climate change is very likely to have both direct and indirect effects on the biota and the structure and function of Arctic freshwater ecosystems (Wrona et al. 2006). The Arctic climate is warming rapidly. In the next 100 years a general increase in both temperature and precipitation is expected due to climate change and this will affect limnic systems (Prowse et al. 2008). Estimates demonstrate that the most severe change in climate will take place in the Arctic; the temperature increase will be approximately twice as big as the global increase (ACIA 2005, IPCC 2007). Førland et al. 2009 concludes in their study that the temperature in northern Norway will increase with 2.3–3.5 °C towards year 2071–2100 compared to the reference period of 1961-1990. There will also be a 20–30 % increase in precipitation in large parts of northern Norway (Førland et al. 2009). The consequences for limnic systems due to climate change can be severe and need to be monitored. Results from the TEC-project found that that the average water temperature in the Pasvik River increased significantly from 1975 to 2013 with an average 0.05 °C/year, which means approximately 2 °C increase for the total period (Ylikörkkö et al. 2015).

In the earlier monitoring programme the focus was mainly on chemical parameters and fish, but only the water chemistry programme was financed and fully carried out. However, in order to full scale monitor the trends and effects of climate change, local pollution and long-range pollution in the region it will be important to include monitoring of biological parameters (e.g. chlorophyll, phytoplankton, zooplankton, periphyton and zoobenthos, in addition to fish) in all three countries. Biological monitoring is also important in the EU Water Framework Directive (WFD).

The continuation of a trilateral monitoring programme in the future is somewhat uncertain due to each country's changing politics of environmental monitoring. Funding allocated to monitoring may not be sufficient in the future to implement the best possible monitoring programme for this vulnerable region. This is why two approaches are suggested, plan A and plan B, for monitoring the Pasvik River. Plan A is the most recommendable, primary option for monitoring. It is designed to answer the most crucial stressors that impact the watercourse and the monitoring network is extensive enough to provide reliable data for the basis. Plan B is a less-inclusive programme with less monitoring stations and monitored variables. However, even though this monitoring is less costly, it does not provide enough reliable information on the stressors impacting the Pasvik watercourse and small lakes in the border region.

1.2 Objectives of the Programmes

“Long-term research and monitoring can provide important ecological insight and are crucial for the improved management of ecosystems and natural resources” (Lindenmayer and Likens 2009).

The primary objective of these suggested monitoring programmes is to provide harmonized, scientifically robust, up-to-date information on the environment and its changes in the joint border area of Norway, Russia and Finland. The goal is to establish long-term adaptive monitoring programmes that take into account important questions local stakeholders, authorities and researchers have for this area. Adaptive monitoring increases the credibility of monitoring programmes within the scientific community by demonstrating the pivotal role of the traditional scientific method of posing and then answering questions and will improve the long-term research (Lindenmayer and Likens 2009).

Some of the main findings in the TEC project and in other ongoing research projects in the region are increasing levels of mercury (Hg) in sediments and freshwater fish (Rognerud et al. 2013, Christensen et al. 2015 in Ylikörkkö et al. 2015). It is of particular concern that mercury levels are continuing to rise in parts of the Arctic biota, despite reductions in global anthropogenic emissions (AMAP 2011). In this region the increase of mercury concentrations in freshwater biota and sediments during the latest decades is likely due to a combination of increased emissions from different sources. These include long-range transboundary air transport and emissions from smelters located at the Kola Peninsula, especially Nikel and Zapolyarny. However, processes in the catchment area, in the lakes and rivers caused by climate change may also lead to increasing levels of mercury in freshwater biota and sediments. Other recent findings, which have been observed in several lakes, are changes in fish communities. It seems that the ratio of perch in several lakes is increasing compared to salmonid fish species (whitefish, trout and Arctic char). This is probably due to climate change.

Demands in the EU Water Framework Directive (WFD) will not be sufficient as a monitoring programme because it does not address all the stressors that are affecting the watercourse in this region. It is therefore necessary to design an adaptive monitoring programme specifically for the Pasvik River and the lakes and rivers in the border region, based on multiple stressors that these unique areas suffer from.

It is essential that this monitoring programme will take into account the crucial questions regarding this border area. These questions must be a defined agreement among natural resource managers, policymakers, locale stakeholders and scientists.

1.3 Target areas

The joint environmental monitoring network includes the Pasvik River basin, which covers areas in Norway, Finland and Russia, and the small lakes and streams in the border area.

The Arctic region of Northern Fennoscandia unique geological, geographical and climatic qualities combined with a moderately high level of industrial development. The joint border area of Norway, Finland and Russia is one of the 10 key areas of the Arctic Monitoring and Assessment Programme (AMAP) working under the Arctic Council.

This monitoring programme constist of two parts. 1) The Pasvik River watercourse and 2) small lakes, in order to distinguish between runoff directly from the Nikel smelter and city, and long-range airborne pollution.

The Pasvik watercourse

Includes Lake Inarijärvi, the Pasvik River watercourse and lakes directly connected to it (e.g. Lake Kuetsjarvi) (Figure 1).

Small lakes and rivers

Includes small lakes which are not directly connected to the Pasvik watercourse and which receive atmospheric transboundary pollution. The monitored small lakes are situated mainly in four areas (Figure 2, Table 1):

1. Finnish area of Vätsäri (1) and Lake Sierramjärvi west from there (4).
2. Norwegian area of Jarfjord – Sør-Varanger (2).
3. Two Russian areas situated near the towns of Nikel and Zapolyarny (3a) and farther south from them (3b).

1.4 Other programmes

The national monitoring programmes in Finland, Norway and Russia are programmes which cover the whole country and are normally designed to address specific issues.

The Norwegian national monitoring programmes that cover lakes and rivers in the Finnmark border region include water chemistry (acidification and metals) in small lakes (Jarfjord lakes), water chemistry in rivers (Pasvik included – every year), contaminants in lake sediments (every 10 years), contaminants in fish (every 10 years), and biodiversity (every 6 years).

In Finland the national monitoring programme for airborne pollution and climate change includes a couple of small lakes in the Vätsäri region. The national lake monitoring programme includes both Inarijärvi and Muddusjärvi. Lake Inarijärvi water quality is monitored in two stations, 4–6 times a year. During growing season chlorophyll and phytoplankton are also sampled. Diatom and profundal zoobenthos are sampled every 3rd year, littoral zoobenthos and macrophytic vegetation every 4th year. Fish survey with gillnets is performed every six years. Lake Muddusjärvi water quality and phytoplankton are monitored every 3rd year. Profundal zoobenthos and fish are sampled every 6th year, and macrophytes surveyed once in every 12 years. There have also been screening studies of mercury and POP (persistent organic pollutant) content in fish of Lake Inarijärvi. The Natural Resources Institute Finland conducts fish monitoring in Lake Inarijärvi (state of the fish population, fishing and stocking).

Russian monitoring programmes in the Pasvik River region include hydrometeorology monitoring and smelters controls. Comprehensive environmental monitoring is conducted by the Institute of North Ecology Problems and the Pasvik Zapovedik nature reserve observes the ecology of the area.

In all three countries it is uncertain how these programmes will continue in the future. When a monitored object is not in the national programme, it will require separate funding to implement.

Figure 1. The Pasvik watercourse.

