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Biological intercalibration: Invertebrates 2022

Photo: Christian Lucien Bodin

International Cooperative Programme on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes

Convention on Long-Range Transboundary Air Pollution

LRTAP
Long-range Transboundary Air Pollution

Norwegian Institute for Water Research

REPORT

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Abstract

The ICP Waters biological intercalibration of invertebrates was executed to harmonise taxonomic work across countries and is of high value in programmes where the focus is on community analyses, e.g., for the classification of ecological status according to the EU Water Framework Directive.

The 26th biological intercalibration of invertebrates in ICP Waters included two participants. A total 95 % of the species and 99 % of the genera were correctly identified in 2022. The mean Quality assurance index (Qi) ranged from 80.7 to 97.5 The results show that the average Qi has remained above 80% since 1992, suggesting skilled taxonomists in the laboratories affiliated to ICP Waters.

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CONVENTION OF LONG-RANGE TRANSBOUNDARY AIR POLLUTION

INTERNATIONAL COOPERATIVE PROGRAMME ON ASSESSMENT AND MONITORING EFFECTS OF AIR POLLUTION ON RIVERS AND LAKES

Biological Intercalibration: Invertebrates 2022

Prepared at the ICP Waters Programme Subcentre
NORCE AS
Bergen, March 2023

Preface

The International Cooperative Programme on Assessment and Monitoring of the Effects of Air Pollution on Rivers and Lakes (ICP Waters) was established under the Executive Body of the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) in July 1985. Since then, ICP Waters has been an important contributor to document the effects of implementing the Protocols under the Convention. ICP Waters has prepared numerous assessments, reports and publications that address the effects of long-range transported air pollution.

ICP Waters and its Programme Centre is chaired and hosted by the Norwegian Institute for Water Research (NIVA). A programme subcentre is established at NORCE, Bergen. ICP Waters is supported financially by the Norwegian Ministry of Climate and Environment and the Trust Fund of the UNECE LRTAP Convention.

The main aim of the ICP Waters programme is to assess, on a regional basis, the degree and geographical extent of the impact of atmospheric pollution, in particular acidification, on surface waters. More than 20 countries in Europe and North America participate in the programme on a regular basis.

An objective of the ICP Waters programme is to establish and maintain an international network of surface water monitoring sites and promote international harmonization of monitoring practices. A tool in this work are inter-laboratory quality assurance tests. Here biases between analyses carried out by individual participants of the programme are identified and controlled. The tests are also a valuable tool for taxonomic discussions and the exchange of identification keys among the participating laboratories, thereby improving the taxonomic skill.

Here we report the results from the 26th intercalibration of invertebrate fauna. We also compare results from all 26 intercalibrations. The report adheres to the format of previous reports on intercalibration published in ICP Waters, including sections with copied text.

Bergen, March 2023

Gaute Velle
ICP Waters Programme Subcentre

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Summary

The ICP Waters biological intercalibration of invertebrates is important for harmonizing taxonomic work across countries and is of high value in programmes where the focus is on community analyses, e.g., for the classification of ecological status according to the EU Water Framework Directive. Intercalibration practices ensures high quality data in the ICP Waters database and increases the taxonomic skills of the participants. The intercalibration under the ICP Waters programme was the first regular test of species level identification and has run annually since 1992. Here, we present results from the intercalibration in 2022 and trends in results from the intercalibration from the initial intercalibration in 1992 and up to the present.

The 26th biological intercalibration of invertebrates in ICP Waters included two participants. A total 95 % of the species and 99 % of the genera were correctly identified in 2022. The mean Quality assurance index (Qi) ranged from 80.7 to 97.5, where 80 which is the limit for good taxonomic work. The highest mean Qi- score for the intercalibration in 2022 was for Plecoptera while the lowest mean score was from the miscellaneous taxa. This deviates from a trend seen the last 26 years, where participants acquire highest scores for Trichoptera and the lowest score for Plecoptera. The average number of participating laboratories over time is 4.5. The results show that the average Qi has remained above 80% since 1992, suggesting skilled taxonomists in the laboratories affiliated to ICP Waters.

1 Introduction

The purpose of the biological intercalibration of invertebrates is to evaluate the quality of the biological data delivered to the Programme centre. The data are used nationally and by ICP Waters to indicate environmental conditions from the species and their tolerances (Raddum et al. 1988, Fjellheim and Raddum 1990, Raddum 1999, Velle et al. 2013, 2016). The significance of potential trends in biotic indices, both for a specific site/watershed and for comparisons of trends among regions or among countries, can be evaluated once the data quality is known. The data are also used in numerical analyses (Larsen *et al.* 1996, Skjelkvåle *et al.* 2000, Halvorsen *et al.* 2002, Halvorsen *et al.* 2003), and in analyses of biodiversity (Velle *et al*., 2013, Velle *et al*. 2016). The results from such data analyses are especially sensitive to the quality of the species identifications. The biological intercalibration focuses on the taxonomic skills of the participants and is a tool for improving the quality of work at the different laboratories, as well as harmonization of the biological database.

The methods for the biological intercalibration that we use were outlined in 1991 at the seventh ICP Waters Task Force meeting in Galway, Ireland. The countries/laboratories should know their native fauna. Since the fauna vary according to geographical regions, specific samples based on their native fauna are prepared for each participating laboratory. We cannot use standardized samples for all participants. Therefore, each laboratory sends identified samples of invertebrates from their own monitoring sites to the organizer (the Programme subcentre). The organizer adds species previously sampled and identified by the specific laboratory. Based on this, each laboratory receives individual test samples composed of species that they sampled and identified themselves and that represent their own monitoring region. Each participant is therefore tested on their ability to identify fauna that are be familiar to them. An important implication of this procedure is that the participant prepares the solution of the test, and that the organizer remains neutral without the ability to influence the results. To highlight that the organizer has little opportunity to influence the results, each participant is given the opportunity to comment on the results and agree on the conclusion from their part of the intercalibration.

The taxonomic skill of the participants is measured by using a quality assurance index (Raddum 2005). This index evaluates the skill of participants when identifying species and genera. It also considers the effort of identifying all specimens in the sample. The highest index score is 100, while a value of 80 is set as the limit of good taxonomic work.

This report mostly adheres to a similar format that has been used in previous reports and contains text partially or completely retained from previous reports (Raddum 2005, Fjellheim et al. 2014, Halvorsen et al. 2016, Velle et al. 2018).

2 Methods

Preparation of the test-samples

Samples of invertebrates were sent from all participating laboratories to the organizer at the ICP Waters subcentre. These samples were used to compose test samples, with the addition of specimens from earlier exercises and from collections at the subcentre. The test samples included caddis flies (Trichoptera), stone flies (Plecoptera), mayflies (Ephemeroptera) and miscellaneous.

