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

Convention on Long-Range Transboundary Air Pollution

Norwegian Institute for Water Research
– an institute in the Environmental Research Alliance of Norway

REPORT

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Abstract

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CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

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

Proceedings of the 28th Task Force meeting of the ICP Waters Programme in Verbania Pallanza, Italy,
October 8 – 19, 2012

Prepared at the ICP Waters Programme Centre
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Preface

The international cooperative programme on assessment and monitoring 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 (LRTAP) in July 1985. Since then ICP Waters has been an important contributor to document the effects of implementing the Protocols under the Convention. Numerous assessments, workshops, reports and publications covering the effects of long-range transported air pollution has been published over the years.

The ICP Waters Programme Centre is hosted by the Norwegian Institute for Water Research (NIVA), while the Norwegian Climate and Pollution Agency (Klif) leads the programme. The Programme Centre's work is supported financially by Klif.

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.

ICP Waters is based on existing surface water monitoring programmes in the participating countries, implemented by voluntary contributions. The ICP Waters site network is geographically extensive and includes long-term data series (more than 20 years) for many sites. The programme yearly conducts chemical and biological intercalibrations.

At the annual Programme Task Force, national ongoing activities in many countries are presented. This report presents national contributions from the 28th Task Force meeting of the ICP Waters programme, held in Verbania Pallanza, Italy, October 8 – 10, 2012.

Brit Lisa Skjelkvåle
ICP Waters Programme Centre

Oslo, January 2013

Contents

1. Introduction

The International Cooperative Programme on Assessment and Monitoring of Rivers and Lakes (ICP Waters) is a programme under the Executive Body of the Convention on Long-Range Transboundary Air Pollution. The main aims of the programme are:

- *To assess the degree and geographic extent of the impact of atmospheric pollution, in particular acidification, on surface waters;*
- *To collect information to evaluate dose/response relationships;*
- *To describe and evaluate long-term trends and variation in aquatic chemistry and biota attributable to atmospheric pollution.*

The national contributions on ongoing activities that were presented during the ICP Waters Task Force meeting in Verbania Pallanza, Italy, October 8 – 10, 2012 were grouped thematically. A short summary of each presentation is given in the Minutes (0. Selected presentations are reported more extensively in the Proceedings.

Water chemistry

- Results from the Italian ICP WATERS network: a focus on nitrogen, *Michela Rogora, Aldo Marchetto, Rosario Mosello*
- Are Alpine lakes really recovering from acidification? An analysis of the main factors affecting long-term changes in high altitude lakes chemistry over 30 years. L*uca Colombo et al., Switzerland and Italy*
- A note on the impact of permafrost melt on high mountain freshwater quality; *Hansjörg Thies, Austria*

Biological response

- Macroinvertebrate as indicators for acidification in high altitude Alpine lakes. *Sandra Steingruber, Switzerland*
- Biological recovery of reservoirs in the Jizera Mountains (North Bohemia, Czech Republic) and their tributaries from acidification (1992 - 2011). *Zuzana Horicka et al. Czech republic*

Heavy metals and POPs

- Stable isotopes of N and C are needed to understand mercury levels in different fish communities. *Bjørn Olav Rosseland, Programme centre, Norway*

2. Workshop on Long-term ecological research networks (LTER): challenges, perspectives and links with ICP waters

As a part of the task Force meeting there were a small workshop on the LTER-Europe network, chaired by *Alessandra Pugnetti, Italy.*

The Task Force meeting concluded as follows :

"The Task Force meeting applauds the important work done by LTER Europe, to support and sustain monitoring networks. Monitoring is at the basis of the work done by ICP Waters, and the data that are collected are highly suitable for analysis of effects of climate change and air pollution. Increased cooperation is expected to be of mutual interest. For ICP Waters, it is particularly important to increase visibility and secure funding at the national level.

The Task Force meeting urges all focal points to contact their national representative in LTER Europe to consider possibilities to include their sites in the LTER network. The Programme Centre will add relevant information on LTER Europe on the ICP Waters homepage

The Task Force meeting suggests that the Programme Centre contacts LTER Europe to get an overview of common sites in both networks

The Task Force meeting recommends that the Programme Centre makes available to LTER Europe the ICP Waters manuals and also their experience with harmonization of data and trend analysis."

3. Results from the Italian ICP Waters network: a focus on nitrogen

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The chemistry of a number of water bodies in the area of Lake Maggiore, North-Western Italy, has been monitored since the 1970s, in the framework of studies on eutrophication and acidification (Mosello et al., 2001). An extensive network for the study of atmospheric deposition chemistry exists in this area and selected sites (alpine lakes and subalpine rivers) have contributed data to ICP Waters (Mosello et al., 2000).

The study area is highly affected by atmospheric N inputs (about 20 kg N ha^{-1} y^{-1} as the sum of ammonium and nitrate), due to a combination of high amounts of precipitation (1700-2000 mm) and high concentrations of N compounds in atmospheric deposition. Atmospheric pollutants are transported from the Po Valley, the most industrialized and urbanized area in Italy, towards the Alps, where they are deposited via atmospheric deposition (Mosello et al., 2001). Furthermore, the wet deposition data collected in the study area underestimate the total deposition of reduced N: dry deposition infact has been estimated to be between 21 and 37% of total N for Alpine and subalpine sites in Northern Italy (Balestrini et al., 2000).

The huge flux of N affecting the Lake Maggiore area has been fairly stable for about 30 years, and it has caused saturation of terrestrial catchments and increasing levels of nitrate in surface waters (Mosello et al., 2001; Rogora et al., 2007). Nitrogen budgets performed for selected river sites showed that the atmospheric input of N cannot be fully retained by soil and vegetation in catchments, with N retention varying from 60-70% of the input in the Northern part of the area, to 20-30% or even lower in the southern catchments (Rogora et al., 2006b).

Recently, monitoring data for both rivers and lakes showed a reversal in NO_3 trends. This change was widespread, affecting high-altitude lakes in the Alps and subalpine lakes and rivers, and occurred at almost the same time at all sites (Rogora et al., 2012). Trends of NO_3 concentrations detected at 11 sites (lakes and rivers) are presented in figure 1, both as yearly mean values and as normalized values (Z-scores). The use of normalised data allows a better evaluation of the shape of the trends and of the presence of common patterns among sites. The data highlight a synchronous pattern, with a dominant positive trend until 2000-2005, followed by a decreasing phase. The high altitude lakes LPS and LPI (Lake Paione Superiore and Inferiore, located at 2269 and 2200 m a.s.l., respectively) showed the steepest decrease of all sites, with the most pronounced decrease in relative terms (-40%, from 20-25 $\mu eq\ L^{-1}$ in the 1980s and 1990s to the recent values of between 10 and 15 $\mu eq\ l^{-1}$). Besides the similarity of trends, a further feature common to most of the data series was the presence of a high interannual variability in the years between 1999 and 2004; 2002 and 2003 in particular were characterized by peak values of NO_3 at several sites (Fig. 1).

To assess changes of NO_3 concentration also at a seasonal level, the mean monthly values were compared for two distinct periods, 2000-2005 and 2006-2010. The latter period was characterised by lower NO_3 levels in every month of the year; furthermore, most of the sites show a decrease in concentrations in June-July of each year, in correspondence with the growing season (Rogora et al., 2012).

Both the long-term trends and the seasonal change of NO_3 in running waters lead to the hypothesis of an initial recovery from elevated N deposition. As lake and river catchments are characterised by sharply different topography, morphology and land cover (Mosello et al., 2001), the similarity of their temporal trends can be ascribed to regional factors, such as changes in atmospheric N deposition or climate drivers.

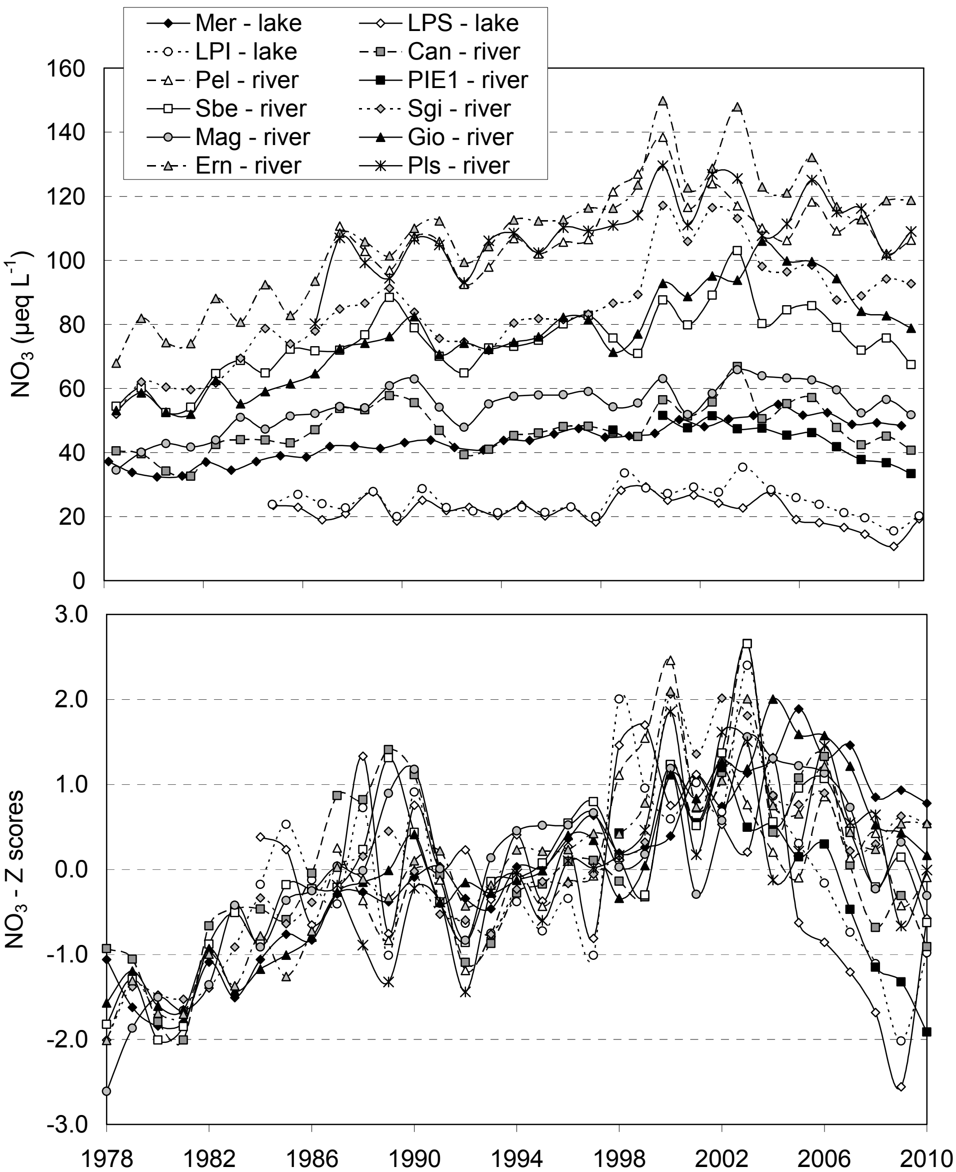

Figure 1. *Long-term trends of yearly NO_3 concentrations (above) and their normalized values (Z-scores) (below) at 12 surface water monitoring sites in the Lake Maggiore area, N-W Italy.*

An analysis of long term trends of N deposition in the study area highlighted a recent decrease, mainly due to decreasing emissions and partly to the lower amount of precipitation occurring between 2003 and 2009 (Rogora et al., 2012). The long-term pattern of deposition values highlighted a high interannual variability, due to the highly variable precipitation amount recorded in different years (Fig.

2). Similarly to surface water sites, also atmospheric deposition data show a fairly similar temporal pattern, with a tendency towards lower values in recent years (2003-2010) compared with the previous period: the decrease in the sum of NH_4 and NO_3 deposition in 2003-2010 compared to the previous period (1984-2002) was between 15 and 30% (Rogora et al. 2012).

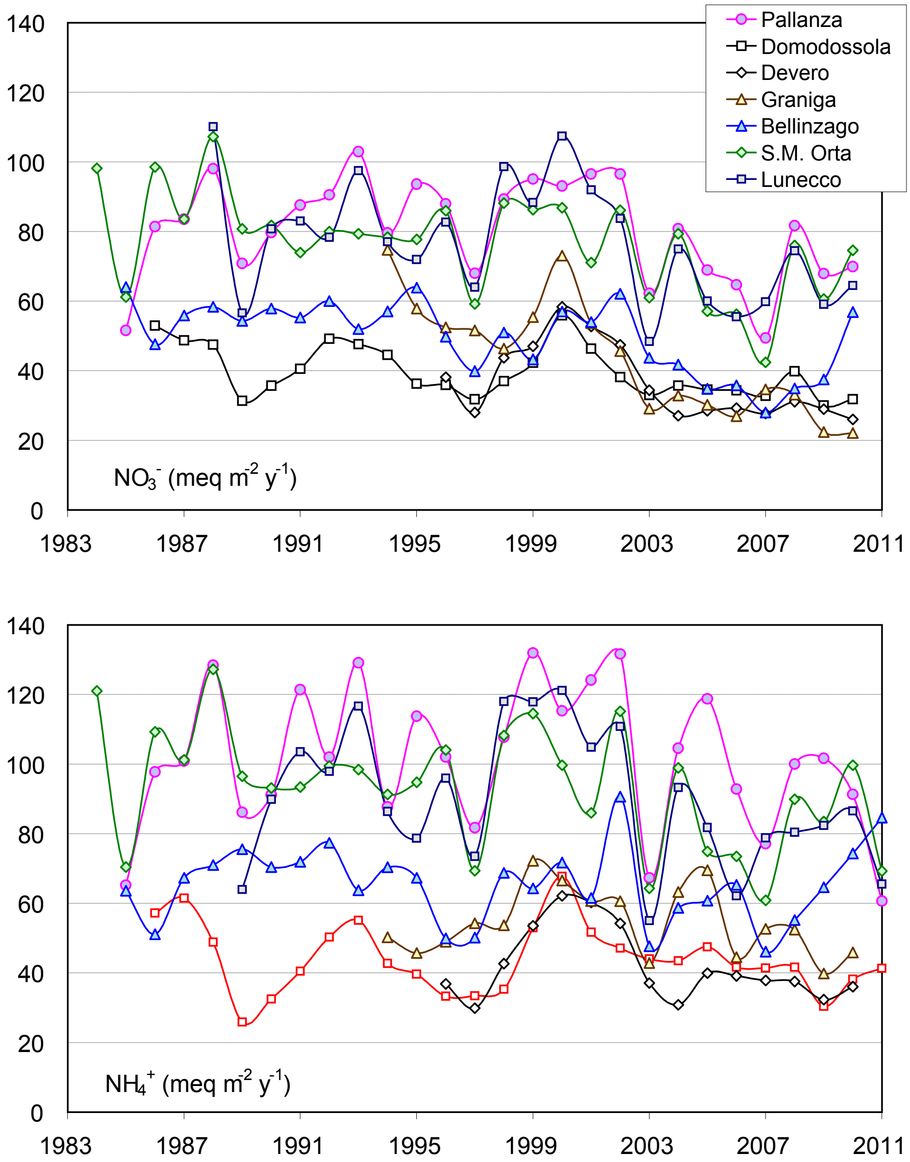

Figure 2. *Long-term trends of NO_3 (above) and NH4 (below) deposition at seven atmospheric deposition sampling sites in the Lake Maggiore area, North-Western Italy.*