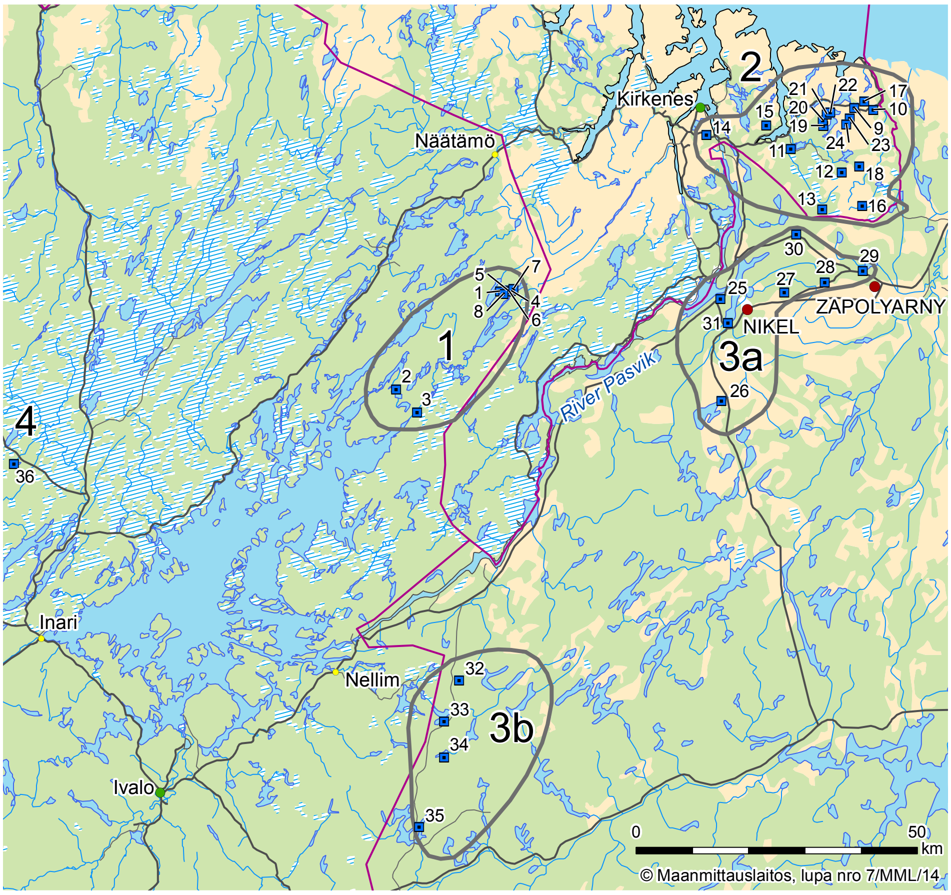

Figure 2. The small lakes and rivers.

Table 1. The monitored small lakes and their position in the sub-areas.

Number	Lake	Country	Area
1	Lampi 222	Fi	1
2	Harrijarvi	Fi	1
3	Pitka-Surnujarvi	Fi	1
4	LAMPI 6/88	Fi	1
5	LAMPI 3/88	Fi	1
6	LAMPI 5/88	Fi	1
7	LAMPI 7/88	Fi	1
8	LAMPI J11	Fi	1
9	Holmvatnet	No	2
10	Gardsjoen	No	2
11	Rabbvatnet	No	2
12	Durvatn	No	2
13	Borsevatn	No	2
14	Runvatn	No	2
15	Dalvatn	No	2
16	Otervatnet	No	2
17	Første Høgfjellsvatn	No	2
18	Store Skardvatnet	No	2
19	Jarfjordfjellet 05	No	2
20	Jarfjordfjellet 06	No	2
21	Jarfjordfjellet 07	No	2
22	Jarfjordfjellet 08	No	2
23	Jarfjordfjellet 12	No	2
24	Jarfjordfjellet 13	No	2
25	Pikkujarvi	Rus	3a
26	Shuonijaur	Rus	3a
27	LN-2	Rus	3a
28	LN-3	Rus	3a
29	Palojarvi	Rus	3a
30	Pachta river	Rus	3a
31	Shuonijoki river	Rus	3a
32	Toartesjaur	Rus	3b
33	Virtuovoshjaur	Rus	3b
34	Riuttikjaure	Rus	3b
35	Kochejaur	Rus	3b
36	Sierramjarvi	Fi	4

Photo: Guttorm Christensen

2 The Pasvik watercourse

2.1 Introduction

The Pasvik watercourse is exposed to multiple environmental stressors including pollution, water regulation, resource exploitation and biological invasions, which can influence the robustness of the systems and thus synergistically enhance any degradation effect of climate change.

There is no monitoring programme designed for this particular watercourse. Demands based on the EU Water Framework Directive (WFD) will not be sufficient as a monitoring programme because WFD does not address all the stressors that are affecting the watercourse. It is therefore necessary to design a specific monitoring programme for the Pasvik watercourse based upon the multiple stressors that this watercourse suffers from.

2.2 Crucial stressors and questions in the Pasvik watercourse

Multiple stressors originating from a number of sources are affecting the watercourse and its biodiversity, and this needs to be taken into account in the future monitoring programme.

These stressors include:

1. Pollution from the Nikel smelters
2. Invasion of new species
3. Water level regulation
4. Fish stocking
5. Resource exploitation
6. Climate change
7. Transboundary air pollution (long-range transport of contaminants)

Stressors 1–5 originate from within the area, whereas stressors 6–7 have their origin outside the region. The questions below are linked to one or several of the above mentioned stressors.

The TEC project and other studies have revealed an increasing trend of the mercury contents in both sediments and fish. There seems, however, to be little correlation between levels of Hg in sediments and fish. Stressors 1, 3, 6, 7

- Will this increasing trend of mercury continue?
- How will this affect the fish communities?
- Is the fish safe for human consumption?
- Which processes and mechanisms are regulating the levels of mercury in freshwater ecosystems in the watercourse?

The nickel and copper concentrations (air, sediments, water and fish) increase with decreasing distance to the smelters. There are also increasing trends in air, sediments and water. Stressors 1, 3, 6, 7

- Do the high levels have any effect on the freshwater ecosystem (benthic invertebrates and fish)?
- How do these levels change over time?

The TEC study has documented elevated levels of POPs downstream the smelters. Stressors 1, 3, 6, 7

- Are the contaminants coming from Nikel settlement?
- Do they have any effect on the ecosystem?

- Is the fish safe for human consumption?

There are elevated levels of contaminants in the Pasvik watercourse. Stressors 1, 3, 6, 7
- Are there any cocktail effects?
- Which contaminants should be prioritized in a monitoring programme?

The fish composition in Pasvik watercourse has changed dramatically over the past 20 years. Stressors 1, 2, 3, 4, 5, 6
- How will the fish communities develop in the future?
- Are there effects on the biodiversity and ecosystem functioning?
- Can this lead to an extinction of fish species?
- How will this affect resource exploitation in the watercourse?

The water temperature in the watercourse has increased over time. Stressor 6
- How will this affect the fish species composition in the Pasvik watercourse?
- Will new species invade and establish in the system?
- Will this affect the food chain and promote an increase of mercury in fish?
- Will this affect the productivity of the system?

Available long-term data and scientific modeling of climate change indicate that the region will be strongly affected. Stressor 6
- How will this impact ecosystem functioning and stability?
- How will this impact the taxa composition?
- How will changes in precipitation regime affect the production?

The TEC project and other studies indicates that perch is a ”climate change winner”. Stressor 6
- How will this affect the ecology of these systems (benthic community, zooplankton, fish populations)?

Does a longer ice-free season stimulate a higher production of benthic algae? Stressor 6

The hydropower regulation companies are carrying out a stocking programme for trout in parts of the Pasvik watercourse. Stressors 4, 5
- Is there any effect on the genetics for the unique original trout population?
- How is the stocking programme affecting the fish communities?
- How does the stocking of trout influence the recreational fishing?

2.3 General methods of sampling

Sampling procedures should follow established standard procedures and recommendations that can be found in Puro-Tahvanainen et al. 2008. Some adjustments are made in order to improve and harmonize sampling methods across borders. Macrophyte monitoring can be done with either the Finnish or the Norwegian method.

Simultaneous sampling of the whole watercourse is preferred. Both lakes/reservoirs and rivers in the area should be sampled. All biological samples should be taken every second year (1st year: collecting of material, 2nd year: analysis and reporting) with the exception of aquatic macrophyte monitoring.

Frequency: sampling conducted in every x year.
Samples: the number of samples in the sampling season.

2.4 The Pasvik River monitoring recommendations: Plan A

The Pasvik River monitoring is based on a continuum of stations from the least polluted areas upstream to more severely polluted reaches. Different parameters may call for different stations, but the main stations remain the same (Table 1):

- Muddusjärvi: natural state, non-regulated, minimal anthropogenic pollution
- Inarijärvi: source of the Pasvik River, regulated, large fish stocking, minimal anthropogenic pollution
- Rajakoski: upstream from the Pechenganikel, regulated, minimal anthropogenic pollution
- Ruskebukta: upstream, regulated, has an established benthos sampling station and “anomalies” in phytoplankton species composition have been detected
- Vaggatem: (incl. lakes Ruskebukta and Tjærebukta) upstream, regulated, has an established benthos sampling station and “anomalies” in phytoplankton species composition have been detected
- Kuetsjarvi: Most polluted due to proximity to the Pechenganikel and the Nikel City
- Skrukkebukta: downstream from the Pechenganikel and the Nikel City, affected by pollution, regulated

Table 1. The monitoring stations, their location in relation to and distance to Nikel.