Miscellaneous included water beetles (Coleoptera), crustaceans (Malacostraca), leeches (Hirudinea), mollusks (Gastropoda), dragonflies (Odonata), water boatmen (Corixidea), midges and flies (Diptera), butterflies and moths (Lepidoptera) and true bugs (Heteroptera). Both larvae and adults were included. Leeches, mollusks, and crustaceans are sensitive to acid water and important for the evaluation of acidification. The tolerance of some miscellaneous species is poorly known. They are often regarded as tolerant to acidic water and of low importance for the evaluation of acidity. They are still important in invertebrate community analysis.

The geographical distribution of the taxa was checked using the Fauna Europaea Web Service 2013 (http://www.faunaeur.org). This is a database of the scientific names and distribution of multicellular European land and fresh-water animals (see example in **Figure 1**).

Identification

To minimize possible faults, the following procedure was used in preparing the test samples:

- The participating laboratory first identified the source material for the test samples and shipped the specimens to the organizer.
- Two persons from the organizing institution verified the identification of the specimen as far as possible without damaging the individuals.
- The content of two test samples per participant was listed in a table. Two persons controlled that the correct numbers and species were placed in the test samples according to the table.

Damage to the material

The quality of the test material may be reduced during handling and shipping. Taxonomically important parts of the body, such as gills, legs, cerci and mouthparts can be lost or damaged during identification, handling and transportation. Mixing of individuals between samples may occur during identification. All above mentioned examples are source of errors that could influence the process of identification and verification of taxa negatively, and thereby the end results.

Evaluation

The participants were invited to comment on the results before the report was published. In this way, we removed potential bias - for example misidentification caused by damaged test material. In cases of disagreement between the participant and the organizer, the material may be checked again by the organizer and by the participant. This procedure may act educational for both parts, and ensures that both the participant agree on the conclusions from the intercalibration.

Figure 1. Geographical distribution of the caddisfly *Rhyacophila nubila* in Europe. This species is widely distributed but is absent from several West-European countries. Map after Fauna Europaea Web Service, http://www.faunaeur.org, Illustration: Arne Fjellheim

For calculation of errors, we took into account possible degradation of the material. Further, a misidentified species counted as only one fault, even if the sample includes many individuals of the species. We encouraged participants to give comments on matters that may impede the identification. For example, a misidentification will not count as a fault if a specimen lacks important taxonomic characters. Such comments must be made before the results are sent to the organizer. We have discriminated between short-comings in identification due to damaged material, and true errors (wrong species – or genus).

The organizer also noted how many specimens a participant has identified per sample. This is referred to as *percent identified*. A low percent means that many individuals were not identified and will

consequently reduce the value of the taxonomic work. In cases where more specimens were identified than sent to the laboratories, each excess specimen counted as one error.

Available material for making test samples vary. Normally, each laboratory receives between 60 and 130 species in the two samples. Samples with low diversity are easier to handle than samples with high diversity (see **Appendix B**). This should also be kept in mind when the results are evaluated. Small samples were avoided, as only a few misidentifications could result in a low score.

The total number of European mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera) species (in 2015) is 1814 (http://www.faunaeur.org). However, the biodiversity differs between countries. Generally, the number of species decreases along a gradient from Southern to Northern Europe. This is also a fact to bear in mind when judging taxonomical capacity. As an example of this, the freshwater fauna of Switzerland is much richer than in Norway and Sweden – despite the fact that the area of Switzerland is approximately 1/10 of the two Nordic countries (**Figure 2**).

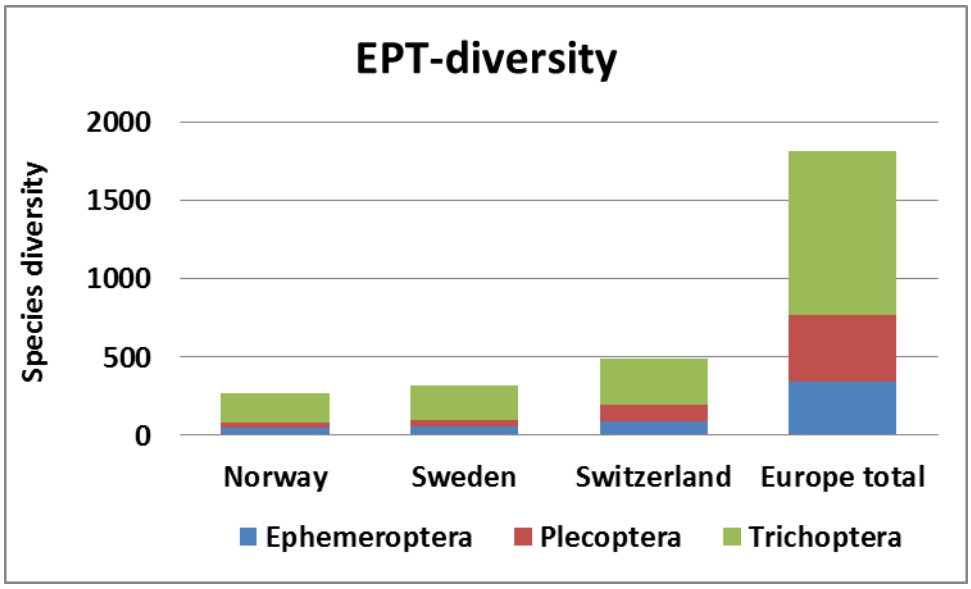


Figure 2. Species diversity of mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) in Norway, Sweden and Switzerland (after Fauna Europaea Web Service, http://www.faunaeur.org.

Quality assurance index

We have calculated the Quality assurance index, Qi, for the invertebrate groups as well as the mean index for each participant. The Qi integrates the separate levels of the identifications as follows:

Qi = (% correct species/10) * (% correct genus/10) * (% identified individuals/100)

Qi will be a number between 0 and 100 with increasing skill. A score ≥ 80 is regarded as good and thus acceptable taxonomical work.

Test of the subcentre

The ICP Waters subcentre in Bergen is tested with the help from the Swedish participant every second year. The Swedish University of Agricultural Sciences in Uppsala prepares and evaluates the test of the subcentre. Methodology and implementation are otherwise identical to the other tests.

3 Results and discussion

Two laboratories participated in the intercalibration of invertebrates in 2022 (**Appendix A**). The species lists and the identification results are shown in **Appendix B**, **Tables B.1-2**.

Mayflies (Ephemeroptera)

The identification of the mayflies (**Figure 3**) was flawless for Laboratory 2 with no misidentifications. Laboratory 1 misidentified a single individual at species level and failed to identify one individual in the sample. However, the Qi-score was above the limit (80) for good taxonomic work for both laboratories.