The two forms of N, reduced and oxidised N, showed a different temporal behaviour, with NH_4 deposition becoming increasingly important compared to NO_3 in terms of N input to both terrestrial and aquatic ecosystems (Fig. 2). The NH_4:NO_3 ratio in atmospheric deposition increased with time at most of the atmospheric deposition sampling sites located in Lake Maggiore area, from about 1.2 in the 1984-2002 period up to 1.4-1.5 in recent years. Ammonium in atmospheric deposition is hence becoming increasingly important as regards its contribution to potential acidity. Results from the application of the MAGIC model to selected sites in the Alpine and subalpine area of North-Western Italy suggest that, without a significant reduction in N deposition, both oxidised and reduced N, reacidification of acid-sensitive ecosystems may occur in the next decades (Rogora et al., 2003).The available data on atmospheric emissions of N compounds in North-Western Italy showed that in 2000 and 2010 there was a decrease in NOx emission of 15 and 40% respectively compared to the levels of 1980, while NH_3 emission only decreased by about 2 and 4% respectively (http://www.ceip.at/emission-data-webdab/). These data on atmospheric emissions partly confirmed the observed changes in deposition at the study sites.

Beside deposition, climate drivers should also be considered when assessing long-term trends of N compounds in surface waters (e.g. Mitchell et al., 1996; Murdoch et al., 2000). For instance, increasing N uptake by plants and microorganisms in the lake and river catchments, as well as enhanced N exploitation by phytoplankton in lake water due to recent climate warming have been suggested as possible mechanisms contributing to the recent N decline in waters (Rogora et al. 2012).

The results of long-tem studies on N levels in surface waters in the Lake Maggiore area provide evidence that these sites responded to decreasing levels of N deposition in the last few years. This positive signal may mean that a phase of recovery from N saturation is beginning across the region. A time lag was observed between the deposition change (beginning in 2003) and the response of surface water (2006-2007), which can be attributed to previously accumulated N in soils. Several factors besides N deposition, including climate drivers, undoubtedly play a role in the long-term N dynamics of both rivers and lakes. As the phase of NO_3 decrease is limited to the very last few years, further data are needed to confirm this trend.

Acknowledgments
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4. Long-term changes in the chemistry of high altitude lakes in the Alps over 30 years

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Introduction
The subalpine and alpine areas in North-Western Italy and Southern Switzerland (Ticino region) are subject to high deposition of atmospheric pollutants transported with the air masses from source region located in the lowland (Rogora et al., 2006). Starting in the 1980s, some these lakes were recognised to be affected by acidification, due to the long-range transport of acidifying compounds, mainly sulphate and nitrate.

In the last 20-25 years sulphate deposition has decreased sharply across Europe, leading to a widespread recovery from acidification of sensitive freshwater ecosystems (Skjelkvale et al., 2005). However, reduction in N deposition has been less marked and has not affected all countries to the same extent. The subalpine and alpine areas of North-Western Italy and Southern Switzerland (Ticino region), in the Western Alps, for instance, were affected by a substantial reduction in sulphate deposition, which almost halved since the 1980s. Deposition of both oxidised and reduced nitrogen did not change at the same extent, showing a slight tendency to decrease only in the most recent period (Rogora et al., 2012).

In response to decreasing acid deposition, lakes in the Western Alps showed signs of recovery from acidification since the mid 1990s (Rogora et al., 2003). Nevertheless pH and alkalinity remained low in several lakes, and just a few examples of biological recolonization by acid-sensitive species were found in the lakes (Marchetto et al., 2004).

Climate change, especially temperature increase, has proved to be an important driver of change for high altitude lakes in the Alps. Lakes lying in catchments containing also basic, soluble rocks, showed a tendency to increasing solute concentrations, primarily as a response to reduced snow cover and more exposed soils and rocks to weathering processes (Rogora et al., 2003).

In this paper we present an analysis of the main chemical changes occurred in a group of lakes, representative of varying levels of sensitivity to acidification and climate change, over a 30-year period.

Study area and methods
Forty one high altitude lakes, 20 located in the Ticino region, Switzerland, and 21 in the Ossola Valley, Piedmont region, Italy were considered in this study. Some of the lakes are included in the ICP WATERS network.

The lakes are all located above the tree line, in the altitude range 1700-2800 m a.s.l. They are small (0.3-16.9 km^2), with a high watershed to lake area ratio. The watersheds consist mainly of bare rocks, with acidic rocks (ortho- and paragneiss) dominating (Tornimbeni & Rogora, 2012; Steingruber and Colombo, 2010). The lakes are representative of different levels of sensitivity to acidification. They can be considered representative of the geographical and morphological features of the entire lake population in the study region (Catalan et al., 2009).

All the lake samples have been analysed for the main chemical variables in the laboratory of CNR Institute of Ecosystem Study (CNR ISE) for lakes in Italy and of the Canton Ticino authority for lakes in Switzerland. Details on sampling and analytical procedures can be found in Tornimbeni and Rogora (2012) and Steingruber and Colombo (2010). The two laboratories regularly perform QA/QC programs. Further quality assurance measures involved the use of control charts, the analysis of synthetic samples on a regular basis and participation in inter-laboratory comparisons on surface water analysis, such those organized within the ICP Waters (e.g. Dahl and Hagebø, 2011).

The lakes in Ticino were regularly sampled two or three times per year (in June/July, September and October), with the sampling starting in 1980, 1983 or 1986 (8, 7 and 5 lakes respectively). Four lakes in the Ossola Valley were also sampled each year since 1984, usually in late summer/autumn. The remaining lakes were sampled during occasional surveys, in the 1980s, 2000, 2001, 2007, 2008, 2010 and 2011.

The lakes were firstly divided into subgroups according to their chemical characteristics using a cluster analysis (Ward's method, Euclidean distance). The Regional Kendall test (RKT; Helsel and Franse, 2006) was then applied to the main subgroups, in order to identify overall trend in water chemistry for the study region. All the statistical analyses were performed using Brodgar vers. 2.5.1 (Highland Statistics Ltd), S-plus 2000 (Math Soft) and the Kendall.exe program (Helsel et al., 2006).

Results and discussion

A summary of the lake water chemistry according to the most recent data (mean values of 2000-2001) is shown in table 1. The lakes span a wide range of chemical characteristics, as shown by the high variability (about 1 order magnitude) of both conductivity (from 7 to more than 80 µS cm^{-1}) and total ionic content (from 100 up to 2000 µeq L^{-1}). Nutrient content is very low: the lakes can be classified as oligotrophic or ultraoligotrophic according to total phosphorus concentrations (1-10 µg g P L^{-1}). Total nitrogen is below 0.50 mg N L^{-1}, and inorganic nitrogen forms dominate on organic nitrogen (75% of IN with respect to 15% of ON). Dissolved organic carbon is usually around 0.50 mg C L^{-1} (Tab. 1).

Tabel 1. *Mean chemical characteristics of the study lakes (n=41; average values of the surveys performed in 2000 and 2001). Cond.: conductivity at 20 °C; BC: base cations. RSi: reactive silica; TP: total phosphorus; TN: total nitrogen; DOC: dissolved organic carbon.*

	pH	Cond	Alk	SO_4	NO_3	BC	RSi	TP	TN	DOC
		µS cm^{-1}	µeq L^{-1}	µeq L^{-1}	µeq L^{-1}	µeq L^{-1}	µg Si L^{-1}	µg P L^{-1}	mg N L^{-1}	mg C L^{-1}
Minimum	5.43	6.5	0	16	2	41	0.24	1	0.09	0.13
25 percentile	6.48	7.7	27	25	11	71	0.66	2	0.23	0.30
Mean	6.89	21.7	143	57	14	218	0.87	3	0.31	0.46
75 percentile	7.30	20.3	112	68	19	185	1.03	4	0.37	0.52
Maximum	8.21	87.3	857	244	26	1051	1.68	10	0.62	1.09
st.dev	0.68	21.9	207	52	6	254	0.31	2	0.12	0.24

The average ionic concentrations of 2010-2011 were also used to identify the main subgroups of lakes by means of cluster analysis. Three main groups were identified, named A, B, and C. Group A consists of 10 lakes, all located in the Ossola Valley; they can be classified as not sensitive to acidification, according to pH and alkalinity values (7.77±0.24 and 461±199 µeq L^{-1}, respectively). These lakes are also characterised by the highest ionic content (conductivity of 56.3±18.4 µS cm-1 at 20 °C), with higher sulphate (121±69 µeq L^{-1}) and base cations (e.g. calcium 482±198 µeq L^{-1}) concentrations with respect to the other groups. The 15 lakes in group B are the most sensitive to acidification: mean pH and alkalinity are 6.04±0.42 and 19±11 µeq L^{-1}, with some lakes in Ticino reaching very low values (5.4-5-5 unit of pH, and alkalinity below 5 µeq L^{-1}). These lakes also show the lowest concentrations of all ions, except nitrate, which is slightly higher than in groups A and C. Group C consists of 16 lakes with intermediate characteristics. pH ranges between 6.6 and 7.3 and alkalinity between 29 and 112 µeq L^{-1}; however, alkalinity certainly reaches lower values at snowmelt and probably falls below 50 µeq L^{-1} in most of the lakes, so that they can be considered as moderately sensitive to acidification. As a consequence, lakes of group B and C were pooled for the regional trend analysis.

The regional trend analysis (RKT) was applied to the following four blocks of data: 1980s (a year between 1984 and 1987, according to the lake) and the average values of 2000-01, 2007-08, 2010-11 (Tab. 2). The analysis was done both considering the whole set of lakes (n=41) and splitting them into two subgroups (not sensitive lakes, cluster A, and sensitive lakes, clusters B+C).

pH and alkalinity increased significantly ($p < 0.001$) both in sensitive and not sensitive lakes, while nitrate showed a widespread decrease. Sulphate decreased significantly at sensitive lakes, and base cations increased, as a typical pattern of acidification recovery. On the other hand, conductivity, base cations and sulphate showed an increasing tendency in buffered lakes; even if not significant, the sulphate increase in this category of lakes is sharply in contrast with the negative trend of sulphate in atmospheric deposition. Hence a climate related effect may be considered to explain these trends. As suggested in Rogora et al. (2003), less snow on the ground and a more exposed portion of the catchments may lead to increasing solute content in surface water: the positive trend of sulphate recorded in some lakes may be due increased weathering of soluble, sulphur-bearing minerals.

Tabel 2. *Results of the Regional Kendall Test (p levels) applied to lake chemical data collected during different periods. Results are shown both for the whole set of lakes and for two subgroups, sensitive and not sensitive lakes, identified by means of a cluster analysis.*

	All lakes n=41		Not sensitive lakes n=10		Sensitive lakes n=31	
pH	↑	0.0000	↑	0.0001	↑	0.0000
Cond	↓	0.6288	↑	0.0027	↓	0.0247
Alk	↑	0.0000	↑	0.0005	↑	0.0000
SO_4	↓	0.0000	↑	0.1865	↓	0.0000
NO_3	↓	0.0000	↓	0.0000	↓	0.0000
BC	↑	0.7069	↑	0.0225	↓	0.3522

The availability of data representative of both the snowmelt period and of the late summer period for the Ticino lakes allowed the evaluation of seasonal difference in the main hydrochemical characteristics. For most parameters (base cations, sulphate, alkalinity, SiO_2 and DOC) and lakes, values at the beginning of the summer are significantly lower than in autumn. Aluminium, H^+ and nitrate frequently have significantly higher concentrations during snowmelt.

Despite the widespread increase of pH and alkalinity, some of the most sensitive lakes are still affected by low pH values (below 5.7) and concentrations of aluminium between 25 and 50 µg L^{-1}. Aluminium is relatively insoluble at pH between 6.0 and 8.0, but its solubility increases under more acid conditions (pH<5). Even small reductions in pH, as those normally occurring at snowmelt, have the potential to increase Al solubility (Tornimbeni & Rogora, 2012). According to the Canadian Water Quality Guidelines, in freshwater with pH≤6, total aluminium concentration must be ≤5 µg L^{-1} (CCME 2001). Hence levels of aluminium in the most sensitive lakes of our survey have to be considered as still too high. Despite an evident recovery, pH values at snowmelt still drop below 5.5-5.6 in recent years and aluminium may be up to 70-90 µg L^{-1}. Considering that these lakes are also affected by extremely low alkalinity values (0-5 µeq L^{-1} as mean values of 2010-11), they can be considered as still acidic.

A sharp decreasing trend of acidity and sulphate deposition was recorded at two sampling sites in the lake area, Devero and Robiei (Fig. 1). The location and main characteristics of these sites can be found in Rogora et al. (2006). Annual fluxes of H^+ and sulphate decreased from 25-30 and 50-60 meq m^{-2} y^{-1} respectively in the late 1990s to about 10 and 25 meq m^{-2} y^{-1} in recent years. These negative trends were mainly driven by decreasing concentration of H^+ and $SO4^=$, but a contribution also came from the lower precipitation amount which characterised some recent years (e.g. 2004, 2005, 2009).