Stations/locations	Country	Location in relation to Nikel	Distance to the Nikel smelter, km
Muddusjärvi	Finland	Upstream	140
Inarijärvi	Finland	Upstream	100
Rajakoski	Russia	Upstream	60
Ruskebukta	Norway	Upstream	40
Vaggatem	Norway	Upstream	40
Kuetsjarvi	Russia	Downstream	0–6
Skrukkebukta	Norway	Downstream	16

2.4.1 Physical parameters

Long-term monitoring of physical parameters is crucial for studies related to climate change and as a support to better understand chemical and biological parameters. The most important parameters are temperature in air and water, light in water, period of ice cover and precipitation regime (Table 2). These physical parameters in should be included in all lakes that are monitored.

Table 2. Monitored physical parameters.

Parameter	Method of monitoring
Temperature	continuous measuring with data loggers
Light	continuous measuring with data loggers
Ice-season	time of freezing and the time of ice break can be detected with data loggers
Precipitation	continuous measuring, data from national meteorological institutes.
Water flow	data from the hydropower companies.

National meteorological institutes with open data:
Finland: https://en.ilmatieteenlaitos.fi/open-data
Norway: www.eklima.no
Russia: http://meteo.ru/english/index.php

2.4.2 Water chemistry

Water chemistry monitoring means that general water quality, metals and acidification effects are all monitored (Table 3). Samples from lakes and reservoirs should be taken every year during the spring (May–early June) and autumn (Sept.–Oct.) turnover and water chemistry from rivers four times per year during the main hydrological phases (March, May, Aug. Sept.–Oct.) (Table 4). If the water chemistry samples are used in chlorophyll/ phytoplankton measurements, then sampling should also be conducted in late summer ((July)–Aug.) The River Kolosjoki should be sampled at two stations, both at the immediate vicinity of Nikel and at upstream from the city.

Table 3. Monitored water chemistry variables.

Element	Variable
General water quality	temperature, conductivity, colour, turbidity, TOC, tot-P, tot-N O_2, NO_3, NH_4, PO_4, Si
Heavy metals	Cu, Ni, Hg, Pb, Zn, Al, Cd, As, Fe, Mn
Acidification	pH, alkalinity, Ca, Mg, Na, K, Cl, SO_4

Sampling methods and analysis

- Use only specified sampling bottles from the laboratory.
- Preserve the samples according to protocol from the laboratory.
- Samples from running water or from the outlet of the lake: sampling bottle is filled directly from the river at a representative place.
- Samples from boat: Sampling depth 0–5 meters. Use standard water sampler (e.g. Rüttner sampler, Limnos sampler, Ramberg sampler).
- Avoid contamination of the sample (e.g. samples for heavy metal samples taken directly into the bottle or with a sampler that contains no metal).

Table 4. Water chemistry monitoring stations.

	Chemical quality monitoring		
		frequency	samples
1	Muddusjärvi	annual	2
2	Inarijärvi	annual	2
3	Rajakoski	annual	2
4	Ruskebukta	annual	2
5	Vaggatem	annual	2
6	Kolosjoki (0 km from Nikel)	annual	4
7	Kolosjoki (14,5 km from Nikel)	annual	4
8	Shuonijoki	annual	4
9	Kuetsjarvi	annual	8
10	Protoka	annual	4
11	Skrukkebukta	annual	2

2.4.3 Sediments

Sediment monitoring includes monitoring of general elements, heavy metals and persistent organic pollutants (Table 5). Samples should be taken every 5th or 10th year (Table 6). This is because most lakes in these latitudes have low sedimentation rates and thus only less frequent sampling can reveal true trends in concentrations of pollutants.

Table 5. Elements and variables in the sediment monitoring.

Element	Variable
General	water content, loss on ignition, Ca, Mg, Na, K, P
Heavy metals	Hg, Ni, Cu, Zn, Cd, Pb, Sr, Mn, Fe, Al, As
Persisten organic pollutants (POPs)*	PCB, dioxins, pesticides, brominated flame retardants

*Optional for each country

Sampling methods and analysis

Sampling time
- Not important.

Sampling site
- Deepest part of the lake.

Sampling method
- Gravity corer with diameter from 6 to 9.5 cm.
- Sediment core is sliced into 0.5 cm slices (0–0.5 cm, 0.5–1 cm, and reference from the lower part of the core).
- The coordinates of each sample station are determined with a GPS device.
- Sediment samples are placed in polyethylene containers, stored at a temperature of +4 °C or frozen until analysis.

Table 6. Sediment monitoring stations.

	Monitoring of lake sediments		
		frequency	samples
1	Muddusjärvi	every 10th year	1
2	Inarijärvi	every 10th year	1
3	Rajakoski	every 10th year	1
4	Vaggatem	every 5th year	1
5	Kuetsjarvi	every 5th year	1
6	Skrukkebukta	every 5th year	1

2.4.4 Phytoplankton

Phytoplankton monitoring includes chlorophyll measurements (Table 7). Chlorophyll and phytoplankton samples should be taken during the open water season (1–4 times) (Table 8). One sample of phytoplankton should be taken in late summer because the ecological classification of WFD is done based on the July-August phytoplankton community composition.

Table 7. Variables in phytoplankton and chlorophyll monitoring.

Element	Variable
Phytoplankton	chlorophyll-α biomass (μg/l), total biomass of phytoplankton (mg/l) taxon-specific biomass (mg/l) for calculation of cyanobacteria relative biomass and Trophic Plankton Index (TPI)

Sampling methods and analysis

Sampling time

- Lakes are sampled 1–4 times from June to September.
- In mid-August if only once a year.

Sampling site

- 'Mid-Lake station', typically the deepest basin.

Sampling method

- Standard water sampler (e.g. Rüttner sampler, flexible tube sampler, Ramberg sampler).
- Sampling depth is normally 0–2 m in epilimnion (or in the euphotic zone).
- The samples are normally mixed in a container / bucket.
- Sub-samples for analyses representing the selected depth interval for analyses (species composition, biomass, cell numbers etc.) are taken from the mixed sample.
- For supplement samples a vertical hawl net of 10–20 μm can be used (or 45 μm at high plankton densities).
- Preservation: Lugol's solution (phytofix). Standard concentration: 0.5–1 ml per 100 ml water sample. For meso-oligotrophic lakes 0.5 ml per 200 ml water sample is recommended.
- Samples for chlorophyll-α analysis are taken from the mixed sample. Volume of filtered water may vary; normally 0.5–1.0 L. Enough water to give colour to the filter paper (GF/F filter) must be filtered. The volume of water filtered must be noted. The filter is packed in a tube, aluminum foil etc. (to prevent exposure to light) and frozen directly after filtration.

Table 8. Chlorophyll and phytoplankton monitoring stations.

		Chlorophyll		Phytoplankton	
		frequency	samples	frequency	samples
1	Muddusjärvi	every 2nd year	3	every 2nd year	2
2	Inarijärvi	every 2nd year	4	every 2nd year	3
3	Rajakoski	every 2nd year	4	every 2nd year	4
4	Ruskebukta	every 2nd year	4	every 2nd year	4
5	Vaggatem	every 2nd year	4	every 2nd year	4
6	Kuetsjarvi	every 2nd year	4	every 2nd year	4
7	Skrukkebukta	every 2nd year	4	every 2nd year	4

2.4.5 Periphyton

Periphyton (benthic diatoms) studies are a reliable way to monitor eutrophication and changes in the production related to climate variations. Monitoring of periphyton in lakes and in running waters is a cost-effective parameter. Periphyton species distribution in the monitoring stations is monitored every second year (once a year) (Tables 9–10).

Table 9.Variables in periphyton monitoring.