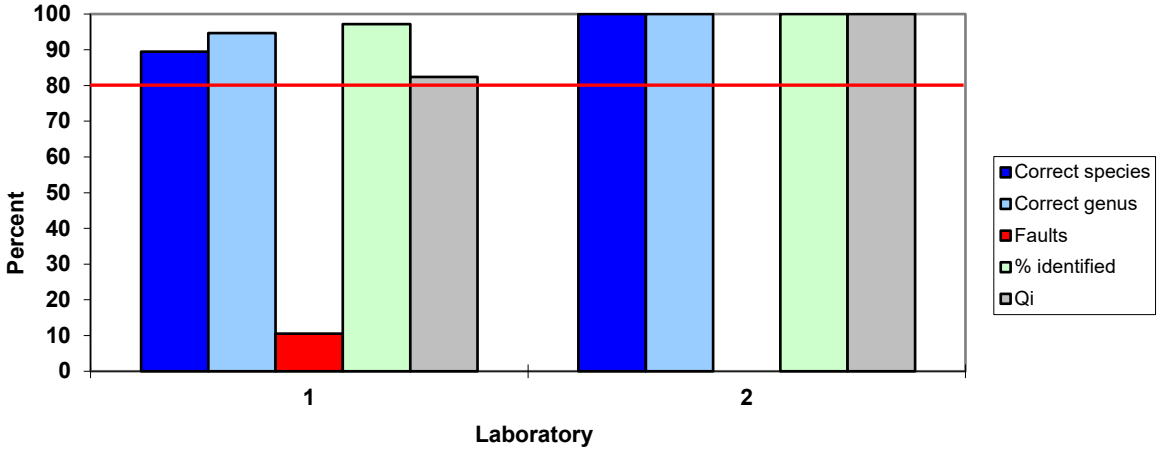


Figure 3. Results from the identification of mayflies. The red line indicates the limit for good taxonomic work. Qi = quality assurance index.

Stoneflies (Plecoptera)

Results for the identification of stoneflies are shown in **Figure 4**. Laboratory 1 was flawless and identified all individuals in the sample correctly, while laboratory 2 failed to identify the species of one individual. Both results were above the limit for good taxonomic work.

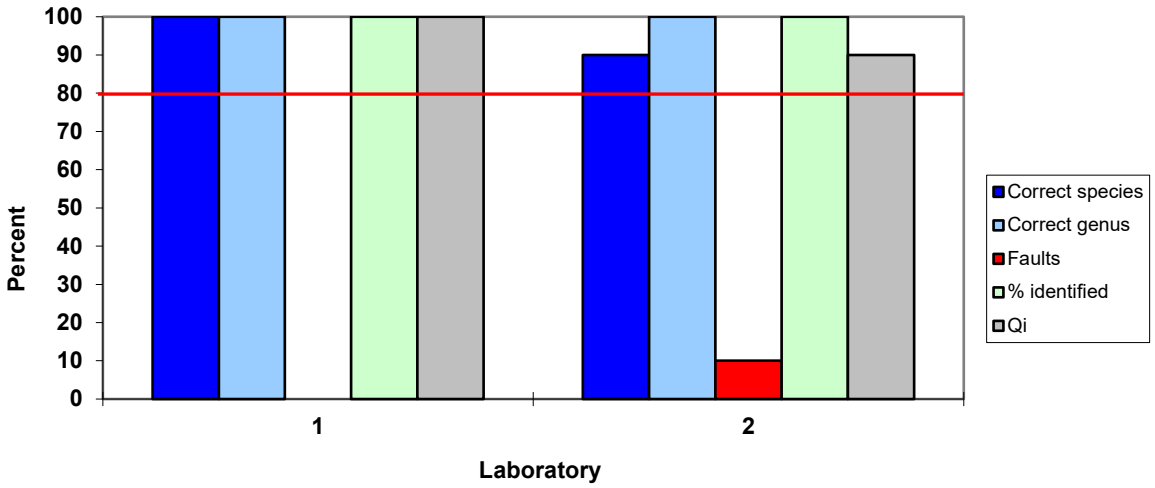


Figure 4. Results from the identification of stoneflies. The red line indicates the limit for good taxonomic work. Qi = quality assurance index.

Caddisflies (Trichoptera)

Laboratory 1 misidentified 3 individuals at genus level, and subsequentially at species level (**Figure 5**). This set the Qi score for caddisflies at 73.8, below the limit for good taxonomic work. This was caused by misidentification of two species. Laboratory 2 was flawless on the identification of caddisflies and acquired a Qi score of 100.

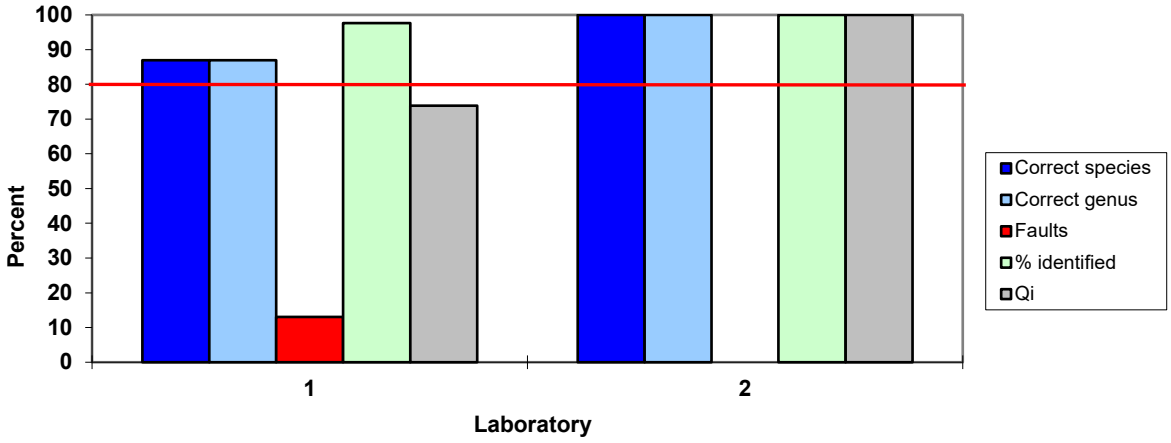


Figure 5. Results from the identification of caddisflies. The red line indicates the limit for good taxonomic work. Qi = quality assurance index.

Miscellaneous

Laboratory 1 misidentified 3 individuals at species level and 2 individuals at genus level and acquired a Qi score of 68.4 (**Figure 6**). This is below the score for good taxonomic work. Laboratory 2 correctly identified all species in their samples and acquired a Qi score of 100.