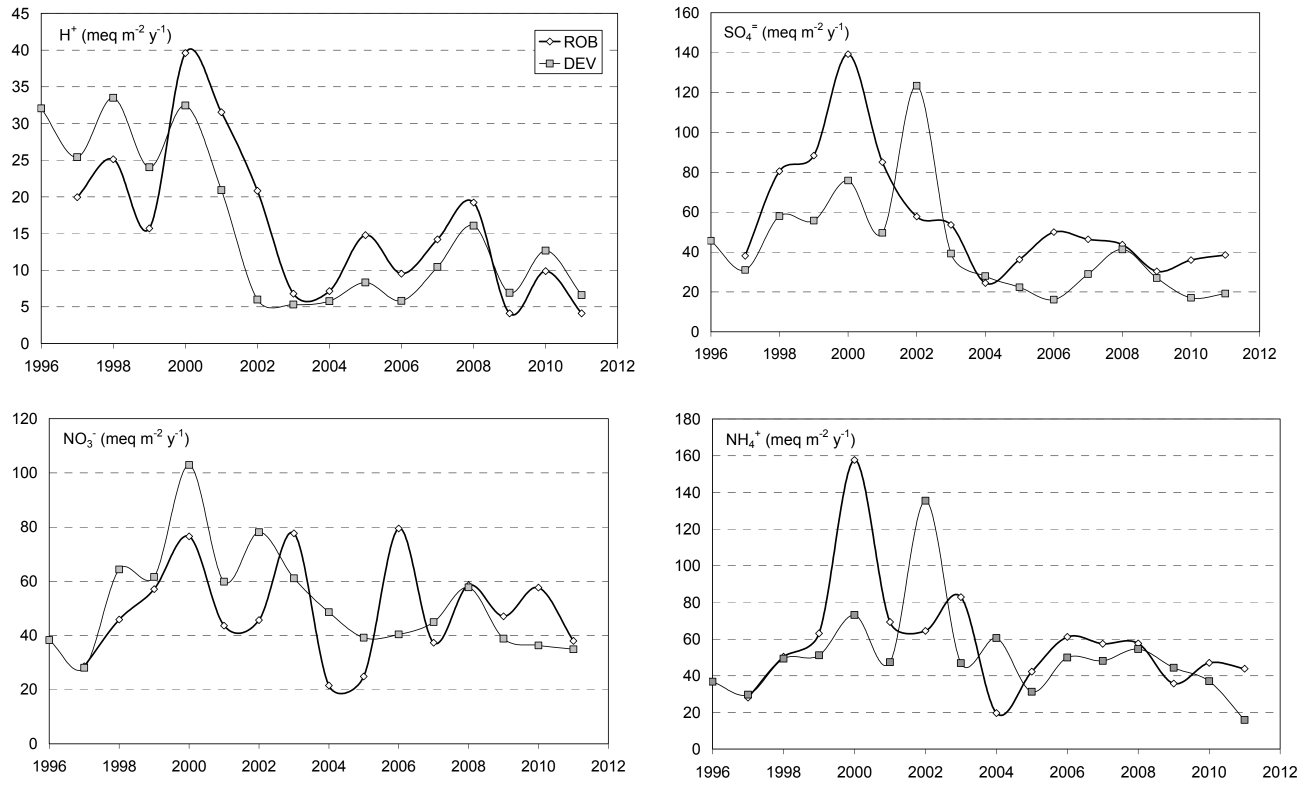

Figure 1. *Trend of atmospheric deposition of selected chemical variables at the atmospheric deposition sampling sites of Robiei and Devero.*

A tendency to lower N deposition in the last few years was also recorded, particularly for NO_3. However, deposition values are still high (42 and 48 meq m^{-2} y^{-1} at Robiei and 32 and 27 meq m^{-2} y^{-1} at Devero for ammonium and nitrate, respectively) with respect to those commonly found in mountain or remote areas (Rogora et al., 2008). A more extended analysis of long-term change of N deposition in North-Western Italy confirmed a recent decrease, mainly due to decreasing emissions and partly to the lower amount of precipitation occurring between 2003 and 2009 (Rogora et al., 2012).

Other studies dealing with acidification recovery showed that climate variation has to be taken into account when evaluating the response of surface waters to decreasing deposition of acidifying compounds (Koinig et al., 1998; Webster & Brezonik, 1995; Houle et al., 2010). Beside deposition, meteorological conditions certainly play a role also both in the long and short-term or interannual variations of lake chemistry in the study area. An analysis of the possible effects of climate drivers (temperature, precipitation, snow cover) on lake chemistry is in course, with the general aim to assess the relative role of deposition and climate change on lake recovery.

Conclusions

The results of trend analysis put in evidence a widespread chemical recovery, more pronounced at the highly sensitive sites. In particular the long-term trends of pH, alkalinity and aluminium at those sites which were more severely affected by acidification in the 80s showed a clear response to decreasing acid deposition. The observed change in the deposition of acidifying compounds, mainly as sulphate, was certainly the main driver of change for lake chemistry. An overall increase of pH and alkalinity and a decrease of sulphate have been recorded in the study lakes and just a few sites, among those classified as not sensitive to acidification, disagree with this general pattern. For these sites, a climate related effect on sulphate concentration can be hypothesised.

Despite a widespread decrease, nitrate concentrations in lake water are still high with respect to those found in lakes of other remote areas (Rogora et al., 2008). As a consequence of the sulphate decrease, nitrate has become the dominant acid anion in lake water; at present N deposition can be considered as the most important agent of acidification for these lakes.

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5. A note on the impact of permafrost melt on high mountain freshwater quality

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High altitude lakes are considered as sensitive indicators of pollution and climate change (The MOLAR water chemistry group, 1999; Battarbee et al., 2005; Nickus et al., 2010). While the UNECE monitoring programme ICP Waters has reported a widespread decline in freshwater sulphate concentrations in North America and Europe as a response of decreasing atmospheric sulphur deposition (Skjelkvale et al., 2005; Skjelkvale & de Wit, 2011), Thies et al. (2007) showed that sulphate concentration in some high altitude lakes in the European Alps has increased extraordinarily despite a concomitant decline in atmospheric sulphate deposition (Rogora et al., 2006).

There is clear evidence that air temperature in the European Alps has been rising significantly since the 1970s (Casty et al., 2005), and effects of climate warming on permafrost have been documented (Harris et al., 2003). Active rock glaciers are a widespread form of permafrost at high altitude (Humlum, 1998), and recently Krainer & Ribis (2012) mapped more than 500 active rock glaciers in the Tyrolean Alps (Austria). Active rock glaciers represent tongue-shaped or lobate bodies of perennially frozen material, which contain ice lenses or a core of massive ice creeping downhill (Barsch, 1996). Active rock glaciers are located near the lower boundary of permafrost and hence their mean annual surface temperature is close to melting conditions (Haeberli et al., 2006), which emphasizes their sensitivity to climate warming.

Some effects of the melting of permafrost ice in rock glaciers on the chemistry of downstream freshwaters have already been reported (Williams et al., 2006; Thies et al., 2007; Baron et al., 2009), but research in this field is still young (Haeberli et al., 2010).

A particular strong rise in freshwater solute concentrations has been described by Thies et al. (2007) for the Italian high mountain lake Rasass See (RAS), where electrical conductivity has increased 19-fold from 1986 to 2005 (from 24 to 451 µS/cm), and sulphate has increased 26-fold (from 167 to 4400 µeq/L). At the Austrian ICP Waters site Schwarzsee ob Sölden (SOS), electrical conductivity has concomitantly increased 3-fold (from 10 to 33 µS/cm), and sulphate has increased 6-fold (from 40 to 230 µeq/L). Apparently, the increase in sulphate concentrations at RAS and SOS has accelerated during the 1990s. In addition, unexpectedly high concentrations of nickel (243 µg/L) have been detected at RAS, while nickel at SOS was just at 7 µg/L.

The higher solute values at RAS were attributed to a 3-fold larger rock glacier area situated at slightly lower altitude and they relate to a 5-fold smaller lake volume of RAS compared to SOS (Thies et al., 2007).

In an outflow of the RG 5 rock glacier in the Colorado Front Range, Williams et al. (2006) found very high concentrations for calcium, magnesium, and sulphate, which had been attributed to internal ice melt of the rock glacier occurring at base flow during autumn. Sulphate in the outflow of the RG 5 rock glacier reached a maximum concentration of 7000 µeq/L (Williams et al., 2006). Baron et al. (2009) found nitrate values in Sky Pond inlet, a high mountain stream draining from Taylor rock glacier (Rocky Mountains), to have risen by about 30% from 2000 to 2006. Rising nitrate values are discussed by Baron et al. (2009) as an indicator of melting glacier and rock glacier ice, which flushes nitrogen from microbially active sediments to adjacent surface waters.

Current studies at rock glaciers in North Tyrol (Austria) and South Tyrol (Italy) within the framework of the EU-Interreg project Permaqua confirm a substantial release of major ions (i.e. calcium, magnesium, and sulphate), which are transported downstream to freshwater lakes and streams. At some sites, metal concentrations in freshwaters can even exceed drinking water limits by more than one order of magnitude (e.g. nickel, aluminium). As the total number of active rock glaciers in the European Alps is in the order of a few thousands (cf. Krainer & Ribis, 2012), more high alpine freshwaters are potentially impacted by permafrost melt.

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6. Macroinvertbrates as indicators of acidification of high-altitude Alpine lakes

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Introduction
High-altitude lakes, due to climatic factors, shallow soil cover, little vegetation, modest dimension of the watershed, long iced surface and rapid flushing rates are known to be particularly sensitive to atmospheric pollution (Wathne et al. 1995). In response to decreased atmospheric acid deposition, lakes in the Western Alps showed signs of chemical recovery since the mid 1990s (Rogora et al. 2003; Steingruber and Colombo, 2010). Neverthless, examples of biological recovery are still rare (Marchetto et al. 2004). Moreover, using benthic macroinvertebrates to assess acidification, for high-altitude Alpine lakes a specific method has not yet been developed. Unfortunately, because of the small data set (macroinvertebrate data from only 5 lakes in Southern Switzerland) the development of such a method goes beyond our possibilities. Instead, the aim of this study was to apply different already existing metrics to macroinvertebrate samples from lakes with different pH (from acid sensitive to alkaline), with the purpose to find which reflects best differences in lake acidity in order to improve temporal assessment of acidification through benthic macroinvertebrates in high-altitude Alpine lakes in Southern Switzerland.

Study site
The study area is located in the Lepontine Alps in the northern part of Canton Ticino, Switzerland (Fig. 1). Annual mean values of the main chemical parameters are shown in Tab. 1.

Figure 1. *Map showing the location of the sampling sites 1: Lago del Starlaresc da Sgiof, 2: Lago di Tomè, 3: Laghetto Superiore, 4: Laghetto Inferiore, 5: Lago Bianco*

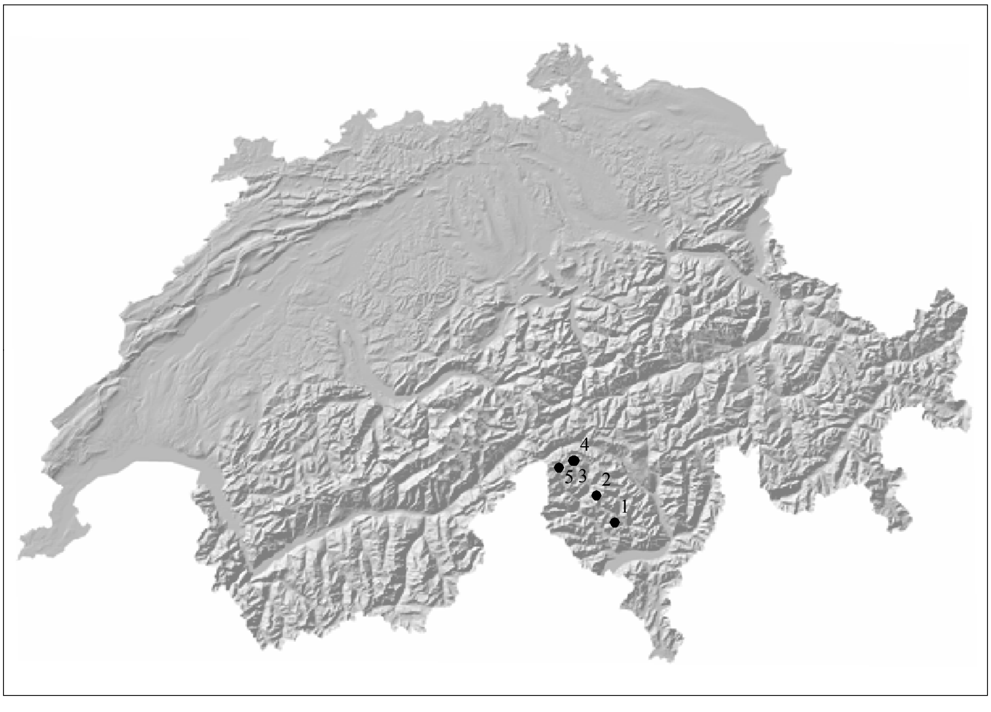

Table 1: *Water chemistry of the lakes: 2007 average values*

Lake name	Conductivity 20°C (µS cm^{-1})	pH	Alkalinity (meq m^{-3})	Ca^{2+} (meq m^{-3})	Mg^{2+} (meq m^{-3})	Na^{+} (meq m^{-3})	K^{+} (meq m^{-3})	NH_4^{+} (meq m^{-3})	SO_4^{2-} (meq m^{-3})	NO_3^{-} (meq m^{-3})	Cl^{-} (meq m^{-3})	DOC (mg C l^{-1})	SiO_2 (mg l^{-1})	$Al_{dissolved}$ (µg l^{-1})	Al_{tot} (µg l^{-1})	$Cu_{dissolved}$ (µg l^{-1})	Cu_{tot} (µg l^{-1})	$Zn_{dissolved}$ (µg l^{-1})	Zn_{total} (µg l^{-1})
Lago del Starlaresc da Sgiof	8.5	5.5	3	25	8	15	4	2	31	22	3	0.78	1.4	65	79	<0.2	<0.4	4.3	4.6
Lago di Tomè	8.6	5.7	5	42	6	14	4	1	32	28	3	0.28	1.8	26	33	<0.2	<0.2	1.7	1.8
Laghetto Superiore	8.8	6.7	33	51	8	12	8	0	28	16	2	0.42	1.2	6	15	<0.2	<0.2	2.0	1.4
Laghetto Inferiore	10.1	6.7	36	59	9	14	11	0	33	19	2	0.34	1.4	6	22	<0.2	<0.2	1.1	1.3
Lago Bianco	64.0	7.6	441	579	59	15	20	0	210	11	3	0.26	1.6	6	19	<0.2	<0.2	<0.3	<1.0

Methods

Macroinvertebrates have been collected by "kick sampling" the littoral and the outlet of each lake with a 250 µm mesh size net according to the ICP Waters Programme Centre Protocol (2010) usually 2 to 3 times a year during the ice free period. Samples have been preserved in 70% ethanol in the field, then sorted, identified to species and if not possible to higher taxa levels and then counted in the lab. Sampling occurred since 2000 but because up to date identification of chironomids and oligochaets was restricted to samples from 2007, we concentrated our first attempt of analysis on these year.