Element	Variable
Periphyton	species distribution

Sampling methods and analysis

Sampling time
- August–mid September.

Sampling site
- Open rocky littoral zone.

Sampling method
- Periphyton sampling method is basically the same both for lakes and for streams and rivers.
- Sample should be taken from 20–40 cm depth from areas that has been submerged (covered with water) most of the growing season, minimum the last 6-8 weeks.
- 5–10 rocks (diameter 10–15 cm) are brushed with a toothbrush and rinsed with clean water into a small bottle.
- The final sample volume should be at least 50 ml.
- The sample is preserved in ethanol (¼ of the sample volume) or formaldehyde (3 drops of 37 % in a 10 ml glass tube).
- Parallel samples from different parts of the lake can be considered (2–4 sites). Areas with point discharges (e.g. farmed areas, houses etc.) should be avoided if the general trophic state of the lake is to be evaluated.

Table 10. Periphyton monitoring stations.

	Periphyton	
		frequency
1	Muddusjärvi	every 2^{nd} year
2	Inarijärvi	every 2^{nd} year
3	Rajakoski	every 2^{nd} year
4	Vaggatem	every 2^{nd} year
5	Kuetsjarvi	every 2^{nd} year
6	Skrukkebukta	every 2^{nd} year
7	Kolosjoki 0 km from Nikel	every 2^{nd} year
8	Kolosjoki 14,5 km from Nikel	every 2^{nd} year
9	Shuonijoki	every 2^{nd} year
10	Protoka	every 2^{nd} year

2.4.6 Zooplankton

Zooplankton is an important prey for fish in many of the lakes in the area. Recent results indicate that fish communities are changing which again influence the zooplankton community. Zooplankton community structure gives important additional information of the fish communities and is needed in the future full scale monitoring. Monitoring of zooplankton is a cost-effective parameter. Zooplankton species distribution in the monitoring stations is monitored every second year (four times per year, with phytoplankton) (Tables 11–12).

Table 11. Variables in zooplankton monitoring.

Element	Variable
Zooplankton	species distribution

Sampling method and analysis

Sampling time
- June to October in this region.

Sampling site
- 'Mid-Lake station', typically the deepest main basin of the lake.

Sampling method
- For relative composition of species and different developmental stages: Vertical haul by standard plankton net; normal diameter: 25–30 cm, mesh size: 90 µm for crustacean zooplankton and 45 µm if small species/rotifers are included.
- Sampling depth is variable; normally 0–10 m (above thermocline).
- The zooplankton is filtered from the water through a plankton net before preservation.
- Preservation is done with ethanol (min. 70 % final concentration) or formaldehyde (min. 4 % final concentration). Lugol's solution (phyto-fix) can also be used (0.5 ml per 200 ml of water).

Table 12. Zooplankton monitoring stations.

	Zooplankton		
		frequency	samples
1	Muddusjärvi	every 2nd year	2
2	Inarijärvi	every 2nd year	3
3	Rajakoski	every 2nd year	4
4	Vaggatem	every 2nd year	4
5	Kuetsjarvi	every 2nd year	4
6	Skrukkebukta	every 2nd year	4

2.4.7 Zoobenthos

Benthic invertebrate sampling includes both littoral and profundal and frequency is every two years (Tables 13–14). Sampling should be carried out following standard procedures and sampling methods, that have been used in the previous sampling (TEC project 2012–2015, for instance), should be kept the same to ensure comparability of the samples taken in different years.

Table 13. Elements and variables in zoobenthos monitoring.

Element	Variable
Zoobenthos, littoral	species distribution relative taxon abundance taxon densities abundance
Zoobenthos, profundal	species distribution relative taxon abundance taxon densities distribution

Sampling methods and analysis

Littoral sampling time
- Normally late fall (late September - October / November).

Littoral sampling site
- Open exposed shore sites, bottom substrate: gravel, pebbles and rocks, depth: 25–40 cm.

Littoral sampling method
- Device: kick net, mesh size 0.25–0.5 mm.
- Norwegian method: Kicking: in the mouth of the net for 20 seconds moving backwards in line with the shoreline. Kicking time: 3 minutes, and approximately 1 m per 20 s., totally 9 m. The net is emptied after 1 min sampling time. Three sites, two replicates from each site.
- Finnish method: Kicking: in the mouth of the net for 20 seconds moving backwards in line with the shoreline 1 meter. The net is emptied after each 20 s period. Three sites, two replicates from each site.
- Preservation: 70 % ethanol (final concentration).

Profundal sampling time
- Normally fall (August / September).

Profundal sampling site
- At least one deep basin per lake.

Profundal sampling method
- Device: Ekman bottom grab sampler (or similar grab).
- Sample is collected from the sediment of profundal area (> 5 m depth).
- Sediment caught in the sampler is sieved with a 0.5 mm sieve and preserved in 70 % ethanol (final concentration).
- Number of replicates: Sampling with at least 6 replicates in different parts of the profundal (8 samples from large, oligotrophic lakes).

Table 14. Zoobenthos monitoring stations.

	Zoobenthos	
		frequency
1	Muddusjärvi	every 2nd year
2	Inarijärvi	every 2nd year
3	Rajakoski	every 2nd year
4	Vaggatem	every 2nd year
5	Kuetsjarvi	every 2nd year
6	Skrukkebukta	every 2nd year
7	Kolosjoki 0 km from Nikel	every 2nd year
8	Kolosjoki 14,5 km from Nikel	every 2nd year
9	Shuonijoki	every 2nd year
10	Protoka	every 2nd year

2.4.8 Fish

Fish monitoring in the region constitutes studies of contaminants in fish and fish communities/populations in selected lakes (Table 15). Monitoring is conducted every second year (Table 16). It is also important to get information of variation of population/communities over time.

Table 15. Variables of fish monitoring.

Element	Variable
Populations	species composition age and length distribution density stable isotopes
Heavy hetals	Hg, Ni, Cu
POPs	PCBs, dioxins (others)

Sampling method and analysis

Sampling time

- Normally fall (August/September).

Sampling site

- The whole lake.

Sampling method

- Sampling is done using standard Nordic gillnets (1.5 x 30 m). The nets are set overnight (approximately 12 h) in different depth zones at randomly chosen sites during period from mid-July until the beginning of September.
- The catch of each mesh size of every gillnet is handled separately: (1) catch is assorted to species, (2) the total amount of every species is counted and weighed and (3) all individuals or a sub-sample (approx. 30

individuals) of every species is measured for length (1 cm length classes).
- Scale sample is the most efficient option for measuring fish growth. For this sample length-measured and gender-identified individuals should be taken and their age calculated.
- Scale samples are taken from whitefish, grayling, trout and arctic char (in Finland). The number of scale samples depends on the catch, but the maximum of 30 individuals would be adequate if the fish are abundant.
- Monitoring parameters of fish includes parameters that are common to all three countries (e.g. lenght, weight, age, sex, maturation) as well as parameters that are monitored only in one or two countries.
- Fish species used for studies include the most common species found in the Pasvik watercourse (eg. whitefish, perch, pike, trout and vendace). Used tissues should include muscle, kidney and liver for Hg, Cu and Ni analyzes, but also other tissues can be used.

Table 16. Fish monitoring stations.

	Fish	
		frequency
1	Muddusjärvi	every 2^{nd} year
2	Inarijärvi	every 2^{nd} year
3	Rajakoski	every 2^{nd} year
4	Vaggatem	every 2^{nd} year
5	Kuetsjarvi	every 2^{nd} year
6	Skrukkebukta	every 2^{nd} year

2.4.9 Macrophytes

Macrophyte monitoring of lakes/reservoirs concentrates on variables dictated in either the Finnish or the Norwegian monitoring methods (Table 17) Monitoring should be done during summer (June–Aug.) and it is kept less frequent (every 6^{th} year) because the changes in macrophyte communities are slow enough to require less frequent monitoring (Tables 18–19).

Table 17. Variables of aquatic macrophyte monitoring.

Element	Variable
macrophytes	species distribution frequency coverage

Sampling method and analysis

Sampling time
- July–August.

Sampling method
- Monitoring can be done either with the Finnish or the Norwegian method.
- Finnish method, see Kuoppala et al. (2008) (in Finnish), Kanninen et al. (2013) (in English).
- Norwegian method, see Hellsten et al. (2014).