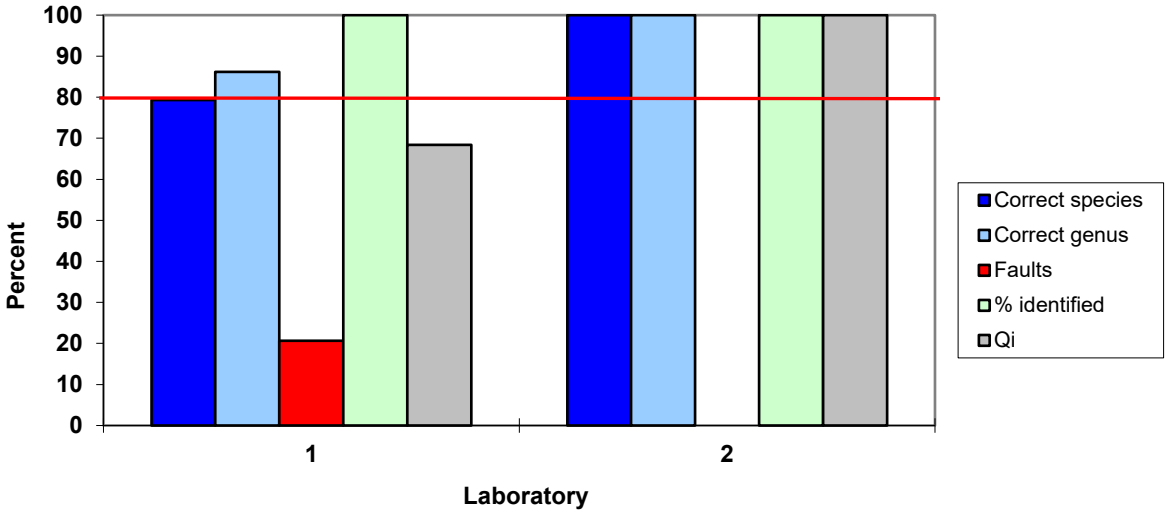


Figure 6. Results from the identification of miscellaneous groups of invertebrates. The red line indicates the limit for good taxonomic work. Qi = quality assurance index.

Total number of species in the sample

A total of 162 individuals were sent to the laboratories. Laboratory 1 received a total of 75 individuals, while laboratory 2 received 87 individuals. Of these, all but three specimens were reported to the organizer.

4 Overall evaluation

The laboratories correctly identified a high proportion of the total number of species in the test, but still acquired a mean Qi-score slightly lower than the average from the previous 26 years. However, the score was 8.9 points above the acceptable limit for good taxonomic work (**Figure 7**). The mean Qi was 80.7 for laboratory 1 and 97.4 for laboratory 2.

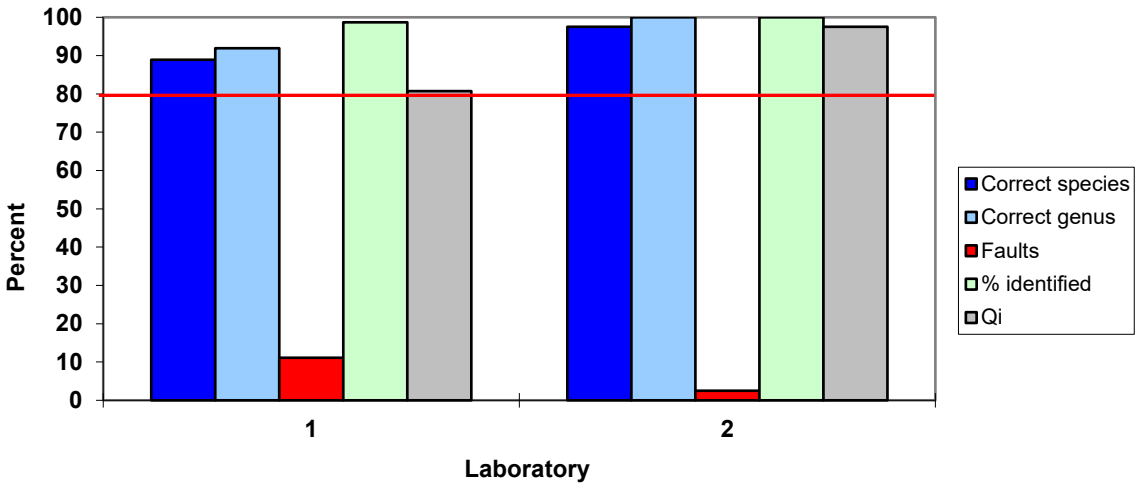


Figure 7. Mean skill in percent of identifying species and genus, and mean Qi for each laboratory. The red line indicates the acceptable limit. Qi = quality assurance index.

The highest mean Qi- score for the intercalibration in 2022 was in the group of Plecoptera with a score of 95%, while the lowest mean score was from the miscellaneous group with 84.2%. This deviates from a trend seen the last 26 years, where participants normally show highest skills in identifying Trichoptera and the lowest skills in identifying Plecoptera. This year, one laboratory achieved an overall QI-score of 80.7, which is right above what is considered a limit for good taxonomic work.

The biological intercalibration is important for harmonizing biological material/databases and will be of high value in projects that focus on community analyses, or where the ecological status of waterbodies should be determined. The biological intercalibration under the ICP Waters programme was the first regular test aiming to test taxonomic skills in identifying benthic invertebrates. Today, similar tests are run by the North American Benthological Society (http://www.nabstcp.com) and by the Natural History Museum, London (Identification Qualifications – IdQ test). The invertebrate groups covered in the latter test are those used in the BMWP water quality score system (Armitage et al., 1983) and include groups used for monitoring freshwater environments under the EU water framework directive (Schartau et al. 2008). In 2018 and in 2020, NORCE also organized biological intercalibrations for Norwegian laboratories that identify benthic invertebrates on a regular basis. The result from the Norwegian tests indicated that the participants assigned specimens from an identical sample to a significant different number of taxa and with a significantly different species composition (Velle et al. 2018, Velle et al. 2020). The differences resulted in a classification of ecological status that to some extent was person-dependent (Velle et al. 2018). These results highlight the importance of quality assurance and coordination of species identifications. Because of the results of the intercalibration in Norway, regular intercalibrations will be performed in the future. Also, the

Norwegian Environment Agency use participations in intercalibrations as part of the evaluation criteria when assigning companies to new projects (Velle et al. 2020).

5 Trends over time

The invertebrate intercalibration in ICP Waters started in 1992. An overall high of 11 laboratories participated during the first intercalibration (**Figure 8**). Since then, the average has been just under five participants per year. Twenty laboratories from 17 countries have participated over the years, including Austria, Belgium, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Latvia, Norway, Russia, Sweden, Switzerland and UK. This year, two laboratories participated in the intercalibration with one taxonomist participating from each laboratory. Several new laboratories have shown interest in participating in 2023.