The applied acidification metrics can be divided in:

- general metrics (total number of taxa, number of taxa and relative abundance of Ephemeroptera, Plecoptera, Trichoptera, Diptera, Chironomidae, Oligochaeta and relative abundance of Predators),
- acidification specific metrics based on presence/absence or relative abundance of acid sensitive taxa (Raddum index (Raddum et al. 1988; Fjellheim and Raddum, 1990; Raddum, 1990), NIVA index (Bækken and Kjellberg, 2004), $AWIC_{fam}$ index (Davy-Bowker et al. 2003, 2005), $AWIC_{sp}$ index (Davy-Bowker et al. 2003), Braukmann index (Braukmann and Biss, 2004), LAMM index (McFarland et al. 2010), number and relative abundances of acid sensitive taxa, reported in literature)
- and classification systems based on both the previous type of metrics (MEDIN (Henrikson and Medin, 1986) and MILA indexes (Johnson and Goedkoop, 2007)).

Results

In the littoral samples a total of 14373 individuals were collected and 70 taxa were determined, while in the outlets the individuals and taxa where 20298 and 99, respectively. Twenty taxa were exclusive to the littoral, 44 to the outlets and 42 were common to both sampling zones. In general *Diptera* was the dominant order regarding both the abundance and the number of taxa. With exception of the littoral of Laghetto Inferiore and Laghetto Superiore, where *Simuliidae* were also abundant, chironomids prevailed in the samples. Oligochaetes were also highly abundant (mainly Naididae in the outlets), excluding the outlets of Lago di Tomè and Lago del Starlaresc da Sgiof and the littoral of the latter. In most littorals nematods were numerous, as well.

Application of acidification metrics to outlet macroinvertebrates

Results from the application of different metrics are shown in Tab. 2. The total number of taxa increased with pH. Also metrics related to Ephemeroptera (number of families, taxa and relative abundance) and to Oligochaeta (number of taxa and relative abundance) increased with pH. For Plecoptera only the number of taxa clearly increased with pH. A clear increase with pH can also be observed for the number of families and taxa of Ephemeroptera/Plecoptera/Trichoptera. The number of taxa of Diptera and Chironomidae also increased with pH. Furthermore as expected from literature (Johnson and Goedkoop, 2007) the relative abundance of Diptera and predators were higher in more acidic waters. Instead, for most of the specific acidification indexes tested differences among pH's could not be observed. Only the Raddum and the MILA index increased with increasing pH, although the first seems not to be very sensitive toward changes in pH. Finally, the number of acid sensitive species also increased in lakes with higher pH, while differences between the relative abundance of acid sensitive taxa can be observed only between acid sensitive lakes (Lago del Starlaresc da Sgiof, Lago di Tomè) and not acid sensitive lakes (Laghetto Superiore, Laghetto Inferiore, Lago Bianco).

Table 2. *Application of existing metrics regarding macroinvertebrates and acidity. For each classification system the possible classes are indicated in brackets from the less acidic toward the most acidic sites.*

METRICS	OUTLET					LITTORAL				
	STA	TOM	SUP	INF	BIA	STA	TOM	SUP	INF	BIA
Total number of taxa	35	40	41	46	55	27	28	41	38	31
Rel. Abundance Ephemeroptera %	0	0	0.3	0.9	1.3	0	0	0	0	0
Number of families Ephemeroptera	0	0	1	1	2	0	0	0	0	0
Number of taxa Ephemeroptera	0	0	1	2	2	0	0	0	0	0
Rel. Abundance Plecoptera %	14.2	36.0	5.9	6.0	10.7	0	0.4	4.1	1.1	0.1
Number of families Plecoptera	2	3	3	3	3	0	1	1	1	1
Number of taxa Plecoptera	1	3	5	6	6	0	1	1	1	1
Rel. Abundance Trichoptera %	1.5	1.1	1.2	0.4	0.6	0.6	6.7	4.9	2.4	0
Number of families Trichoptera	3	3	3	3	4	1	2	2	2	0
Number of taxa Trichoptera	4	4	4	3	5	1	2	3	2	0
Rel. Abundance Ephemeroptera/Plecoptera/Trichoptera %	15.7	37.2	7.3	7.2	12.6	0.6	7.1	9.0	3.5	0.1
Number of families Ephemeroptera/Plecoptera/Trichoptera	5	6	7	7	9	1	3	3	3	1
Number of taxa Ephemeroptera/Plecoptera/Trichoptera	5	7	10	11	13	1	3	4	3	1
Rel. Abundance Diptera %	76.7	60.7	47.5	55.6	40.4	88.5	61.6	45.1	74.5	55.1
Number of taxa Diptera	19	23	23	27	30	15	13	22	21	17
Rel. Abundance Chironomidae %	67.7	52.1	27.9	35.0	39.8	72.3	61.6	44.2	73.0	55.0
Number of taxa Chironomidae	16	21	21	24	27	13	12	19	19	15
Rel. Abundance Oligochaeta %	0.7	0.3	40.7	31.5	45.8	3.0	21.4	8.2	12.3	29.6
Number of taxa Oligochaeta	3	3	4	4	7	4	7	10	9	10
Rel. Abundance Predators%	11.3	10.5	6.1	7.5	2.7	13.8	52.7	21.5	30.3	9.9
Braukmann index (1-5)	4	5	5	5	5	4	4	4	4	4
Raddum index (1-0)	0	0.5	0.5	0.5	1	0	0	0.5	0.25	0
NIVA index (1-4)	4	4	4	4	4	4	4	3	3	4
AWICfam index (6-0)	3.9	4.0	3.5	3.5	3.8	5.5	3.7	4.0	4.0	3.7
AWICsp index (10-0)	5.7	5.3	5.2	5.2	5.3	6.0	5.1	5.5	5.4	5.0
MEDIN index (1-5)	5	5	5	5	5	5	5	4	5	5
MILA index (100-1)	15	21	28	29	33	25	7	13	3	23
LAMM index (6-0)	4	4	4	4	4	6	2	4	3	4
Relative abundance of acid taxa species according to Table 5 %	0.0	0.3	5.6	9.1	3.6	0.1	0.0	0.1	0.0	6.7
Number of acid taxa species according to Table 5	0	3	4	7	8	1	0	2	0	2

Application of acidification metrics to littoral macroinvertebrates

Interestingly, most of the existing metrics applied to littoral samples seemed not to correlate with pH. Considering that the number of taxa in Lago Bianco is probably reduced compared to the other two not acid sensitive lakes (Laghetto Superiore and Laghetto Inferiore), because of its more monotone substrate consisting mainly of silt, only the number of total taxa, Diptera, Chironomidae and Oligochaeta seemed to slightly increase with pH. All other general metrics concerning relative abundances, the specific acid indexes and the number of acid sensitive taxa did not seem to correlate with lake acidity.

Discussion

Results showed that many general metrics gave a good description of differences in pH in outlet samples. The number of total identified taxa (often used to compare community diversity), and the number of EPT taxa (recognized as being the most sensitive to pollution, Weber, 1973), are known to decrease with water quality. In fact, both metrics seem to increase with lake pH. Not surprisingly, in the two acid sensitive lakes no Ephemeroptera were found. Ephemeroptera are known to be the most sensitive order for acidification (Raddum et al., 1988),. The number of EPT families was also higher in lakes with higher pH but was a less sensitive metric. The relative abundance of Diptera (mainly Chironomidae) and of predators that are known to increase with acidification (Johnson and Goedkoop. 2007), effectively follow this trend. Interestingly, the number of taxa of the numerically important chironomids and oligochaetes, increased with pH, suggesting that an improvement of lake pH is also reflected in their taxa richness. Although chironomids have not generally been regarded as sensitive indicators for acidity (Wiederholm and Eriksson, 1977; Mossberg and Nyber, 1979; Meriläinen and Hynynen, 1990; Schnell, 2001; Olander, 2002), results from other studies were consistent to ours (Raddum and S± ther, 1981; Allard and Moreau, 1987; Schnell and Raddum, 1993; Halvorsen et al., 2001). With regard to oligochaetes, taxa richness and relative abundance increased with lake pH. Oligochaetes are generally known to be tolerant to acidification (Wathne et al. 1997), or even prefer acidified environments (Rota, 1995). However, some studies observed that although the diversity of oligochaetes does not change significantly with pH, their total abundance may decrease with decreasing pH (Keller et al. 1990; Lonergan and Rasmussen, 1996; Sommer and Horwith, 2001). Regarding the acidification metrics. only the number of sensitive taxa and the MILA index correlated with lake pH, which is not surprising. In fact, the number of acid sensitive taxa is based on a list of species occurring at the study site and the MILA index is a multimetric index based on general metrics, most of them just shown to correlate positively with lake pH in this study (relative abundance of Ephemeroptera, Diptera and Predator, number of taxa of Ephemeroptera and Gastropoda, $AWIC_{fam}$ index). The negative results of the other metrics also could be expected: the Raddum and the NIVA indexes are based on the presence/absence of acid sensitive species in Norway, the $AWIC_{fam}$ and $AWIC_{sp}$ indexes on the average sensitivity score of families or species from the UK. Both the MILA and the LAMM index were developed specifically for lake ecosystems. However, the first is based on the presence/absence of many taxonomic groups that are rare or absent in high-altitude Alpine lakes even at high pH (Amphipoda, Hirudinea, Elmididae, Gastropoda, Bivalvia) and on the presence/absence of acid sensitive species from Sweden. The second is based on the relative abundance of acid sensitive species common in the UK and their sensitivity score. Finally, the Braukmann index, although developed for German river ecosystems, is based on a list of acid indicator taxa, were most of species identified in this study (except chironomids and oligochaets) are considered. However, results from the application of these metrics are negative, as well, because it considers also the relative abundances of sensitive indicator taxa, that are higher in river ecosystems compared to high-altitude Alpine lake outlets.

Regarding lake littoral samples, results from the application of general and specific metrics gave much less encouraging results. One of the reasons is that many taxa known to be acid sensitive are rhephil or rheobiont and prefer or need flowing waters (many Ephemeroptera, Plecoptera and Trichoptera) and are therefore absent in the littorals. Another reason may be the fact that other environmental factors than lake acidity may vary significantly among lakes (especially substrate) hiding a little the effect of different acidity on macroinvertebrate population. From this study the only metrics that can be tried to use to determine effects on littoral macroinvertebrates as a result of variations in lake acidity may be the total number of taxa, the relative abundance and number of taxa of Diptera, Chironomidae and Oligochaeta.

Conclusion

In general macroinvertebrates from lake outlets are better indicators of acidity than from lake littorals. Moreover, because of the high relative abundance and taxa richness of especially chironomids but also oligochaetes and their responding to some extent to changes in pH and the poorness of other taxonomic groups, in high-altitude Alpine lakes determination to species of these 2 taxonomic groups, especially the first, should be recommended. Finally, more studies on the acid sensitivity of chironomids and oligochaetes species are necessary.

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7. Biological recovery of reservoirs in the Jizera Mountains, the Czech Republic, from acidification

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Key words: Acidification, recovery from acidification, reservoirs, the Jizera Mountains, phytoplankton, zooplankton

At the 8th ICP Waters Task Force meeting in Winnipeg in 1992, Evžen Stuchlík presented the first results of a hydrobiological survey of strongly acidified reservoirs in the Jizera Mountains and their inflows (Stuchlík et al. 1997). The sites and their watersheds have been monitored since then, through the period of their heavy degradation and restoration.

The Jizera Mountains region (Northern Bohemia, 350 km^2, latitude 50°40' to 50°52', longitude 15° 08' to 15°24'), a part of the "Black Triangle", belongs to the earliest and most heavily damaged areas of the world by acid atmospheric deposition. Anthropogenic acidification, which strongly affected surface waters as well as watersheds on the upper plateau of the mountains, occurred in this territory probably as early as in the mid-1940ies. However, a drop in the total acid load, caused by the damage of spruce stands and their complete clear-cut during the 1980ies, together with a decrease in sulphur and nitrogen deposition, led to a very fast chemical and biological recovery of waters from acidification (Křeček & Hořická 2001, 2007). pH of the water in reservoirs, which ranged between 5.0-5.5 in June-July 1992, was 6.2-6.7 in the summer of 2008 (*in-situ* values for surface).