Table 18. Lakes included in the macrophyte monitoring in Finland.

	Macrophyte monitoring, Finnish lakes	
		frequency
1	Muddusjärvi	every 6th year
2	Inarijärvi	every 6th year

Table 19. Macrophyte monitoring sites of the Pasvik River (sites of Moiseenko et al. 1993).

	Macrophyte monitoring, the Pasvik River	
		frequency
0	Hestefoss (new site as of 2013)	every 6th year
1	Gjøkbukta	every 6th year
2	Ruskebukta, Kulbukta near Nyheim	every 6th year
3	Tjerebukta, Kveldro	every 6th year
4	Lyngbukta	every 6th year
5	Vaggatem, Hauge	every 6th year
6	Nordvestbukta, Skogum	every 6th year
7	Langvatnet, Krokvika near Leite	every 6th year
8	Langvatnet, upstream Skogfoss	every 6th year
9	Fuglebukta	every 6th year
10	Pasvik River, Perslåtta*	every 6th year
11	Kuetsjarvi, Akhmalakhti*	every 6th year
12	Kuetsjarvi, Salmijarvi*	every 6th year
13	Kuetsjarvi, south*	every 6th year
14	Svanevatn, Svanvik	every 6th year
15	Svanevatn, Skrotnes	every 6th year
16	Svanevatn, Seljeli	every 6th year
17	Bjørnevatn, Sandneset*	every 6th year
18	Skrukkebukta, Nordvik	every 6th year
19	Skrukkebukta, Brattli	every 6th year

*Russian side of the river, not studied in TEC project, monitoring should be started.

Subularia aquatica. Photo: Jukka Yli-körkkö

2.5 The Pasvik River monitoring recommendations: Plan B

Network of carefully chosen sampling sites will be established so that there is a continuum of monitoring stations (lakes/reservoirs, no river stations) from the polluted areas near the smelters to farther away. Number of samples and sampling frequency are low: up to every 6 years with biological samples (Tables 20–22).

Even though the sampling sites are limited, the monitoring should be conducted in the same manner as in the more extensive monitoring plan.

Frequency : sampling conducted in every x year.
Samples: the number of samples in the sampling season.

Table 20. Chemical quality monitoring stations.

	Chemical quality monitoring		
		frequency	samples
1	Muddusjärvi	every 3rd year	4
2	Inarijärvi	annual	4
3	Rajakoski	annual	1
4	Vaggatem	annual	1
5	Kuetsjarvi	annual	4
6	Skrukkebukta	annual	1

Table 21. Sediment monitoring stations.

	Monitoring of sediments		
		frequency	samples
1	Muddusjärvi	every 15th year	1
2	Inarijärvi	every 15th year	1
3	Rajakoski	every 15th year	1
4	Vaggatem	every 15th year	1
5	Kuetsjarvi	every 6th year	1
6	Skrukkebukta	every 15th year	1

Table 22. Biological monitoring stations.

	Biological monitoring	Chlorophyll		Phyto/zooplankton		Periphyton	
		frequency	samples	frequency	samples	frequency	samples
1	Muddusjärvi	every 3rd year	3	every 3rd year	2	every 6th year	2
2	Inarijärvi	every 2nd year	3	every 2nd year	2	every 6th year	2
3	Rajakoski	every 2nd year	1	every 2nd year	2	every 6th year	2
4	Vaggatem	every 2nd year	1	every 2nd year	2	every 6th year	2
5	Kuetsjarvi	every 2nd year	4	every 2nd year	4	every 6th year	2
6	Skrukkebukta	every 2nd year	1	every 2nd year	2	every 6th year	2

	Biological monitoring	Zoobenthos	Fish	Macrophytes
		frequency	frequency	frequency
1	Muddusjärvi	every 6th year	every 6th year	every 6th year
2	Inarijärvi	every 6th year	every 6th year	every 6th year
3	Rajakoski	every 6th year	every 2nd year	every 6th year
4	Vaggatem	every 6th year	every 2nd year	every 6th year
5	Kuetsjarvi	every 6th year	every 2nd year	every 6th year
6	Skrukkebukta	every 6th year	every 2nd year	every 6th year

3 The small lakes

3.1 Introduction

The small lakes in Jarfjord, Vätsäri and the two Russian areas are mainly exposed to long-range transboundary pollution and airborne pollution from the Pechenganikel copper-nickel production plants in the towns of Nikel and Zapolyarny. The airborne emissions include sulfur dioxide (SO_2), heavy metals (Ni, Cu, Cd, Cr, As etc.) and persistent organic pollutants (POPs). During the summer, wind direction is variable, but winds from the northeast can be considered most dominant. The most frequently occurring wind direction during winter is from the south and south-west. Wind from the east normally increases emissions into Norwegian area of Jarfjord in large quantities (Flatlandsmo Berglen et al. 2014). In the past Jarfjord has suffered from acidification, as have the Vätsäri lakes, but to a smaller extent. The lakes in Russia near the emission sources have a better buffering capacity and acidic rain has little to no effect. Also some alkaline emissions of the Pechenganikel concentrate on these lakes and they enhance the natural buffering capacity of the lakes.

Cost-effectiveness of the programme is taken into consideration by choosing the best suited lakes, based on location and chemical and biological variables (Table 1). Some of the small lakes included in this programme are also in national monitoring programmes. This makes the programmes more cost-effective and helps secure continuing monitoring in the future. Challenges caused by industrial pollution and climate change were also taken into consideration when selecting lakes for this monitoring programme. Further, in order to achieve an adaptive monitoring programme for this particular region, multiple stressors affecting the aquatic ecosystems were comprehensively assessed.

Table 1. Lakes selected in the TEC project for the border region monitoring programme.

Country	Lake	Km^2	masl	Depth (m)	Distance from smelters (km)
Finland	Lampi 222	0.2	222	22	40
	Harrijärvi	1.0	127	11	60
	Pitkä-Surnujärvi	0.7	126	11,3	60
	Sierramjärvi	1.1	254	18,6	130
Russia	Pikkujärvi	0.4	21	2.0	5.4
	Shuonijaur	11.3	180	10	17
	Toartesjaur	0.6	195	7	82
	Virtuovoshjaur	1.3	182	13	88
	Riuttikjaure	0.9	190	11	94
	Kochejaur	3.2	133	8	105
Norway	Gardsjøen	0.71	82	25	40
	Holmvatn	0.8	156	>20	40
	Rabbvatn	0.38	83	23	27
	Durvatn	0.4	231	16	30
	Børsevatn	0.4	178	>20	21
	Rundvatn	0.4	37	15	30

3.2 Crucial stressors and questions in lakes and streams in the border area

Multiple stressors originating from a number of sources are affecting the lakes and streams and their biodiversity. Multiple stressors need to be taken into account in the future monitoring programme.

These stressors include:
1. Pollution from the Nikel smelters
2. Resource exploitation
3. Climate change
4. Transboundary air pollution (long-range transport of contaminants)

Stressors 1–2 originate from within the region, whereas stressors 3–4 have their origin outside the region. The questions below are linked to one or several of the above mentioned stressors.

The TEC project and other studies have revealed an increasing trend of the mercury contents in both sediments and fish. According to AMAP there is generally little knowledge about mercury in this region and how mercury behaves in the environment. Stressors 1, 3, 4
- Will this increasing trend of mercury continue?
- How will this affect the fish communities?
- Is the fish safe for human consumption?
- Which processes and mechanisms are regulating the levels of mercury in freshwater ecosystems in the watercourse?

There are elevated levels of contaminants in lakes and rivers in the border region. Stressors 1, 3, 4
- Are there any cocktail effects?
- Which contaminants should be prioritized in a monitoring programme?

The nickel and copper concentrations (in air, sediments, water and fish) increase with decreasing distance to the smelters. Stressors 1, 3, 4
- Do the high levels have any effect on the freshwater ecosystem (benthic invertebrates and fish)?
- How do these levels change over time?

The fish composition in some of the investigated lakes has changed severely in the past 20 years. Stressors 1, 2, 3, 4
- How will the fish communities develop in the future?
- Are there effects on the biodiversity and ecosystem functioning?
- Can this lead to an extinction of fish species?
- How will this affect resource exploitation in the lakes and streams?