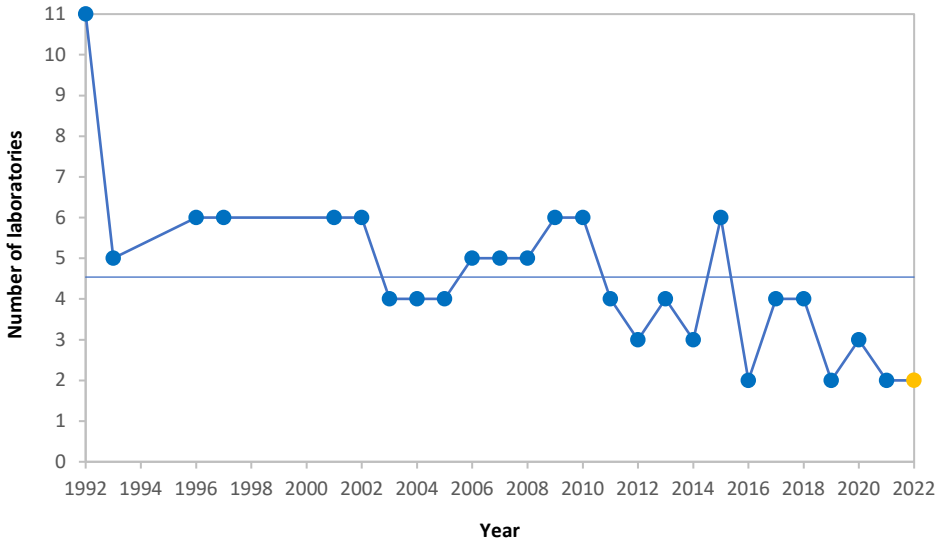


Figure 8. The number of participating laboratories in the ICP Waters invertebrate intercalibration since the first intercalibration in 1992. The number of participants in 2022 is shown in yellow.

The intercalibration laboratory protocol is unchanged since 1992, while the quality assurance index (Qi) has been used since it was introduced in 2005 (Raddum, 2005). After back calculating the Qi for the period prior to 2005 the Qi now is available from 1992 and up to the present (**Figure 9**). Trends in the Qi-score show that the mean has remained above 80%, suggesting good taxonomic work and skilled taxonomists in the laboratories affiliated to ICP Waters. When the Qi is broken into individual invertebrate groups, it is clear that the laboratories, on average over the years, perform best for caddisflies and worst for stoneflies (**Figure 10**). The results from this year's intercalibration deviated from the previous trends by showing a higher average Qi-score in the plecopteran group than the trichopteran group.

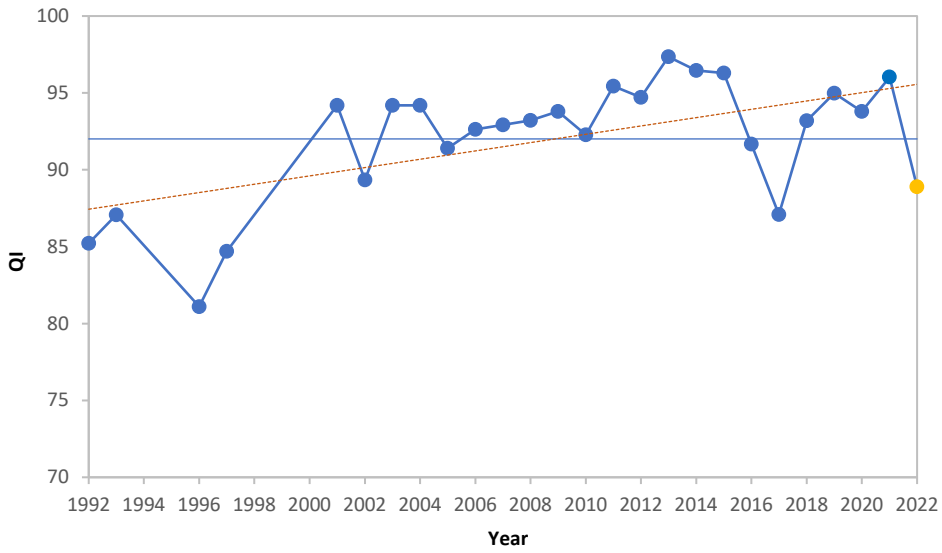


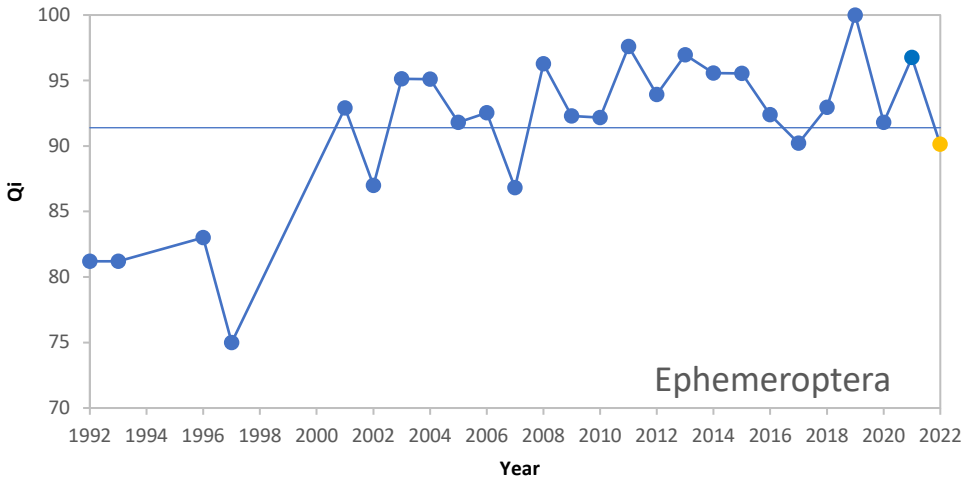
Figure 9. The mean quality assurance index for the invertebrate intercalibration through time. Horizontal line represents the mean quality assurance index (QI) for the last 30 years. Results from 2022 are shown in yellow.

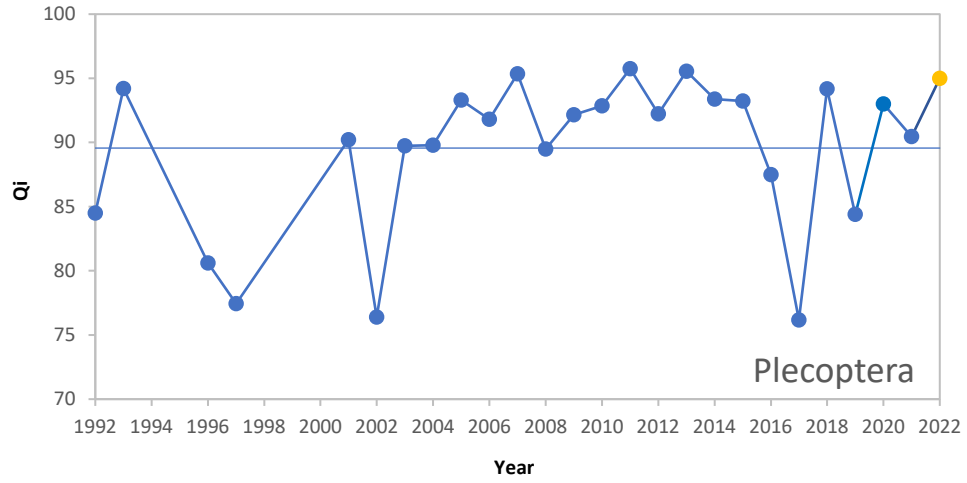
One of the aims of the intercalibration is to improve the taxonomic skill of the participating laboratories. The mean Qi has increased since the intercalibration started, suggesting that the skills have improved (**Figure 9**). Still, at least four issues influence the Qi:

1) The Qi varies according to the skills of the participants. A consequence is that the Qi often decreases when new laboratories participate or if a skilled taxonomist retires. As an example, the expert on the miscellaneous group retired from Laboratory 2 in 2018, which resulted in a low Qi.
2) The Qi varies according to the difficulty of the test, which mostly depends on the size of the specimen and the rarity of the species. For example, more species in the miscellaneous group were included in the intercalibration around 2005 since new acidification indices demanded a higher taxonomic resolution for this group. Hence, the Qi subsequently dropped for some years before it gradually increased (**Figure 10**). The increase likely reflects improved taxonomic skill.
3) There is inevitably some chance involved. For example, samples have occasionally dried out, a taxonomist may have overlooked a specimen or forgotten to make comments on a damaged specimen.
4) Some years, the participants send too few specimens from their home region to the intercalibration organizer. This may influence the results since the organizer then needs to include specimen from other regions to the test of that specific participant. It is therefore important that the participants send an abundance of specimens to the organizer.
5) The mean Qi is calculated as the average of the scores from each taxonomic group. The Qi-score for each group is calculated from the percentage of errors made in the group. This means that a taxonomic error in a group with few individuals will have a larger negative impact on the Qi-score than an error in a group with many individuals.

The mean Qi has decreased during 2012-2017, more steeply between 2015 and 2017, to increase again towards the present. According to the taxonomists, the difficulty increased during 2015-2017, and especially for stoneflies. In addition, it seems some other above-mentioned factors apply; there was a new participant, one key taxonomist retired, one sample dried out and one laboratory sent too few specimens from their home region. Hopefully, the abundance of such events will decline during

forthcoming intercalibrations. The mean Qi for 2022 decreased from 2021, however as previous years where laboratories have had poor results, similar factors are often in play. As with the results from 2015-2017, one laboratory this year had a key taxonomist retire, meaning this was the first time the participant worked alone in the laboratory. Consulting and discussing keys with other taxonomist colleagues, is an important part of correctly identifying species as many key traits are very similar between species and are extremely hard to detect. This underlines the difficulty of the job and though some years, the score decline, the trend from the last 30 years clearly indicates an overall increase in skill among the laboratories that participate.





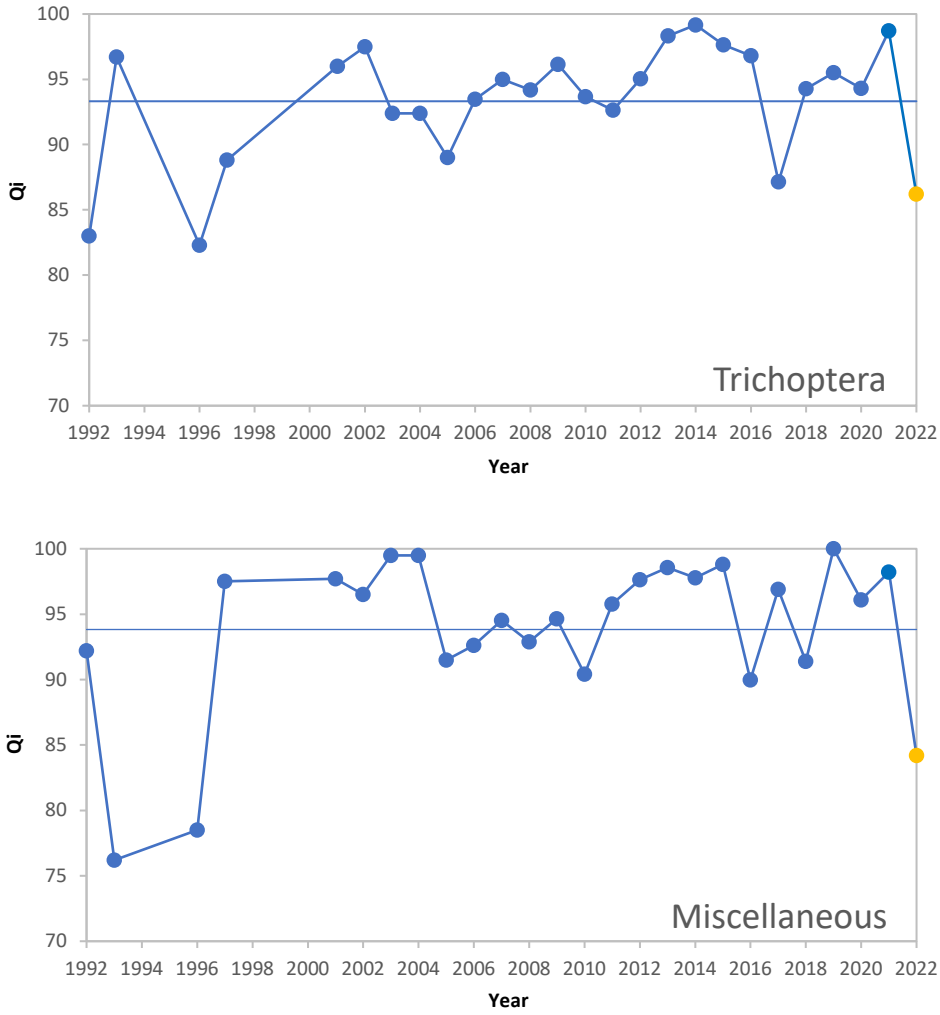


Figure 10. The mean quality assurance index (Qi) of the intercalibrations through time for mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera) and miscellaneous groups of invertebrates. The horizontal line represents the overall mean Qi for each invertebrate group. The yellow marker indicates results from 2022. Qi above 80 is regarded as good taxonomical work.

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Velle, G., Birkeland, I.B., Landås, T., Johannessen, A. 2020. Ringtest for artsbestemmelser av bunndyr i ferskvann 2019. NORCE LFI rapport nr. 392, Miljødirektoratet rapport M-1824|2020. 36s.

Appendix A. Responsible laboratories

Each participating laboratory is identified by a number, which is identical with laboratory numbers in the report and Appendix B. Laboratories participating in the intercalibration of invertebrates in 2022 are:

1. Norwegian Research Centre AS, P.O. box 7810 N-5020 Bergen, Norway. Responsible taxonomist: Torunn S. Landås

2. Swedish University of Agricultural Sciences, Dept. of Environmental Assessment, P.O. Box 7050, S-75007 Uppsala, **Sweden**. Responsible taxonomist: Dr. Magda-Lena Wiklund.