Three water dams (Bedřichov and two drinking water reservoirs, Souš and Josefův Důl; for details, see Stuchlík et al. 1997, Křeček & Hořická 2007) and their inflows have been studied since 1992. The waters are naturally acidic, with a high content of humic acids (DOC 10-12 mg l^{-1}), which allowed a limited number of planktonic and benthic species to survive the peak of acidification in the 1980ies. Their population densities were very low, though. The first signs of a biological recovery (e.g., a return of *Daphnia longispina* into the Souš reservoir) appeared already in the first half of the 1990ies; further development of the communities was significantly influenced by liming (Souš, since 1996) and re-introduction of salmonid fish (brook char, *Salvelinus fontinalis*) into all the three reservoirs between 1991 and 1998. Recently, the succession of plankton and benthos seems to be driven primarily by mechanisms other than chemical recovery from acidification – the climate shift and biotic parameters (quality and quantity of food, competition, predation, and life strategy).

Phytoplankton were dominated by Dinophyta (*Gymnodinium uberrimum*) in the period of acidification and the number of taxa was very low, just like in strongly acidified lakes elsewhere (Stuchlík et al. 1997). Although Dinophyta continued to form a substantial part of algae in all the reservoirs, the large species *Gymnodinium uberrimum* was later replaced in biomass by a smaller-size *Peridinium umbonatum* and other phytoplankton succeeded (namely Chrysophyta, Cryptophyta, Chlorophyta), which brought about a decrease in the total biovolume in the Bedřichov reservoir. The species richness has significantly increased in all the three water dams but the majority of phytoplankton species recorded during the peak of acidification remained unchanged. While seasonal maxima of large Dinophyta complicated the water treatment process in Souš in the past, both the drinking water reservoirs have to face difficulties with an early summer peak of Bacillariophyta and especially water blooms of *Merismopedia tenuissima* (blue-green alga, Cyanoprokaryota) nowadays.

In the **zooplankton**, a limited amount of acidophilous and acid-tolerant species, or species with a wide range of pH tolerance, was present at the beginning of the 1990ies. By species composition and the predominance of *Brachionus sericus*, *Keratella valga*, and *Microcodon clavus* (Rotifera), *Ceriodaphnia quadrangula* (Cladocera), and *Acanthocyclops vernalis* (Copepoda), the reservoirs were very similar (details in Stuchlík et al. 1997). The number of rotifer taxa was highest in the brown-water Bedřichov reservoir in 1992; since 1993, Josefův Důl and Souš were richer than Bedřichov in both the species number and abundance of Rotifera. The abundance of the ever-prevailing crustacean, *Ceriodaphnia quadrangula*, grew up in the mid-1990ies with the improved chemical climate in the waters, but the brook char re-introduction reversed the trend. From the turn of the century, the zooplankton were enriched with species recorded in the past (*Keratella cochlearis*; *Bosmina longirostris*, *Daphnia longispina*; *Eudiaptomus gracilis*), as well as new species for the sites (*Holopedium gibberum*, *Polyphemus pediculus*, *Sida crystallina*). The changes in Rotifera and their recent variety are much bigger than those in Crustacea. Table 1 gives a long-term record of zooplankton in the Souš reservoir.

Despite the improvement in chemistry and biology of the reservoirs, the inflows are still affected by acid events, when water pH drops below 4.5. Benthic macroinvertebrates and fish tissues show an elevated content of metals; in the branchial apparatus of brook char, acid-stress derived deformations were found. Further development of water ecosystems will depend primarily on the forest management in the watersheds and the tree species composition. Considering an elevated throughfall deposition, recently measured in reforested spruce stands, a new peak of acidification may be expected with fatal consequences for the biota.

Table 1. *The occurrence of zooplankton in the Souš reservoir (built 1915). 1924: Gessner, 1925, 1929; 1949-1951: Sládeček, 1955; 1959: Jirásek et al., 1959; 1992: Stuchlík et al., 1997. 1993, 1997, 2008: unpublished data. x – occurrence, xx – abundant/dominant, (x) only remains (shells/loricas) found. pH: surface layer, June to October; laboratory values. NA – reliable pH values not available. * In 1924, there were only pools in the deepest part of the basin (Souš was drained for dam reconstruction in 1916-1925). ** In 1996, the reservoir started to be regularly limed, and was re-stocked with brook char. *** Some old rotifer findings require a critical interpretation – species determination could be wrong.*

	1924 *	1949-1951	1959	1992	1993	1997 **	2008
pH of water	**NA**	**NA**	**NA**	**5.2-6.2**	**5.5-6.3**	**6.3-6.7**	**6.2-6.8**
Taxon							
ROTIFERS							
Ascomorpha cf. *saltans*						x	x
Asplanchna priodonta						x	x
Bdelloida g. sp.					x	x	
Brachionus sericus	x	xx	x	(x)	x		
Collotheca mutabilis						xx	
Kellicottia longispina		x					
Keratella cochlearis	x	(x)			x	xx	xx
Keratella hiemalis						x	x
Keratella quadrata (*K. hiemalis*? ***)	x	(x)					
Keratella serrulata		x	x	(x)	x		x
Keratella valga				xx	x	x	
Lecane closterocerca						x	
Lecane flexilis					x		
Lecane cf. *glypta*					x		
Lecane lunaris					x	x	
Lecane cf. *stichaea*					x		
Monommata sp. div.						x	
Polyarthra dolichoptera (*P. vulgaris* / *P. remata*? ***)			x				
Polyarthra minor			x				
Polyarthra remata						xx	xx
Polyarthra vulgaris			xx				x
Synchaeta lakowitziana					x	xx	x
Synchaeta pectinata						x	
Trichocerca cf. *insulata*					x	x	
CLADOCERA							
Acroperus harpae					x		x
Alona affinis					x		x
Alona guttata					x		
Alonella nana					x		
Bosmina longirostris	x	(x)	x				x
Ceriodaphnia quadrangula	x		x	xx	xx	xx	xx
Chydorus sphaericus		x		(x)	x	x	x
Daphnia longispina	x				x		x
Eurycercus lamellatus					x		
Holopedium gibberum					x		
Ilyocryptus sp.					x		
Polyphemus pediculus					x		
Sida crystallina					x	x	x
Scapholeberis sp.					x		
COPEPODA							
Acanthocyclops trajani							x
Acanthocyclops vernalis	x	x	x	x	x	x	
Cyclops strenuus							x
Cyclops vicinus				x			
Eudiaptomus gracilis	x		x				x

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8. Stable isotopes of N and C are needed to understand mercury levels in different fish communities

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Mercury (Hg) and its compounds are highly toxic to people and animals, and represents one of the most important environmental contaminants through its anthropogenic use and long range transport (Morel *et al.* 1998; Rognerud *et al.* 2002; Chen *et al.* 2005). Among species of total Hg (THg), methylmercury (MeHg) is of particular interest because of its toxic and mobile nature, as well as its bioaccumulation properties in food chains, both in freshwater and marine environments (Morel *et al.* 1998; Atwell et al. 1998). Most of the Hg in fish tissues (>90%) is in the form of MeHg (Agah *et al.* 2007), and will be taken up nearly 100% when eaten, and stored in vital organs, mainly as MeHg (84%, Carrier et al. 2001). Fish is also the main source of MeHg exposure to man (Campbell *et al.* 2003; Counter and Buchanan 2004). The whole body excretion rate of Hg is slow in both fish and mammals, with 323 days for MeHg in fish, 500-1000 days for seals and dolphins, and a half time of MeHg in human blood of 52-93 days (Carrier et al. 2001). Hg acts as a free radical, is very neurotoxic, and its effects are pronounced in "groups at risk", i. e. children and growing fetus of pregnant women (Counter and Buchanan 2004; Sanfeliu et al. 2004).

MeHg is both bioaccumulating and biomagnifying in food chains, and the total mercury concentrations in most fish species are usually consistent with their trophic position, with highest concentrations in piscivores, and lower concentrations in omnivores, insectivores and detritivores (Rognerud et al. 2002; Campbell *et al.* 2003). Despite the same "baseline" MeHg in an aquatic ecosystem, the concentration in a specific top predator can appear at very different levels depending on the complexity and biotic levels of the food chain. Within a given species, individuals at similar age and size might therefore have different Hg concentrations, depending on the availability of food and specific food prefere (Desta et al. 2006; Rosseland et al. 2007).

Characterization of food web structure and identification of piscivorous fish species have traditionally been done by analyzing stomach contents. However, stomach contents alone will only reflect the food ingested in the previous hours or days before capture (Rosseland *et al.* 1999), and is not a sound method to characterize food web structure unless extensive sampling is carried out, since diet composition may show large seasonal variability (Kidd *et al* 1995). In tissues, the ratio of ^{15}N to ^{14}N (i.e., $\delta^{15}N$) increases consistently with trophic transfers because of the retention of the heavier ^{15}N from the food resource relative to ^{14}N (Peterson and Fry 1987), and this value increases by 3-4‰ from prey to predator (Kidd *et al.* 1995). Thus, stable isotopes of nitrogen may be used to identify the relative trophic position of an organism, and characterize the food web structure, as well as quantify Hg transfer patterns (Rognerud et al. 2002, Sharma et al. 2008, Jenssen et al. 2010).

Since Hg concentrations increase with increasing trophic level, they correlate with $\delta^{15}N$, and the slope of the regression of log transferred Hg concentrations (log THg) against $\delta^{15}N$ values show the biomagnification rate of Hg within the food web (Kidd et al. 1995; Atwell et al. 1998; Sharma et al. 2008). On the other hand, stable carbon isotopes may be used to quantify the relative importance of different carbon sources in the diet (Rognerud et al. 2002). Because of the small enrichment of the heavy carbon isotope (^{13}C) from one trophic level to the other (around 1‰), $\delta^{13}C$ values of organisms reflect the average $\delta^{13}C$ of their diets, and thereby identify the main feeding habitat of an individual (Peterson and Fry 1987).

At Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, many Master and PhD students have been graduated during the last ten years with studies of mercury and stable isotopes of N and C in fish populations in Norway, Nepal, countries in Central Asia, and Africa, all following the methods of EMERGE (Rosseland et al. 2002) and ICP Waters (2010). We report here from a study at Lake Øyeren in south-eastern Norway which may illustrate the importance of combining contamination loads in fish with trophic position in the aquatic ecosystem.

Lake Øyeren, County of Akershus and Østfold, South East Norway.

Lake Øyeren is one of Norway's largest lakes, situated about 10 km from City of Oslo, at 101 m.a.s.l. with a lake area of 87 km^2, and a catchment of 40.000 km^2. A total of 25 fish species inhabit the lake, giving a fish community divided into 3-4 levels in the food chain. In three Master thesis's, the concentration of THg in sediments and 10 fish species, as well as MeHg in one species, have been studied (Moseby 2011; Svae 2011; Greipsland 2011). Lake Øyeren is one of a few Norwegian locations inhabited by the piscivorous cyprinid asp (*Aspius aspius*), which at a length of 35 cm, and 60 cm, respectively, exceeded the recommendation level for Hg in food for people at risk (0.2 mg Hg/kg, WHO 2007, 2012), and EU trade level (0.5 mg Hg/kg) (Figure 1; Svae 2011).

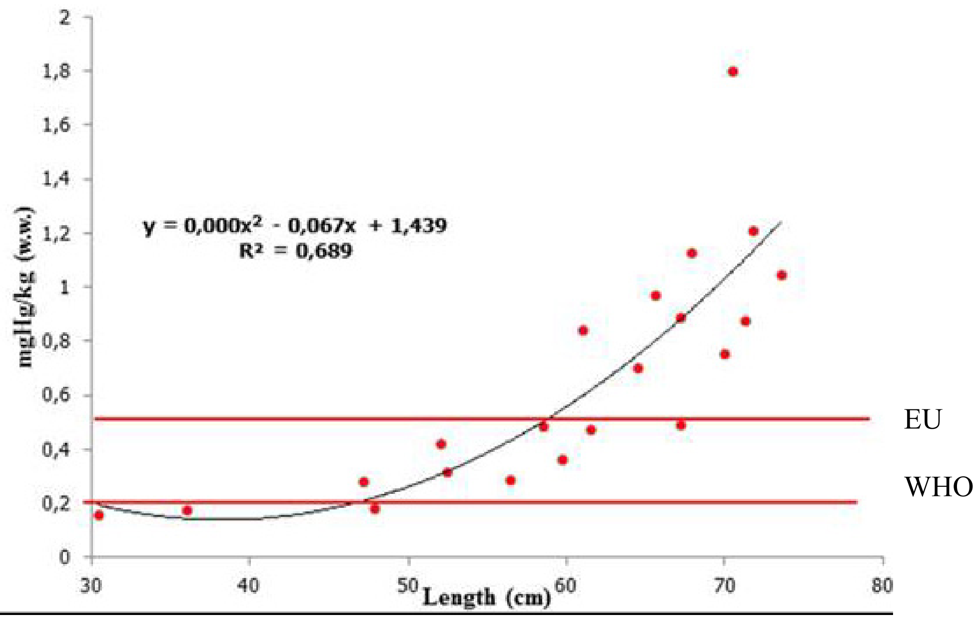

Figure 1. *The concentration of total mercury (THg) in muscle tissue of Asp (Asius asius) as a function of length from Lake Øyeren, South East Norway, in August - September 2010. Food recommendations (WHO) and trade levels (EU) are indicted. After: Svae (2011).*

Among the other piscivorous species, perch (*Perca fluviatilis*) had a higher THg concentration than pike (*Esox lucius*) and pikeperch (*Stizostedion lucioperca*), although being at the same trophic level based on $\delta^{15}N$ signals (Figure 2; Moseby 2011). The complex fish community, with many species feeding on algae and invertebrates, and fish species specializing on prey fish with different Hg concentrations, is the key to understand the variations in THg concentrations in both species and individual fish (Figure 3).