The water temperature in the lakes has increased over time. Stressor 3
- How will this affect the fish species composition?
- Will this affect the food chain and promote an increase of mercury in fish?
- Will this affect the productivity of the system?

Available long-term data and scientific modeling of climate change indicate that the region will be strongly affected. Stressor 3
- How will this impact ecosystem functioning and stability?
- How will this impact the taxa composition?
- How will changes in precipitation regime affect the production?

The TEC project and other studies indicate that perch is a ”climate change winner.” Stressor 3

- How will this affect the ecology of these systems (benthic community, zooplankton, fish populations)?

Does a longer ice-free season stimulate a higher production of benthic algae? Stressor 3

3.3 General methods of sampling

Sampling procedures are based on standard procedures and recommendations that can be found in Puro-Tahvanainen et al. 2008. However, some adjustments are made in order to improve and harmonize sampling methods across borders.

3.4 The small lakes monitoring recommendations

3.4.1 Physical parameters

Long-term monitoring of physical parameters is crucial for studies related to climate change (variations) and as a support to better understand chemical and biological parameters. The most important parameters are temperature in air and water, light in water, ice coverage and precipitation regime (Table 2). The physical parameters in should be included in all lakes that are monitored.

Table 2. Physical elements included in monitoring of small lakes in the border region.

Element	Method of monitoring
Temperature	continuous measuring with data loggers
Light	continuous measuring with data loggers
Ice-season	time of freezing and the time of ice break can be detected with data loggers
Precipitation	continuous measuring, data from national meteorological institutes

National meteorological institutes with open data:
Finland: https://en.ilmatieteenlaitos.fi/open-data
Norway: www.eklima.no
Russia: http://meteo.ru/english/index.php

3.4.2 Water chemistry

Water chemistry from small lakes includes general water quality variables, heavy metals and acidification effects (Table 3). Samples should be taken minimum once per year. The most important period is after autumn turnover when the whole water column is mixed. According to methods in the EU Water Framework Directive (WFD) a minimum of four samples should be taken during the ice-free season, which is not feasible due to most of the lakes being difficult to reach.

Water chemistry monitoring ensures and obtains comprehensive and current information of the changes taking place under the varying anthropogenic load in the joint border area.

A comprehensive list of the small lakes can be found in Table 4. The water quality status in selected lakes* and selected sites in Pasvik watercourse is reported in a separate report every third year (Ylikörkkö et al. 2014, Puro-Tahvanainen et al. 2011). This is the only monitoring reported explicit for this area. Out of the Finnish lakes some** are not included in national monitoring.

Table 3. Elements and variables in the water quality monitoring of small lakes in the border region.

Element	Variable
General water quality	temperature, conductivity, colour, turbidity, TOC, tot-P, tot-N, O_2, NO_3, NH_4, PO_4, Si
Metals	Cu, Ni, Hg, Pb, Zn, Al, Cd, As, Fe, Mn
Acidification	pH, alkalinity, Ca, Mg, Na, K, Cl, SO_4

Sampling methods and analysis

- Use only specified sampling bottles from the laboratory.
- Preserve the samples according to protocol from the laboratory.
- Samples from running water or from the outlet of the lake: sampling bottle is filled directly from the river at a representative place.
- Samples from boat: Sampling depth 0–5 meters. Use standard water sampler (e.g. Rüttner sampler, Limnos sampler, Ramberg sampler).
- Avoid contamination of the sample (e.g. samples for heavy metal samples taken directly into the bottle or with a sampler that contains no metal).


Photo: Esko Jaskari

Table 4. Water quality monitoring in lakes in the border region.

Country	Lake	Samples per season	Sampling interval	Next sampling	
Finland	LAMPI 6/88**	1	Annual	2015	included in the existing water quality programme
	LAMPI 3/88*	1	Annual	2015	
	LAMPI 5/88**	1	Annual	2015	
	LAMPI 7/88**	1	Annual	2015	
	LAMPI J11**	1	Annual	2015	
	Harrijärvi*	3	every 3rd year	2016	TEC programme
	Pitkä Surnujärvi*	3	every 3rd year	2016	
	LAMPI 222*	3	Annual	2015	
	Sierramjärvi	6	Annual	2015	
Russia	LN-2*	1	Annual	2015	included in the existing water quality programme
	LN-3*	1	Annual	2015	
	Palojarvi*	1	Annual	2015	
	River Pachta*	1	Annual	2015	
	River Shuonijoki*	1	Annual	2015	
	Shuonijaur*	1	every 2nd year	2015	
	Kochejaur	1	every 2nd year	2015	TEC programme
	Virtuovoshjaur	1	every 2nd year	2015	
	Pikkujarvi	1	Annual	2015	
Norway	Dalvatn*	1	Annual	2015	included in the existing water quality programme
	Otervatnet*	1	Annual	2015	
	Første Høgfjellsvatn*	1	Annual	2015	
	Store Skardvatnet*	1	Annual	2015	
	Jarfjordfjellet 05*	1	Annual	2015	
	Jarfjordfjellet 06*	1	Annual	2015	
	Jarfjordfjellet 07*	1	Annual	2015	
	Jarfjordfjellet 08*	1	Annual	2015	
	Jarfjordfjellet 12*	1	Annual	2015	
	Jarfjordfjellet 13*	1	Annual	2015	
	Rabbvatn	1	Annual	2015	TEC programme
	Gardsjøen	1	Annual	2015	
	Durvatn	1	Annual	2015	
	Holmvatn	1	Annual	2015	
	Rundvatnet	1	Annual	2015	
	Børsevatn	1	Annual	2015	

3.4.3 Sediments

Sediment studies allow the determination of status, historical trends and background levels of airborne pollutants. General variables, heavy metals and persistent organic pollutans are all recommended to be monitored (Table 5). Lake bottom sediment monitoring should be sampled every 5th or 10th year (Table 6). This is because most lakes in these latitudes have low sedimentation rates and thus only less frequent sampling can reveal true trends in concentrations of pollutants. However, some of the lakes in the Jarfjord area have higher sedimentation rates than average lakes in same latitudes and should therefore be sampled more often to get true trends of contaminants.

Table 5. Elements and variables in the sediment monitoring of small lakes in the border region.

Element	Variable
General	water content, loss on ignition, Ca, Mg, Na K, P
Heavy metals	Hg, Ni, Cu, Zn, Cd, Pb, Sr, Mn, Fe, Al, As
Persistent organic pollutants (POPs)*	PCB, dioxins, pesticides, brominated flame retardants

*Optional for each country

Sampling methods and analysis

Sampling time

- Not important.

Sampling site

- Deepest part of the lake.
- Sampling method.
- Gravity corer with diameter from 6 to 9.5 cm.
- Sediment core is sliced into 0.5 cm slices (0–0.5 cm, 0.5–1 cm, and reference from the lower part of the core).
- The coordinates of each sample station are determined with a GPS device.
- Sediment samples are placed in polyethylene containers, stored at a temperature of +4 ˚C or frozen until analysis.

Table 6. Lakes included in monitoring of sediments in the border region.

Country	Lake	Sampling interval	First sampling
Finland	Harrijärvi	every 10th year	2018
	Lampi 222	every 10th year	2018
Russia	Shounijaur	every 5th year	2019
	Virtuovoshjaur	every 5th year	2019
Norway	Rabbvatn	every 5th year	2018
	Gardsjøen	every 5th year	2018
	Durvatn	every 5th year	2018
	Holmvatn	every 5th year	2018
	Rundvatnet	every 5th year	2018
	Børsevatn	every 5th year	2018

3.4.4 Phytoplankton

Phytoplankton in lakes is often used as a parameter for monitoring of eutrophication. Massive algae blooms have been observed in several lakes in the border region over the last years. The reason for this is not clear.

Ideally, phytoplankton samples should be taken once per month in the growing season (June–September). At least one sample of phytoplankton should be taken in late summer because the ecological classification of WFD is based on the July-August phytoplankton community composition.

Chlorophyll concentration measurements, along with species distribution and biomass, are important. Species identification should be done according to similar identification guides. Indexes used may vary between the three countries according to their national regulations and needs: according to WFD for classification of phytoplankton in lakes, for instance (Table 7). Sampling interval may also vary (Table 8).