Appendix B. Species lists

Table B. 1. Identified species/genus in sample 1 and 2 by Laboratory 1

Laboratory 1	***Sample 1***		**Sample 2**	
	Delivered	**Identified**	**Delivered**	**Identified**
Ephemeroptera				
Arthroplea congener	1	1	1	1
Baetis niger	1	1	1	1
Baetis rhodani	1	1	1	1
Caenis horaria				
Caenis luctuosa	1	1	1	1
Centroptilum luteolum	1			
Ephemera danica	1	1		
Ephemerella aurivilli	1	1	1	1
Ephemerella ignita	1	1		
Caenis rivulorum			2	2
Ephemera vulgata			1	1
Heptagenia sulphurea			1	1
Leptophlebia marginata			1	1
Baetis muticus			1	1
Plecoptera				
Amphinemura borealis	1	1	1	1
Dinocras cephalotes	1	1		
Diura nanseni	1	1		
Protonemura meyeri	1	1	1	1
Leuctra nigra	1	1	1	1
Nemoura avicularis	1	1		
Nemoura cinerea	1	1	1	1
Nemoura flexuosa	1	1		
Nemurella pictetii	1	1	1	1
Perlodes dispar			1	1
Amphinemura sulcicollis			1	1
Leuctra fusca			1	1
Trichoptera				
Brachycentrus subnubilus	1	1		
Ceraclea annulicornis	1	1		
Cyrnus insolutus				
Glyphotaelius pellucidus	1			
Hydropsyche siltalai	1	1		
Micrasema setiferum	1	1		
Micrasema gelidum	1	1	1	1

Oecetis testacea	1	1	1	1
Oecetis ochracea	1	1		
Potamophylax latipennis	1	1		
Psychomyia pusilla	1	1		
Rhyacophila nubila	1	1	1	1
Athripsodes aterrimus			1	1
Beraeodes minutus			1	1
Hydropsyche pellucidula			1	1
Hydatophylax infumatus			1	
Ceraclea nigronervosa			1	1
Molannodes tinctus			1	1
Nemotaulius punctatolineatus			1	1
Potamophylax cingulatus			1	1
Tinodes waeneri			1	
Coleoptera				
Elmis aenea	1	1	1	1
Graphoderus cinereus	1			
Hygrotus versicolor	1	1		
Limnius volckmari	1	1	1	1
Stenelmis canaliculatus	1	1		
Rhantus frontalis			1	1
Diptera				
Chaoborus flavicans	1	1		
Dicranota sp.	1	1	1	1
Eloeophila sp.			1	1
Odonata				
Cordulea aenea	1	1		
Cordulegaster boltonii	1	1	1	1
Ischnura elegans	1			
Enallagma cyathigerum			1	1
Somatochlora metallica			1	1
Div				
Gyraulus albus	1	1		
Gyraulus acronicus	1	1		
Planorbis planorbis	1			
Sialis lutaria	1	1		
Erpobdella octoculata	1	1		
Aphelocheirus aestivalis			1	1
Galba truncatula			1	1
Gyraulus crista			1	1
Hippeutis complanatus			1	
Physa fontinalis			1	1

Gammarus lacustris			1	1

Table B. 2. Identified species/genus in sample 1 and 2 by Laboratory 2

Laboratory 2	**Sample 1**		**Sample 2**	
	Delivered	**Identified**	**Delivered**	**Identified**
Ephemenoptera				
Leptophlebia marginata	1	1	1	1
Caenis horaria	1	1		
Baetis rhodani	1	1		
Ephemera vulgata	1	1		
Baetis muticus	1	1		
Ephemerella aurivilli	1	1		
Centroptilum luteolum	1	1		
Leptophlebia vespertina	1	1		
Heptagenia dalecarlica	1	1		
Ephemerella mucronata	1	1		
Caenis luctuosa			1	1
Caenis rivulorum			1	1
Kageronia fuscogrisea			1	1
Ameletus inopinatus			1	1
Baetis digitatus			1	1
Ephemera danica			1	1
Rhitrogena germania			1	1
Plecoptera				
Taeniopteryx nebulosa	1	1		
Protonemura meyeri	1			
Nemoura cinerea	1	1		
Brachyptera risi	1	1		
Leuctra fusca	1	1		
Siphonoperla burmeistreri			1	1
Leuctra nigra			1	1
Amphinemura sulcicollis			1	1
Diura nanseni			1	1
Capnopsis schilleri			1	1
Trichoptera				
Phryganea bipunctata	1	1		
Hydropsyche pellucidula	1	1		
Holocentropus dubius	1	1		
Rhyacophila nubila	1	1		
Mystacides azurea	1	1	1	1
Molannodes tinctus	1	1		

Micrasema gelidum	1	1		
Lepidostoma hirtum	1	1		
Goera pilosa	1	1		
Polycentropus flavomaculatus	1	1		
Philopotamus montanus	1	1		
Tinodes waeneri	1	1	1	1
Athripsodes cinereus	1	1		
Chimarra marginata	1	1		
Athripsodes aterrimus			1	1
Micrasema setiferum			1	1
Hydropsyche saxonica			1	1
Cyrnus insolutus			1	1
Holocentropus picicornis			1	1
Ecnomus tenellus			1	1
Oecetis testacea			1	1
Sericostoma personatum			1	1
Cheumatopsyche lepida			1	1
Molanna angustata			1	1
Hydropsyche siltalai			1	1
Neureclipsis bimaculata			1	1

Miscelaneous

Elmis aenea	1	1	1	1
Laccophilus hyalinus	1	1		
Hygrotus versicolor			1	1
Haliplus sp.			1	1
Limnius volckmari			1	1
Normandia nitens			1	1
Limnophora sp.			1	1
Gammarus pulex	1	1		
Asellus aquatius			1	1
Bithynia leachii	1	1		
Potamopyrgus antipodarum			1	1
Bithynia tentaculata			1	1
Phyrrosoma numphyla	1	1		
Onychogomphus forcipatus	1	1		
Erythromma najas			1	1
Ilyocoris cimicoides	1	1		
Aphelocheirus aestivalis			1	1
Erpobdella octoculata	1	1		

Appendix C. Thematic reports from the ICP Waters programme

Since its establishment in 1985, the ICP Waters programme has prepared numerous assessments, reports and publications that address the effects of long-range transported air pollution, including thematic reports, chemical intercalibrations, biological intercalibrations, proceedings of Task Force meetings, and peer-reviewed articles. Reports and publications are available at the ICP Waters website; http://www.icp-waters.no/

Thematic reports from the ICP Waters programme from 2000 up to present are listed below.

Austnes, K., Hjermann, D.Ø., Sample, J., Wright, R. F., Kaste, Ø., and de Wit, H. 2022. Nitrogen in surface waters: time trends and geographical patterns explained by deposition levels and catchment characteristics. NIVA SNO 7728-2022. **ICP Waters report 149/2022**.