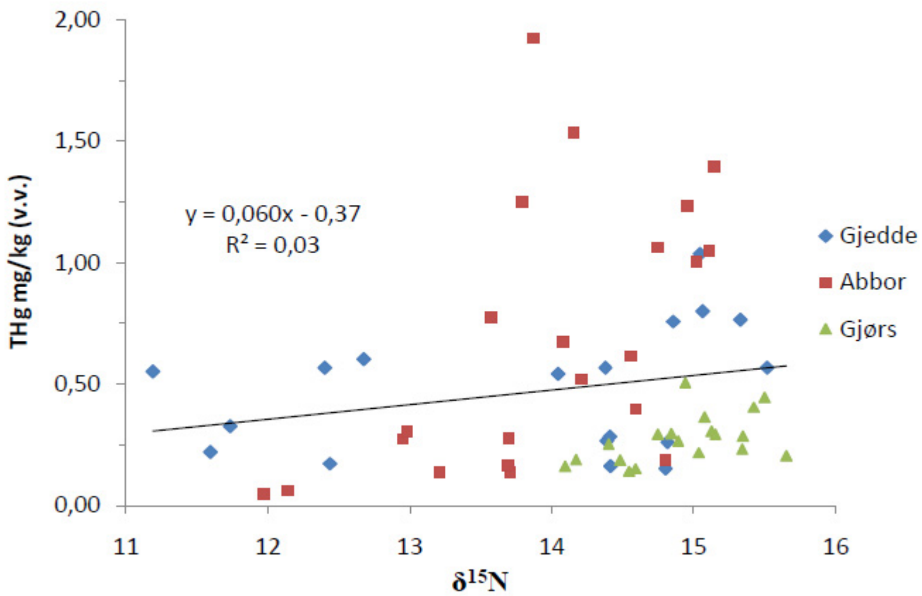

Figure 2. *Total Hg and $\delta^{15}N$ in muscle tissue of pike (Esox lucius, Gjedde), perch (Perca fluviatilus, Abbor) and pike perch (Stizostedion lucioperca ,Gjørs) from Lake Øyeren in August - September 2010. After: Moseby (2011).*

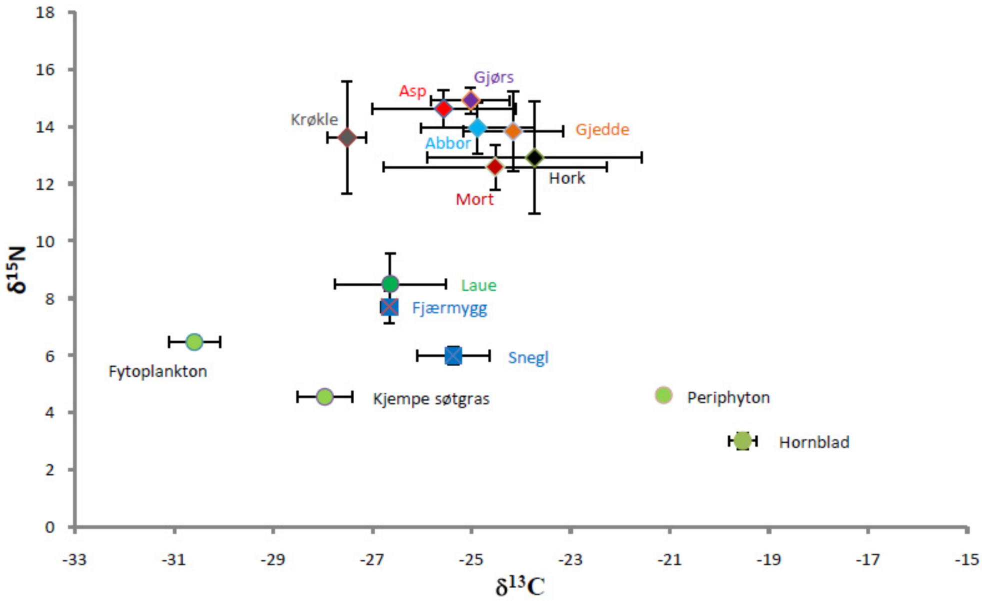

Figure 3. *The stable isotope signals from eight fish species (Gymnocephalus cernuus (Hork), Rutilus rutilus (Mort), Osmerus eperlanus (Krøkle) and Albumus albumus (Laue), invertebrates (Chironomids (Fjærmygg) and snails (Snegl)), phytoplankton, periphyton and plants (Ceratophyllum demersum (Hornblad), and Glyceria amxima (Kjempe søtgras)) from Lake Øyeren, South East Norway in August – September 2010. After Greipsland (2011), Moseby (2011) and Svae (2011).*

Trends in Hg concentrations in fish

An important part of the ICP Waters is to study trends in pollution load and levels, both in water and biota. Fjeld and Rognerud (2009) found many perch populations with increased THg concentration, when comparing 1991 and 2008 datasets. One explanation for such an increase, is the increased total organic carbon (TOC) levels in freshwaters in most boreal areas in the Northern hemisphere (Monteith 2007), giving more organic material available for methylation of mercury, combined with increased water color which reduces photo-degradation of MeHg. Comparing THg data for perch and pike in Lake Øyeren between 1986-1990 and 2010, however, showed no significant trends (Moseby 2011). This may reflect that the levels of Hg in this aquatic ecosystem has not changed, or that these fish species have changed their food preferences to include prey fish at lower trophic levels, masking the general trend with increased Hg availability.

Conclusion

In any future studies including concentration of biomagnifying pollutants (Hg, POPs etc.) in fish populations, it is of utmost importance to include stable isotopes of N and C, since δ15N and δ13C may be a major explanatory component in studies of trends, separating changes in pollution load and concentrations from biotic and ecological factors, such as changes in food preferences.

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9. Task Force minutes of the twenty-eighth meeting of the Programme Task Force held in Pallanza, Italy, October 8-12, 2012

International Cooperative Programmeon Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes (ICP Waters)

Convention on long-range transboundary air pollution (CLRTAP)

Working Group on Effects (WGE)

Task Force minutes

of the twenty-eighth meeting of the Programme Task Force held in Pallanza, Italy, October 8-12, 2012

Key messages from the task Force meeting

Biodiversity

The Task Force meeting was impressed by the new data analysis and ongoing work regarding biodiversity, which will culminate in an ICP Waters report early in 2013. Data presented at the Task Force meeting from several countries showed clear recovery of key species and communities of species in lakes and streams as a response to decreasing acidity in the water. By these measures biodiversity is improving. The Task Force meeting urges continued monitoring of biodiversity, by various metrics, in acid-impacted waters recovering from chronic acid deposition.

Ecosystem services

The Task Force is content with the focus on ecosystem services and urges all focal points to contribute with national examples to the ICP Waters Ecosystem services report that is under progress.

Cooperation between ICP Waters and LTER Europe

The Task Force applauded the important work done by European Long-Term Ecosystem Research Network (LTER Europe; www.lter-europe.net), to support and sustain monitoring networks. Monitoring is the basis of the work done by ICP Waters, and the data that are collected are highly suitable for analysis of effects of climate change and air pollution. Increased cooperation is expected to be of mutual interest. For ICP Waters, it is particularly important to increase visibility and secure funding at the national level. The Task Force meeting urges all Focal centres to contact their national representative in LTER Europe to consider possibilities to include their sites in the LTER network.

Nitrogen

The Task Force noted several contributions from individual countries which demonstrated recent decrease in trends of aquatic nitrogen concentrations. Causal explanations include changes in nitrogen deposition and climate change. Continued monitoring of water chemistry is essential to understanding the fate of nitrogen in ecosystems.

Sulphur

The Task Force was impressed by country presentations showing the full story of chemical and biological effects of reduced sulphur deposition since the 1970s, underlining the success of emission reduction measures.

Dynamic modeling/critical loads

The Task Force was happy to see that empirical indicators of acidification status (presence/absence of fish) agreed very well with modeled acidification status of acid-sensitive lakes. Value of monitoring data was yet again proven.

EECCA

The Task Force urged the Programme centre to continue its effort in including EECCA countries in the Programme

1. The meeting of the International Cooperative Programme on Assessment and Monitoring of the Effects of Air Pollution on Rivers and Lakes (ICP Waters) was attended by 38 experts from the following Parties to the Convention on Long-range Transboundary Air Pollution (CLRTAP): Armenia, Austria, Canada, the Czech Republic, Estonia, Finland, Ireland, Italy, Latvia, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom and the United States of America. In addition the chair of the Working Group on Effects (WGE) and representatives for ICP Integrated Monitoring and ICP Modelling and Mapping participated. The list of participants is attached as **Annex I.**

Introductions

2. Mr. Marco Zacchero, Major of the city of Verbania (Italy) welcomed all participants to the ICP Waters meeting in Pallanza. He is also the president of the Committee of Fisheries of the Lake Lago Maggiore. The fish amount and species are varying from year to year in Lago Maggiore. He wishes us a fruitful meeting.
3. Ms. Berit Kvaeven (Norway), Chair of the Programme Task Force, thanked Mr. Marco Zacchero for opening the meeting and the warm welcoming words. She thanked Ms. Michela Rogora and Mr. Rosario Mosella (Italy) for inviting us. Then she welcomed all participants to the 28th Task Force Meeting of ICP Waters in Pallanza. New representatives from Czech Republic, Norway, Sweden, and Switzerland were specifically mentioned. The Chair of the WGE was welcomed.
4. The Task Force adopted the agenda of the meeting (**Annex II**).
5. Mr. Rosario Mosello, Director of CNR Institute of Ecosystem Study (Italy), welcomed us to Pallanza. He reminded us of the long history of cooperation in the ICP Waters network, which was extremely important for developing acid rain research. He gave short overview of the history and activities of the Institute of Ecosystem Study.
6. Ms. Michela Rogora (Italy) gave general information on the meeting and the excursion.
7. Mr. Rosario Mosello (Italy) gave a presentation on the Italian ICP Waters network with a focus on nitrogen. The Italian network consists of high-altitude lakes in Northern Italy and tributaries to Lago Maggiore. The high-altitude lakes receive high loads of pollutants, especially ammonia, with a decrease in wet nitrogen deposition in the last five or six years. River and lake nitrogen concentrations also show a tendency for recent declines, especially after 2004. Before 2004, nitrate concentrations in lakes and rivers were increasing. Deposition and climate effects (drought) are both considered as causes for the observed changes.
8. Mr. Peringe Grennfelt (Chair of WGE) reported from the Working Group on Effects (WGE) and Executive Body (EB). He gave a presentation on transboundary air pollution in perspective of environmental effects work.
   - Mr. Grennfelt underlined the importance of long-term data sets, such as compiled by each country that participates in ICP Waters. A tremendous amount of work is done under WGE, of high quality, with separate but also joint reports from the ICPs (http://www.unece.org/fileadmin/DAM/env/lrtap/WorkingGroups/wgs/ece_eb_air_wg_1_2012_13_E.pdf) which is very valuable for the work on the Convention. Mr. Grennfelt emphasized that the work undertaken in each country is at the basis of the activities in WGE. A challenge for the future is the visibility of the work under the ICPs. The WGE work was not used as a basis for the revision of the Gothenburg protocol.
   - Mr. Grennfelt reminded us of the history of acidification work. Observations of effects in the 1970s and before - fish death for instance - were at the basis for the Convention. The success of the Convention has depended on the close link between science and policy. The effect-based approach was special, different from for instance ‘most reduction for the lowest cost’ approach, which was advocated by industry. Critical loads of deposition were an important tool for the Convention.

- Today's situation of the Convention is summarized thus: the Gothenburg Protocol was revised in May 2012, and the HM protocol will be revised soon. The European Commission will put forward a new Thematic Strategy on Air Pollution in 2013. Another revision of the Gothenburg Protocol could be 5-7 years ahead. Until then, the work under WGE has the opportunity to contribute with reports and results relating to for example climate change, nitrogen, biodiversity, new concepts, air pollution at the hemispheric scale, and more advanced assessments.
- The Convention today has new challenges, opportunities and perhaps threats. The ongoing review identifies these, but sees a strong need for science in the future work (http://www.unece.org/fileadmin/DAM/env/documents/2012/EB/Informal_document_6_CLRTAP_subsid_bodies_review_24Sep2012_with_recommendations_from_final_summary_report_CLEAN.pdf), and considers the scientific bodies as vehicles for future development of traditional work and new challenges.
- The Action Plan under WGE and its Bureaux includes evaluation of subsidiary bodies under the Convention, further development of indicators, encouragement of the widest possible participation (EECCA and SEE countries). At present, the key scientific deliverables from the Convention are from the TF IAM. Contribution from the ICPs goes through the CCE, which makes the results from the ICPs rather invisible in the Convention work. Additionally, ICPs contribute to assessment reports. In the future, the evaluation group recommends assessment reports from all ICPs that go directly to the policy process. This implies a change in how work under the WGE is done. The question of merging WGE – EMEP was presented. Better collaboration is necessary, but there are several arguments pro and con merging. The expert group has not come to a recommendation, but the EB will take a decision in December. The expert group recommends a review of the ICPs in 2013.
- Work from the WGE was reported. Present and future items include ecosystem services. Also, the Task Force of Hemispheric Transport will organize a workshop of impacts of hemispheric pollution in November 2013 in India. WGE and EMEP will be organized back-to-back in 2013. At the next WGE-meeting the parties will be encourage to report on national WGE-activities.

9. Mr. Richard Wright (Norway) commented that the targets for S deposition under Gothenburg Protocol have been met, which is relevant for ICPs working with sulphur effects. Also, the ICP Forest results were used under the revision of the Convention.
10. Mr. Grennfelt suggested that the visibility of the ICP's might be increased in different ways, for instance nationally – to ensure that the negotiators of each contribution are oriented. Under the WGE, the ICPs should strive for more joint reports to the convention bodies.
11. Mr. Peringe Grennfelt (WGE) ended his presentation with a warm thank to Ms. Berit Kvaeven (Climate and Pollution Agency, Norway) for her long commitment to ICP Waters and the work under the Convention, since the start in 1985, and as a chair for ICP Waters since 1986, as this is her last meeting
12. Mr. Martin Forsius (Finland) reported from the ICP Integrated Monitoring Programme (ICP IM). Activities under the ICP IM involve a catchment and process-oriented approach and budget calculations. A special issue in Ambio was produced in 2012. The main work in 2012 was related to modelling S and N input-output budgets and critical loads, to demonstrate links between policy indicators and empirical thresholds. The comparison showed that exceedance of critical loads (CLs) and empirical indicators (pH, ANC, nutrient nitrogen) for aquatic ecosystems were consistent. For ground vegetation, the patterns were less clear. High exceedances appeared to be associated with more changes in ground vegetation indicators. For acidity, CLs were not exceeded at most sites. For nutrient N, CLs were exceeded at most sites. The work is documented in scientific papers. Changes in catchment retention were calculated for S and N. Most catchments retain almost 90-95% of deposited N, while now some catchments are releasing S, which was stored in the system from years of S deposition. The release of S delays surface water recovery.