Table 7. Variables of phytoplankton and chlorophyll monitoring in small lakes in the border region.

Element	Variable
Phytoplankton	chlorophyll-α biomass (µg/l), total biomass of phytoplankton (mg/l) taxon-specific biomass (mg/l) for calculation of cyanobacteria relative biomass and Trophic Plankton Index (TPI) saprobic index*

*in Russia

Sampling method and analysis

Sampling time

- Lakes are sampled 1–4 times from June to September.
- In mid-August if only once a year.

Sampling site

- 'Mid-Lake station', typically the deepest basin.

Sampling method

- Standard water sampler (e.g. Rüttner sampler, flexible tube sampler, Ramberg sampler, Limnos sampler).
- Sampling depth 0–2 meter, normally in epilimnion (or in the euphotic zone).
- The samples are normally mixed in a container / bucked.
- Sub-samples for analyses representing the selected depth interval for analyses (species composition, biomass, cell numbers etc.) are taken from the mixed sample.
- For supplement samples a vertical hawl net of 10–20 µm can be used (or 45 µm at high plankton densities).
- Preservation: Lugol's solution (phytofix). Standard concentration: 0.5–1 ml per 100 ml water sample. For meso-oligotrophic lakes 0.5 ml per 200 ml water sample is recommended.
- Samples for chlorophyll-α analysis are taken from the mixed sample. Volume of filtered water may vary; normally 0.5–1.0 L. Enough water to give colour to the filter paper (GF/F filter) must be filtered. The volume of water filtered must be noted. The filter is packed in a tube, aluminum foil etc. (to prevent exposure to light) and frozen directly after filtration.

Table 8. Lakes included in monitoring of chlorophyll and phytoplankton in the border region.

Country	Lake	Chlorophyll – Samples per season	Phytoplankton – Samples per season	Sampling interval	First sampling
Finland	Pitkä Surnujärvi	2	1	every 3rd year	2017
	Harrijärvi	2	1	every 3rd year	2017
	Lampi 222	1	1	Annual	2015
	Sierramjärvi	1	1	Annual	2015
Russia	Shounijaur	4	4	Annual	2015
	Kochejaur	4	4	Annual	2015
	Virtuovoshjaur	4	4	Annual	2015
	Pikkujarvi	2	2	annual	2015
	Riuttikjaur	4	4	every 5th year	2019
	Toartesjaur	4	4	every 5th year	2015
Norway	Rabbvatn	1	1	Annual	2015
	Durvatn	1	1	Annual	2015
	Børsevatn	1	1	Annual	2015
	Rundvatnet	1	1	Annual	2015

3.4.5 Periphyton

Periphyton (benthic diatoms) studies are a reliable way to monitor eutrophication and changes in the production related to climate variations. Monitored variables and sampling interval may vary (Tables 9–10). Monitoring of periphyton in lakes and in running waters is a cost-effective parameter.

Table 9. Variables in the monitoring programme for periphyton in small lakes in the border region.

Element	Variable
Periphyton	species distribution saprobic index*

*in Russia

Sampling methods and analysis

Sampling time
- August–mid-September.

Sampling site
- Open rocky littoral zone.

Sampling method
- Sampling method is basically the same for lakes as for streams and rivers.
- Sample should be taken from 20–40 cm depth from areas that has been submerged (covered with water) most of the growing season, minimum the last 6-8 weeks.
- 5–10 rocks (diameter 10–15 cm) are brushed with a toothbrush and rinsed with clean water into a small bucket.

- The final sample volume should be at least 50 ml.
- The sample is preserved in ethanol or formaldehyde (3 drops of 37 % in a 10 ml glass tube).
- Parallel samples from different parts of the lake can be considered (2–4 sites). Areas with point discharges (e.g. farmed areas, houses etc.) should be avoided if the general trophic state of the lake is to be evaluated.

Table 10. Lakes included in monitoring of periphyton in the border region.

Country	Lake	Samples per season	Sampling interval	First sampling
Finland	Pitkä Surnujärvi	1	every 3rd year	2017
	Harrijärvi	1	every 3rd year	2017
	Lampi 222	1	every 3rd year	2017
	Sierramjärvi	1	every 3rd year	2017
Russia	Shounijaur	1	Annual	2015
	Kochejaur	1	Annual	2015
	Virtuovoshjaur	1	Annual	2015
	Pikkujarvi	1	Annual	2015
	Riuttikjaur	1	Annual	2019
	Toartesjaur	1	Annual	2015
Norway	Rabbvatn	1	every 2nd year	2015
	Durvatn	1	every 2nd year	2015
	Børsevatn	1	every 2nd year	2015
	Rundvatnet	1	every 2nd year	2015

3.4.6 Zooplankton

Zooplankton is an important prey for fish in many of the lakes in the area. Recent results indicate that fish communities are changing which again influences the zooplankton community. Zooplankton community structure gives important information of the fish communities and is needed in future full scale monitoring. Monitored variables and sampling interval may vary, and sampling is optional in Finland (Tables 11–12). Monitoring of zooplankton is a cost-effective parameter.

Table 11. Variables in the monitoring programme for zooplankton in small lakes in the border region.

Element	Variable
Zooplankton	species distribution biomass* saprobic index*

*in Russia

Sampling method and analysis

Sampling time

- June to October in this region.

Sampling site

- 'Mid-Lake station', typically the deepest main basin of the lake.

Sampling method

- For samples at different depths, different sampling devices can be used.
- For relative composition of species and different developmental stages: Vertical haul by standard plankton net; normal diameter: 25–30 cm, mesh size: 90 µm for crustacean zooplankton and 45 µm if small species/rotifers are included.
- Sampling depth is variable; normally 0–10 m (above thermocline).
- The zooplankton is filtered from the water through a plankton net before preservation.
- Preservation is done with ethanol (min. 70 % final concentration) or formaldehyde (min. 4 % final concentration). Lugol's solution (phyto-fix) can also be used (0.5 ml per 200 ml of water).

Table 12. Lakes included in monitoring of zooplankton in the border region.

Country	Lake	Samples per season	Sampling interval	First sampling
Finland	optional	1	every 2nd year	2016
Russia	Shounijaur	4	Annual	2015
	Kochejaur	4	Annual	2015
	Virtuovoshjaur	4	Annual	2015
	Pikkujarvi	2	Annual	2015
	Riuttikjaur	4	every 5th year	2019
	Toartesjaur	4	every 5th year	2015
Norway	Rabbvatn	1	every 2nd year	2015
	Durvatn	1	every 2nd year	2015
	Børsevatn	1	every 2nd year	2015
	Rundvatnet	1	every 2nd year	2015

3.4.7 Zoobenthos

Zoobenthos sampling should be carried out in the rocky littoral following standard procedures. Monitored variables may vary (Table 13). Littoral sampling should be done in all countries but profundal sampling can be omitted in Finland and Norway because the low amounts of animals that were caught in the soft lake bottoms during the ENPI TEC (2012–2015) project do not enable any kind of ecological status assessment (Tables 14–15). Alternative sampling of benthic fauna in outlet streams could be carried out in Norway and Finland.

Table 13. Elements and variables in the monitoring programme for zoobenthos in small lakes in the border region.

Element	Variable
Zoobenthos, littoral	species distribution ecological indexes*
Zoobenthos, profundal	species distribution relative taxon abundance taxon densities distribution

*in Russia

Sampling method and analysis

Littoral sampling time
- Normally late fall (late September – October/November).

Littoral sampling site
- Open exposed shore sites, bottom substrate: gravel, pebbles and rocks, depth: 25–40 cm.

Littoral sampling method
- Device: kick net, mesh size 0.25–0.5 mm.
- Norwegian method: Kicking: in the mouth of the net for 20 seconds moving backwards in line with the shoreline. Kicking time: 3 minutes, and approximately 1 m per 20 sec., totally 9 m. The net is emptied after 1 min sampling time. Three sites, two replicates from each site.
- Finnish method: Kicking: in the mouth of the net for 20 seconds moving backwards in line with the shoreline 1 meter. The net is emptied after each 20 s period. Three sites, two replicates from each site.
- Preservation: 70 % ethanol (final concentration).