Thrane, J.E., de Wit, H. and Austnes, K. 2021. Effects of nitrogen on nutrient-limitation in oligotrophic northern surface waters. NIVA report SNO 7680-2021. **ICP Waters report 146/2021.**

Garmo, Ø., Arle, J., Austnes, K. de Wit, H., Fölster, J., Houle, D., Hruška, J., Indriksone, I., Monteith, D., Rogora, M., Sample, J.E., Steingruber, S., Stoddard, J.L., Talkop, R., Trodd, W., Ulańczyk, R.P. and Vuorenmaa, J. 2020. Trends and patterns in surface water chemistry in Europe and North America between 1990 and 2016, with particular focus on changes in land use as a confounding factor for recovery. NIVA report SNO 7479-2020. **ICP Waters report 142/2020**

Austnes, K. Aherne, J., Arle, J., Čičendajeva, M., Couture, S., Fölster, J., Garmo, Ø., Hruška, J., Monteith, D., Posch, M., Rogora, M., Sample, J., Skjelkvåle, B.L., Steingruber, S., Stoddard, J.L., Ulańczyk, R., van Dam, H., Velasco, M.T., Vuorenmaa, J., Wright, R.F., de Wit, H. 2018. Regional assessment of the current extent of acidification of surface waters in Europe and North America. NIVA report SNO 7268-2018. **ICP Waters report 135/2018**

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De Wit, H., Hettelingh, J.P. and Harmens, H. 2015. Trends in ecosystem and health responses to long-range transported atmospheric pollutants. NIVA report SNO 6946-2015. **ICP Waters report 125/2015**.

De Wit, H. A., Garmo Ø. A. and Fjellheim A. 2015. Chemical and biological recovery in acid-sensitive waters: trends and prognosis. **ICP Waters Report 119/2014**.

Holen, S., R.F. Wright and Seifert, I. 2013. Effects of long-range transported air pollution (LTRAP) on freshwater ecosystem services. NIVA report SNO 6561-2013. **ICP Waters Report 115/2013**.

Velle, G., Telford, R.J., Curtis, C., Eriksson, L., Fjellheim, A., Frolova, M., Fölster J., Grudule N., Halvorsen G.A., Hildrew A., Hoffmann A., Indriksone I., Kamasová L., Kopáček J., Orton S., Krám

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Wright, R.F., Helliwell, R., Hruska, J., Larssen, T., Rogora, M., Rzychoń, D., Skjelkvåle, B.L. and Worsztynowicz, A. 2011. Impacts of Air Pollution on Freshwater Acidification under Future Emission Reduction Scenarios; ICP Waters contribution to WGE report. NIVA report SNO 6243-2011. **ICP Waters report 108/2011**.

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ICP Waters Programme Centre 2010. ICP Waters Programme manual. NIVA SNO 6074-2010. **ICP Waters report 105/2010**.

De Wit, H.A. and Lindholm M. 2010. Nutrient enrichment effects of atmospheric N deposition on biology in oligotrophic surface waters – a review. NIVA report SNO 6007 - 2010. **ICP Waters report 101/2010**.

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Skjelkvåle, B.L., and De Wit, H. (eds.) 2008. ICP Waters 20 year with monitoring effects of long-range transboundary air pollution on surface waters in Europe and North-America. NIVA report SNO 5684-2008. **ICP Waters report 94/2008**.

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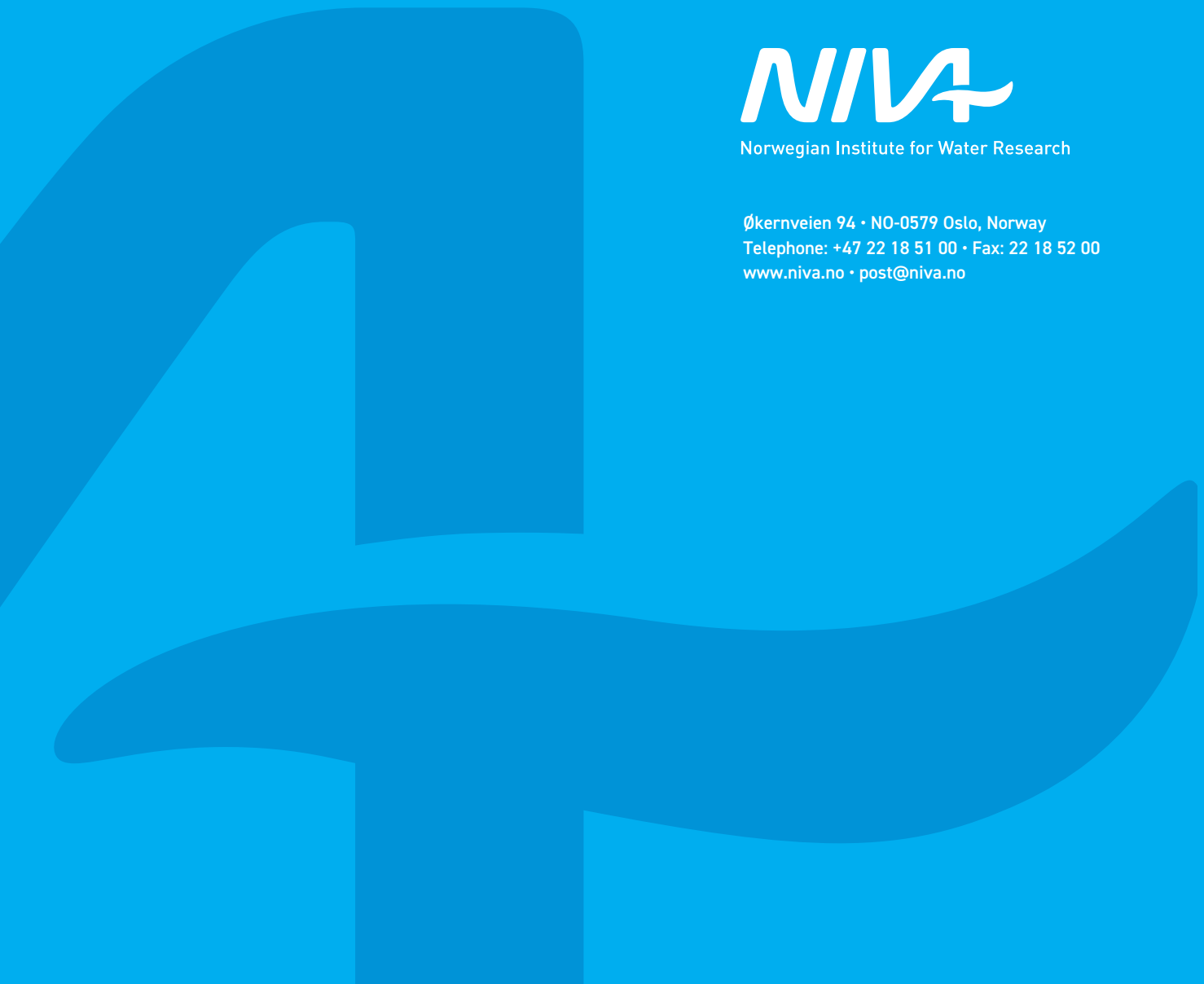

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