13. Mr. Max Posch (the Netherlands) reported from the ICP Modelling and Mapping (ICP M&M). Some impacts of the revised Gothenburg Protocol were assessed, together with TFIAM. Exceedances of critical loads for acidity and nitrogen for 2005, 2010 and 2020 were shown. Less area will be exceeded if the Protocol is realized in 2020, but half of Europe will still be exceeded for nitrogen, and circa 5% for acidity. Much remains to be done for nitrogen. The NEC (national emission ceilings) directive was also assessed – for acidification, eutrophication and ozone. There are various methodological challenges, which results in different maps of exceedances, such as spatial resolution of deposition maps. Activities for 2013 were presented.

Workshop on LTER networks: challenges, perspectives and links with ICP Waters

14. Ms. Michela Rogora (Italy) opened the workshop and introduced the theme.

15. Ms. Allessandra Pugnetti (Italy) gave a presentation on the LTER-Europe network, which is associated with the EU Life programme and the EU project EnvEurope. The EnvEurope project is funded by the EU Life programme, which does not support research, but supports environmental policy and the knowledge base for environmental policy. EnvEurope was initiated in response to challenges of research in LTER-Europe. There are 11 LTER Europe partners, and 17 beneficiaries. EnvEurope is a network of sites (67 sites, from marine, terrestrial, freshwater, wetland ecosystems), with long-term dataseries, high quality intensive observations (and experiments). The aims include promotion of scientific understanding, synthesis, information (databases), education and outreach. No central funding is available, so the network has started with existing facilities (national networks) with LTER potential. LTER-Europe consists of 400 sites from very different ecodomains. The challenge is lack of comparability. The integration of information and methods from the different sites in EnvEurope is under development ('learning to be a network'). There are several technical actions concerning information management, (meta)databases, standardization and harmonization, testing in the field. Initiatives on data analyses include eutrophication and climate change, and N deposition and vegetation change.

16. Mr. Martin Forsius (Finland) reported from Finnish experiences with LTER activities. The Finnish LTER network is part of LTER Europe and ILTER. The theme areas are broad – from biodiversity to climate change to water cycle, etc. LTER Finland receives national funding. FinLTSER consists of 9 platforms, and include existing monitoring sites (ICP IM, ICP W, ICP Forests), and are spread all over the country and include all ecosystems, from coastal to urban. The Finnish research infrastructure process includes national proposals and also EU projects such as LifeWatch (www.lifewatch.eu). The LTER network was used in an EU project Vaccia, on vulnerability of ecosystem services and climate change. National and international funding is available for research infrastructure processes.

17. Ms. Michela Rogora (Italy) presented on activities from ICP W and LTER in Italy: long-term studies on remote lakes. LTER Italia consists of 22 sites, and part of ILTER since 2006. The work to create the network started in the late 1990s. Universities, research institutes, national and local authorities are involved. There are parent sites that include several research sites. In the mountain lakes, long-term changes that are reported are acidification and recovery, climate effects on lake chemistry, weathering effects on lake chemistry, biological recovery.

18. Ms. Heleen de Wit (Norway) reported from experiences with an LTER site in Norway. The LTER site is not part of LTER Europe. National funding and funding from the institute helped to create infrastructure at Langtjern. The long timeseries in combination with the new instrumentation makes Langtjenrn a very relevant site for types of networks like LTER Europe.

19. Mr. Hansjörg Thies (Austria) reported from LTER activities in Germany and Austria. Research activities and long-term records of environmental data (phosphorus, nitrogen, phytoplankton) at several sites were presented, and relations to climate and climate change were highlighted. The sites have high potential as LTER sites, but do not receive national long-term funding (even when it is an LTER site).

20. The Task Force meeting applauds the important work done by LTER Europe, to support and sustain monitoring networks. Monitoring is at the basis of the work done by ICP Waters, and the

data that are collected are highly suitable for analysis of effects of climate change and air pollution. Increased cooperation is expected to be of mutual interest. For ICP Waters, it is particularly important to increase visibility and secure funding at the national level.

- The Task Force meeting urges all focal points to contact their national representative in LTER Europe to consider possibilities to include their sites in the LTER network. The Programme Centre will add relevant information on LTER Europe on the ICP Waters homepage
- The Task Force meeting suggests that the Programme Centre contacts LTER Europe to get an overview of common sites in both networks
- The Task Force meeting recommends that the Programme Centre makes available to LTER Europe the ICP Waters manuals and also their experience with harmonization of data and trend analysis.

The 2012 ICP Waters report: Biodiversity – effects of air pollution and climate change

21. Mr. Gaute Velle (Norway) from the Programme Centre presented preliminary results from the new ICP Waters report on biodiversity of benthic invertebrates. The concept of biodiversity was introduced. It is crucial to define the level – genetic, species, ecosystem – that is considered. In the report, the focus in on the species level - all species, not just the sensitive ones. Diversity depends on sample size, and therefore harmonized sampling methodology is important. Alfa-diversity and beta-diversity include different types of biodiversity. There are many indices of biodiversity, and here the Shannon index was used. At a global scale, drivers of diversity are latitude (further south, more diversity) and disturbance. At the local scale, other factors enter such as temperature, water flow, TOC. The data in the report are from 5 countries, rivers and lakes, benthic invertebrates, and water chemistry is measured (not for all biological data). Much time was needed for data handling prior to analysis. The results indicated increasing biodiversity in German streams, and in Latvia, Sweden, Norway, but not in the UK. Acidification indices changes, while beta-diversity remained fairly constant. The species that come back (acid-sensitive) are not the dominant species. Relations with water chemistry were considered, and it was found that changes in biodiversity correlated with sulphate and nitrogen (nutrient status).
22. Ms. Brit Lisa Skjelkvåle (Norway) commented that the results are a very important contribution to the WGE and activity in ICP Waters, ploughing new earth with regard to combining changes in water quality to changes in biodiversity.
23. The Task Force meeting is impressed by the new data analysis and ongoing work regarding biodiversity.
    - Data presented at the Task Force meeting from several countries showed clear recovery of key species and communities of species in lakes and streams as a response to decreasing acidity in the water. By these measures biodiversity is improving
    - The Task Force meeting urges continued monitoring of biodiversity, by various metrics, in acid-impacted waters recovering from chronic acid deposition.

Heavy metals and POPs

24. Mr. Bjørn Olav Rosseland (Norway) gave a presentation on the importance of stable C and N isotopes for mercury in fish. Methylmercury is a neurotoxin, a large environmental hazard. Food chain data determining trophic position are essential for understanding the risk of MeHg contamination in fish. Stable N isotope data give that information. Stable C isotope data give information on diet carbon source (terrestrial vs. limnic). Fish species have very different diet preferences, and therefore very different stable isotope signatures, which can explain MeHg levels. There are large local differences. MeHg appear to be increasing, which could be related to TOC. Invasive species can lengthen the food chain, leading to higher MeHg at the highest trophic level. For all future studies of biomagnifying pollutants in fish, it is necessary to measure stable C and N isotopes – in particular it is necessary for trend assessments.

The 2013 ICP Waters report: economic evaluation of freshwater ecosystems

25. Ms. Silje Holen (Norway) gave a presentation of the structure and approach that will be used in the 2013 report on economic evaluation of damage to freshwater ecosystems caused by long-range transported air pollution. An economic view of acidification involves considering resource allocation and human welfare. The emitters of pollution (fossil fuels) do not pay the full cost of pollution, and therefore they 'overuse' the resources. Our welfare depends on ecosystem services and functions, which we can try to valuate, although many things in nature cannot be priced. The intention is to show that nature protection can be good economics. The framework for ecosystem services comes from the Millennium assessment. There are supporting, provisioning, regulating, cultural services. Ecosystem services of oligotrophic lakes and rivers at risk for acidification are drinking water, food supply, genetic resources, carbon sequestration, recreation, tourism, fishing, biodiversity, habitat. Monetized impacts are lost fish stocks, reduced tourism, liming, etcetera. Strengths and weaknesses of different methods for valuation of services were discussed. Examples of valuation of the acidification effect on the Atlantic salmon and of recreation related to water bodies were given.
26. Comments included – why not include mercury in fish? Mr. Peringe Grennfelt (Sweden) asks what could be gained from a wider ICP approach, about the time perspective – because the EU commission needs this input.
27. Ms. Brit Lisa Skjelkvåle (Norway) commented that the report will be finished in the spring 2013, with a draft ready before the WGE meeting in February. She urged the Task Force to contribute with examples of ecosystem valuation, from the grey literature, from different parts of Europe and North America.
28. A scientific question: can we separate problems to nitrogen from problems related to sulphur. This could have been useful because we need to address the problems of nitrogen more specifically. Answer: nitrogen for acidification is not the biggest problem, and does not seem to be increasing. Still, we need to mention nitrogen. Eutrophication is also important, and here nitrogen plays a role. Eutrophication of coastal areas is also related to leaching of N. Industry has a different perspective: the cost of having a bad image (think of Bhopal) as polluters.
29. Mercury is also an important air pollution with effects on human health.
30. The Task Force meeting is content with the focus on ecosystem services and urges all focal points to contribute with national examples.

Water chemistry

31. Mr. Luca Colombo (Switzerland) gave a presentation on chemical recovery in alpine lakes in Italy and Switzerland. The time series are 30 years long. The area is highly impacted by air pollution, mostly from the Po area in Northern Italy. The lakes are clustered in the Alps around the Swiss-Italian border, with circa 20 on each side, above the treeline between 1700 and 2800 m altitude. The lakes vary in acid-sensitivity. A regional trend analysis for the sensitive lakes show increases in pH and alkalinity, mixed trends for sulphate, and dominating downward trends for nitrate. In sensitive lakes, there was a typical pattern showing chemical recovery. Deposition shows declining sulphate and nitrogen. Snow cover also affects recovery – and winters vary between snow poor and snow rich. After snow-rich winters, alkalinity and base cations were lower. Recovery is clear, but some lakes are still very acid with low pH and buffer capacity. Work in progress includes dynamic modelling, determining preindustrial pH and pH under different emission scenarios. At present, nitrate is the dominating acidifying ion at these high-altitude lakes. It was commented that the dilution of water chemistry after a snow rich winter can inhibit spawning and survival of young of the year, which would be interesting to monitor.
32. Mr. Hansjörg Thies (Austria) presented water chemistry data from high mountain freshwaters on crystalline bedrock in Germany and Austria. These freshwaters are affected by meltwaters from

active “rock glaciers”, which are a widespread form of alpine permafrost, sensitive to climate warming. Headwater lake chemistry has been impacted by melting rock glaciers, as demonstrated by higher solute concentrations. Sulphur deposition in the Central Eastern Alps has declined strongly, and is no longer a main driver of lake chemistry. High concentrations of heavy metals are found in lakes, exceeding drinking water limits, which are related to rock glacier melting. A research project is conducted where cores from the rock glaciers are collected and analysed chemically. The melting of rock glaciers in high mountain regions is a clear symptom of climate warming and are a concern for lake acidification and drinking water quality

33. Mr. John Gunn (Canada) gave a presentation on chemical and biological recovery of acid and metal contaminated lakes near the smelters of Sudbury in Canada. The Sudbury smelters were one of the largest point source of sulphur emissions globally, and were located in an acid-sensitive area with over 7000 lakes. Lakes were studied around the smelters, still showing increased heavy metal concentrations. Forests were heavily damaged, and now conditions have much improved. Emissions of sulphur have been reduced to a small fraction of the levels in the 1960s, and now lake sulphate is no longer much affected by emissions from the smelter. Now, the biological recovery is nearing a complete state (fish, invertebrates). Calcium levels are declining to below levels necessary for invertebrates, lower than preindustrial levels. Now, forest reestablishment effects on lakes are studied. Climate is warming in Sudbury, resulting in drought, which resets recovery. Acid episodes occur after droughts, and this effect is stronger because of forest reestablishment. Surface wind speed declines because of forest growth, affecting thermal stratification of lakes, resulting in cooler lakes. DOC has tripled in some lakes since the 1980s, which also affect the thermal structure of the lakes. Phytoplankton community changed towards reference conditions. Zooplankton richness has recovered. Urban disturbances (road salt) can trigger biological recovery (if the populations survive). Fish and beavers are recolonizing the areas. This is all good, but some people still value fish-free lakes because of privacy are now disturbed by fishers. However, birds (loons) need fish, which again warms the hearts of the lake-owners (relevant for ecosystem service valuation). The improvements for reducing emissions in industry have often been beneficial for the industry (better image, lower production costs, higher profits), because of forced innovation and better, cleaner and more energy-effective production methods. There is a need for more sensitive indicators to document effects of the last 5% reduction of pollution, such as organisms, genomics, DOM properties. A catchment manipulation experiment is done to study effects of forest and forest management. Presence of wetlands is important for the colonization of sensitive organisms. More information on www.livingwithlakes.ca

Biological response

34. Ms. Sandra Steingruber (Switzerland) gave a presentation on macroinventebrates as indicators for acidification in high-altitude alpine lakes. Taxonomic groups were identified, and were very different between lakes of varying acid-sensitivity. Varying indices were used to describe the macro-invertebrate communities. Some groups of macro-invertebrates were changing and were correlated with pH. Both lake outlets and littoral zones were studied. The communities in the outlets were most sensitive and better indicators of acidity. Communities in littorals did not change so much, probably in part because the species living there are not very sensitive to acidification.