Profundal sampling time
- Normally fall (August/September).

Profundal sampling site
- At least one deep basin per lake.

Profundal sampling method
- Device: Ekman bottom grab sampler (or similar grab).
- Sample is collected from the sediment of profundal area (> 5 m depth).
- Sediment caught in the sampler is sieved with a 0.5 mm sieve and preserved in 70 % ethanol (final concentration).
- Number of replicates: Sampling with at least 6 replicates in different parts of the profundal (8 samples from large, oligotrophic lakes).

Table 14. Lakes included in monitoring of littoral zoobenthos in the border region.

Country	Lake	Samples per season	Sampling interval	First sampling
Finland	Pitkä Surnujärvi	1	every 3rd year	2017
	Harrijärvi	1	every 3rd year	2017
	Lampi 222	1	every 3rd year	2017
	Sierramjärvi	1	every 3rd year	2017
Russia	Shounijaur	1	Annual	2015
	Kochejaur	1	Annual	2015
	Virtuovoshjaur	1	Annual	2015
	Pikkujarvi	1	Annual	2015
	Riuttikjaur	1	Annual	2019
	Toartesjaur	1	Annual	2015
Norway	Rabbvatn	1	every 2nd year	2015
	Durvatn	1	every 2nd year	2015
	Børsevatn	1	every 2nd year	2015
	Rundvatnet	1	every 2nd year	2015

Table 15. Lakes included in monitoring of profundal zoobenthos in the border region.

Country	Lake	Samples per season	Sampling interval	First sampling
Finland	optional	1	every 2nd year	2016
Russia	Shounijaur	1	Annual	2015
	Kochejaur	1	Annual	2015
	Virtuovoshjaur	1	Annual	2015
	Pikkujarvi	1	Annual	2015
	Riuttikjaur	1	Annual	2019
	Toartesjaur	1	Annual	2015
Norway	optional	1	every 2nd year	2015

3.4.8 Fish

Fish monitoring in the region constitutes studies of fish communities/populations and contaminants in selected lakes (Tables 16–17). It is important to get information in variation of populations and communities over time and sampling procedures should be kept the same as in earlier samplings to ensure comparability.

Table 16. Elements and variables in the monitoring programme for fish population in small lakes in the border region.

Element	Variable
Populations	number of species indicator species, biomass (CPUE g/net) number (number/net) biomass proportion of cyprinids biomass proportion of predatory fishes fry and juvenile of sensitive species fish growth
Heavy metals	Hg, Cu, Ni, Zn, Cd (in perch of 10–15 cm (15–20 cm in Finland) and in other fish common for consumpti-on)
POPs*	PCB, pesticides, dioxins, flame retardants
Malformations**	kidney, liver, gonads, gills, external changes

*Norway and Russia

**Russia only

Sampling method and analysis

Sampling time

- Normally fall (August/September).

Sampling site

- The whole lake.

Sampling method

- Sampling is done using standard Nordic gillnets (1.5 x 30 m). The nets are set overnight (approx. 12 h) in different depth zones at randomly chosen sites during period from mid-July until the beginning of Septem-ber.

- The catch of each mesh size of every gillnet is handled separately: (1) catch is assorted to species, (2) the total amount of every species is counted and weighed and (3) all individuals or a sub-sample (approx. 30 individuals) of every species is measured for length (1 cm length classes).
- Scale sample is the most efficient option for measuring fish growth. For this sample length-measured and gender-identified individuals should be taken and their age calculated.
- Scale samples are taken from whitefish, grayling, trout and arctic char (in Finland). The number of scale samples depends on the catch, but the maximum of 30 individuals would be adequate if the fish are abundant.
- Monitoring parameters of fish includes parameters that are common to all three countries as well as parameters that are monitored only in one or two countries.

Table 17. Lakes included in monitoring of fish populations in the border region.

Country	Lake	Samples per season	Sampling interval	First sampling
Finland	Pitkä Surnujärvi	1	every 6th year	2019
	Harrijärvi	1	every 6th year	2019
	LAMPI 222	1	every 6th year	2020
	Sierramjärvi	1	every 6th year	2020
Russia	Shounijaur	1	every 3rd year	2015
	Kochejaur	1	every 3rd year	2015
	Virtuovoshjaur	1	every 3rd year	2015
	Riuttikjaur	1	every 3rd year	2019
	Toartesjaur	1	every 3rd year	2015
Norway	Rabbvatn	1	every 3rd year	2015
	Durvatn	1	every 3rd year	2015
	Børsevatn	1	every 3rd year	2015
	Rundvatnet	1	every 3rd year	2015


Photo: Guttorm Christensen

4 Quality Assurances

All data generated by the various participants should be comparable on an objective basis. Data needs to be of a good quality and consistent in both time (in order to assess trends) and space (for the comparison of different areas). A quality assurance programme must be carried out to demonstrate that results of adequate accuracy are being obtained. Quality assurance and quality control procedures should include all parts of the activities performed on site and in laboratory.

Traditionally, the greatest amount of attention in quality assurance programmes is given to laboratory procedures. However, a significant source of error is related to field sampling, transportation, and sample preparation.

Field sampling must be done by trained personnel and sampling procedures must be harmonized between the three countries. Prevention of sample contamination or mix-up of samples during sampling or storage is critical in obtaining accurate measurements. All sampling equipment, containers and bottles used for sample collection or storage must be cleaned with specified methods depending on analyses. The containers and bottles must also be made of material that will neither absorb nor release measurable quantities of the determinant.

It is important that water sample bottles are kept away from light during and after sampling. Further, biological material should be preserved and stored according to uniform, established practices. Samples should be transported to the laboratory as soon as possible.

Parallel samples and field blanks (blank samples of distilled water) are taken regularly. Laboratory quality assurance will be managed with both external and internal quality assurance

Sediment sampling must be done by trained personnel. Laboratory quality assurance is a key factor.

Phyto- and zooplankton, periphyton and zoobenthos taxonomy analyses must be harmonized. Use of same identification guides and keys would assure the uniformity of species identification. Use of similar indexes would be beneficial in comparing lakes situated in different countries. For zoobenthos commonly agreed minimum level of identification is needed and a species list which fulfils the needs of EU Water Framework Directive would be convenient (e.g. Meissner et al. 2013).

Aquatic macrophytes monitoring needs to be done by personnel trained to recognize the flora of the area to a sufficient level. Either the Finnish or the Norwegian indexes need to be employed in data analysis.

Fish monitoring methods must be similar in all three countries, for example the use of similar gill nets (Nordic) is obligatory. In environmental status assessment similar indexes must be used to achieve comparability between all the countries.

5 Reporting and data updating

All monitoring data on water quality, sediments, phyto- and zooplankton, periphyton, zoobenthos, aquatic macrophyte and fish studies will be made available to all participant organizations. These data will be used for reporting of the monitoring programme.

A short report on water quality in the Pasvik watercourse and the small lakes will be prepared after every 3 years. Previous reports were published in 2011 and 2014. A joint report of the water quality, sediments and biological studies will be prepared after every 6 years. A more extensive assessment of the state of the freshwater ecosystems will be prepared after 12 years.

The monitoring programme will be evaluated and, if necessary, revised after 6 years. Also other times for evaluation are open because the programme is based on the principles of adaptive monitoring.

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Appendixes

Appendix 1. The recommended number of gillnet nights in proportion to the lake surface area in hectares and number depth zones (I-IV).

Table 1. Recommended number of gillnets according to size and depth of the lake.

Hectares	I	II	III	IV
<20	6	10	16	24
21-50	10	16	25	37
51-100	15	21	30	42
101-250	20	26	35	47
251-500	24	30	39	51
501-1000	28	36	48	64
> 1000	32	40	52	68

If a lake has maximum depth of 3 m it is considered to have only one depth zone (0–3 m) and the first (I) column is followed. The second (II) column is for two depth zones in lakes up to 10 m (< 3, 3–10 m). The third (III) column is for three depth zones in lakes up to 20 m (< 3, 3–10, 10–20 m). For the lakes deeper than 20 m, considered to have four depth zones (< 3, 3–10, 10–20, > 20 m), the fourth (IV) column is followed.

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