35. Ms. Zuzana Horicka (Czech Republic) gave a presentation on biological recovery of reservoirs and their tributaries in the Jizera Mountains in North Bohemia in the Czech Republic for the period 1992 to 2011. The water bodies are located in the region that was formerly known as the Black Triangle. The dead forests, spruce monocultures, were clear-cut. Chemical and biological recovery must be seen in context of clear-cutting, reforestation, high natural acidity, fish restocking, liming and low nutrient status. The clear-cutting of the forest resulted in high nitrate and lowering of pH. Phytoplankton biomass has decreased (related to a species change), but the number of phytoplankton species have increased. Some zooplankton records go back to the 1920s. Some changes in zooplankton species are happening, partly related to re-establishment of char (which was related to liming). Brown trout disappeared in the lakes in the early 1900s, and brook

char was introduced in the early 1990s. The lakes were fishless in between. Minnow was introduced in 2007. The char population survived the 1990s because of the tributaries and thermal stratification, with suitable chemistry. Aluminium concentrations are still high enough to cause deformations in fish gills. Recent fast forest growth may lead to renewed, but less intense, acidification. Modelling lake chemistry with the MAGIC model with forest growth suggests that Al concentrations may increase in the future.

36. Mr. Godtfred Anker Halvorsen (Norway) gave presentation on the effects on benthic invertebrates after acid aluminium treatment against the salmon parasite *Gyrodactylus salaris* in the river Lærdalselva in Western Norway. The invertebrates (key species and community composition) are sensitive to the aluminium addition, and it takes more than half a year to recover to the pre-treatment level.

37. The Task Force noted several contributions from individual countries which demonstrated recent decrease in trends of aquatic nitrogen concentrations. Causal explanations include changes in nitrogen deposition and climate change. Continued monitoring of water chemistry is essential to understanding the fate of nitrogen in ecosystems.

38. The Task Force was impressed by country presentations showing the full story of chemical and biological effects of reduced sulphur deposition since the 1970s, underlining the success of emission reduction measures.

Dynamic modelling / Critical Loads

39. Mr. Jens Fölster (Sweden) gave a presentation on correspondence between biological recovery observations and modelling effects of acidification, with specific focus on roach. The work is relevant for the Water Framework Directive, to determine ‘reference conditions’. The lakes were classified as acidified based on MAGIC modelling and on the Swedish fish database, and both classifications were compared. The approaches gave comparable results. Some anomalies between fish and model results existed, which had plausible explanations such as fish migration and weaknesses in the fish database, and weaknesses in estimation of pH in high-DOC lakes. This study validates the model results and the use of the model for modelling reference conditions.

40. Mr. Julian Aherne (Ireland) gave a presentation on the status of Irish rivers and lakes. The data from Irish rivers are now again updated in the ICP Waters database. There is relatively little air pollution in Ireland due to the dominance of westerly winds. The lakes are now also included in the Water Framework Directive monitoring. The monitoring includes rivers, inlets, mid-lake chemistry and also deposition, and soils. The data show responses to changing deposition and climate.

Intercalibration/intercomparison

41. Ms. Bente Wathne (Norway) gave a presentation on the Chemical intercomparison 1226. 68 laboratories from 26 countries participated. All usual variables were included, and also aluminium and TOC. The quality of results was similar to former years. In total 74% of all results were acceptable. Lead and TOC had the lowest scores. Sodium, manganese, cadmium and copper showed the best results and the worst was alkalinity. Improvements should be made for some variables. Also, concentrations close to the detection limit can give problems, suggesting that some laboratories should employ more sensitive methods. It is suggested to ship the samples earlier (April/May rather than June).

42. Mr. Arne Fjellheim (Norway) gave a presentation of the biological intercalibration. Three laboratories participated in the Biological intercalibration 2012. The laboratories identified a high portion of the individuals in the test samples, usually > 95% of the total number of species. The quality of the identification of the different groups was above the level of acceptance for all laboratories. The taxonomic quality was sufficient for stating the acidity index. The average Quality assurance index ranged between 88 and 98, well above the target value at 80 - indicating good taxonomic work.

Reports from the ICP Waters Programme activities 2011/2012 and workplan

43. Ms. Brit Lisa Skjelkvåle (Norway) reported on recent achievements from the ICP Waters activities in 2011/2012. She gave a résumé of the main results from the last TF meeting, showed the aims of the Programme and described its main activities. The status of participation and data collection as of October 2012 is shown in Annex III. The participation in the Task Force meeting is declining slightly, but the number of sites for which data are delivered is stable or slightly increasing. New data for sites both in Austria and Ireland have been included in 2012, and we will also receive data from Montenegro. Participation in the chemical intercomparison and biological intercalibration is stable.

44. Ms. BL Skjelkvåle (Norway) reported on representation of ICP Waters in other bodies/meetings under the Convention:

- Joint expert group on dynamic modelling, Sitges, Spain, October 2012
- Working group on Effects, Extended bureau, Geneva, February 2012
- Workshop Coordination Centre for Effects, Warszawa, April 2012
- Task Force meeting of ICP IM, Kaunas, Lithuania, May 2012
- Joint EMEP/ Working group on Effects Workshop Geneva September 2012
- Working group on Effects, Extended bureau meeting, Geneva, September 2012.
- Meeting of lead countries of ICPs, Berlin, October 2012
- There was also a Swedish/Norwegian intercalibration workshop on invertebrates in February in Bergen, Norway.

45. Ms. Brit Lisa Skjelkvåle (Norway) provided information on the most important 2011 and 2012 publications presenting the results of ICP Waters. The following documents were mentioned:

- ICPW106/2011. Skjelkvåle, B.L. and de Wit, H.A. (eds) Trends in precipitation chemistry, surface water chemistry and aquatic biota in acidified areas in Europe and North America from 1990 to 2008.
- ICP Waters report 108/2011. Wright, R.F., Helliwell, R., Hruska, J., Larssen, T., Rogora, M., Rzychoñ, 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 SNO 6243-2010.
- ICP Waters report 109/2011. Fjellheim, A., Johannessen, A., Svanevik Landås, T. Biological intercalibration: Invertebrates 1511.
- ICP Waters report 110/2012. Skjelkvåle, B.L. Wathne B.M., Moiseenko, T. Proceedings of the 27th meeting of the ICP Waters Programme Task Force in Sochi, Russia, October 19 – 21, 2011.
- ICP Waters report 111/2012. Dahl, I. Intercomparison 1226: pH, Cond, HCO3, NO3-N, Cl, SO4, Ca, Mg, Na, K, TOC, Al, Fe, Mn, Cd, Pb, Cu, Ni, and Zn.
- Draft report: Freshwater biodiversity in a changing environment
- The following other written contributions were also mentioned, i.e. the contribution to the WGE Joint report from all ICPs: "Impacts of air pollution on ecosystems, human health and materials under different Gothenburg Protocol scenarios", reporting to WGE, and the new «Impacts brochure» from WGE. This brochure is available from the Programme Centre.

46. Ms. Skjelkvåle (Norway) presented how findings from ICP Waters are reported to WGE, i.e. new findings and reports of particular interest to the Convention, and interactive effects between air pollution and other environmental problems (biodiversity, climate change).

47. Ms. BL Skjelkvåle (Norway) reported on participation with EECCA countries, that we have good cooperation with Russia and that cooperation with Armenia started last year.

48. Ms. BL Skjelkvåle (Norway) reported on cooperation with bodies within and outside the Convention. LTER Europe and EU Water Framework Directive are two bodies outside the convention. At present, there is little contact with EU projects, but there is some contact with Refresh and Biofresh (two EU projects).

Workplan

49. Ms. BL Skjelkvåle (Norway) presented the 2013 Workplan for ICP Waters (Appendix IV). The Task Force approved the workplan. The Programme Centre will add papers to the list of papers published by ICP Waters at the webpage, but it was suggested to limit the papers to those that acknowledge ICP Waters (or mention ICP Waters in the materials and methods). The possible themes for 2014 were presented. It is suggested to include more data in the trend assessment than only ICP Waters sites. This suggestion is approved of.

Other Business

50. Mr. Jakub Hruska (Czech Republic) oriented that the Czech Republic may have the possibilities to host the Task Force meeting 2013, if possible in south Bohemia in Ceský Krumlov.
51. Ms. Kvaeven (Norway) thanked Mr Hruska (Czech Republic) for offering to organize the next Task Force meeting.
52. Ms. Kvaeven (Norway) thanked the organizing committee, especially Ms. Michela Rogara and Mr. Rosario Mosello for the excellent organization of the Task Force meeting. All participants were thanked for attending the meeting and for contributing to the discussions. The Programme Centre was thanked for the preparation of the scientific programme for the meeting. Mr. Gunnar Skotte, at the Climate and Pollution Agency (Klif, Norway) will take over as Chair for ICP Waters, after the present Chair, Ms. Berit Kvaeven, retires in December this year. Ms. Berit Kvaeven, also at Klif, has been the Chair of ICP Waters since the first Task Force meeting in 1986.
53. The Task Force expressed its appreciation to the Programme Centre for its scientific and coordinating work and acknowledged its important contribution to the programme's successful implementation. It again stressed the importance of the continuing contributions of the National Focal Centres and cooperating institutes and the essential role in ensuring the high quality of the overall programme results.
54. The Task Force also expressed its appreciation and thanks for the longlasting work of Ms Kvaeven for chairing the ICP Waters and The Task Force meetings steady and with enthusiasm since 1986.

Adoption of the minutes

55. The Task Force meeting adopted the Minutes.

Annex I: Participants at the ICP Waters 27th Task Force meeting

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Annex II: Agenda for the 28th Task Force ICP Waters October 8-10, 2012

1. **Introductions**
   - Meeting welcome;
     - *Rosario Mosello, Director of CNR Institute of Ecosystem Study*
     - *Marco Zacchera, Major of the city of Verbania*
   - Adoption of the agenda, Berit Kvaeven, ICP Waters Chair
   - General information about the meeting and excursion*, Michela Rogora, Italy*
   - Results from the Italian ICP Waters network: a focus on nitrogen. *Rosario Mosello, Italy*
   - Reports from the Executive Body, Working Group on Effects and work undertaken by the Bureau of Working Group on Effects, *Peringe Grennfelt, Working Group on Effects Chair*
   - Reports from ICP IM, *Martin Forsius, Finland*
   - Report from ICP M and M, *Max Posch, The Netherlands*
2. **Workshop on LTER (Long-term ecological research) networks: challenges, perspectives and links with ICP waters**
   - Looking for harmony in the LTER-Europe network: the Life + project EnvEurope. *Alessandra Pugnetti, Italy*
   - LTER activities in Finland, *Martin Forsius, Finland*
   - ICPW and LTER in Italy: long-term studies on remote lakes, *Michela Rogora, Italy*
   - Long ecological research site Langtjern in Norway: evolving science, evolving monitoring, *Heleen de Wit, Programme centre, Norway*
   - LTER activities in Germany and Austria. *Hansjörg Thies, Austria*
   - Discussion; ICPW has an impressive network of long-term surface water study sites, mainly for chemistry but also for biology. How can a cooperation towards LTER contribute to secure existing monitoring networks
3. **The 2012 ICP Waters report: Biodiversity - effects of air pollution and climate change**
   - Freshwater biodiversity in a changing environment, *Gaute Velle, Programme subcentre, Norway*
4. **Heavy metals and POPs**
   - Stable isotopes of N and C are needed to understand mercury levels in different fish communities. *Bjørn Olav Rosseland, Programme centre, Norway*
5. **The 2013 ICP Waters report: Economic evaluation of freshwater ecosystems**
   - Economic evaluation of damage to freshwater ecosystems caused by long-range transported air pollution, *Silje Holen, Programme centre, Norway*
6. **Water chemistry**
   - Are Alpine lakes really recovering from acidification? An analysis of the main factors affecting long-term changes in high altitude lakes chemistry over 30 years. *Luca Colombo et al., Switzerland and Italy*
   - High mountain freshwaters on crystalline bedrock. Pristine as a crystal ? *Hansjörg Thies, Austria*
   - Chemical and Biological Recovery of Acid and Metal Contaminated Lakes near the Smelters in Sudbury, Canada. John Gunn, Canada
   - Does modelling of acidification correspond to a century of biological observations? Comparing the MAGIC model and presence of roach. JensFølster, Sweden
7. **Biological response**

- Macroinvertebrate as indicators for acidification in high altitude Alpine lakes. Sandra Steingruber, Switzerland
- Biological recovery of reservoirs in the Jizera Mountains (North Bohemia, Czech Republic) and their tributaries from acidification (1992 - 2011). *Zuzana Horicka et al. Czech republic*
- Acid aluminium treatment against the salmon parasite Gyrodactylus salaris Malmberg in the river Lærdalselva, 2005 - 2006. Effects on the benthic invertebrates. *Godtfred Anker Halvorsen and Einar Heegaard, Programme subcentre, Norway*

8. Dynamic modelling/critical loads

- Does modelling of acidification correspond to a century of biological observations? Comparing the MAGIC model and presence of roach. *JensFølster, Sweden*
- Irish acid-sensitive lake, a n update, *Julian Ahern, Ireland*

9. Intercalibration/intercomparison

- Chemical intercomparison, *Bente Wathne, Programme centre*
- Biological intercalibration, *Arne Fjellheim, Programme subcentre*

10. ICP Waters reporting

- Report from the ICP Waters Programme 2011/2012, *Brit Lisa Skjelkvåle, Programme centre*
- Draft 2013 Workplan, Programme centre, *Brit Lisa Skjelkvåle, Programme centre*

11. Other Business

- TF meeting 2013
- Adoption of the minutes
- Final words

Annex III: Status of participation in the ICP Waters programme as of October 2012

	Chemical data	Biological data	Participation in TF meetings 2010-2012	Participating in chemical intercomparison	Participating in biological intercalibration
Armenia			●		
Austria	2012		●	●	
Belarus	2011				
Canada	2012		●	●	
Croatia			●		●
Czech Rep.	2012	●	●	●	●
Estonia	2012		●	●	●
Finland	2012	●	●	●	●
France			●	●	
Germany	2012	●	●	●	●
Ireland	2012		●	●	
Italy	2012		●	●	
Latvia	2012	●	●	●	●
Montenegro	2012				
Netherlands			●		
Norway	2012	●	●	●	●
Poland	2012	●	●	●	
Russia			●	●	
Spain	2012		●	●	
Sweden	2012	●	●	●	●
Switzerland	2012	●	●	●	●
UK	2011	●	●	●	●
USA	2012		●	●	
Total	**18**	**9**	**21**	**18**	**10**
Belgium				●	
Iceland				●	
Lithuania				●	
Portugal				●	
Romania				●	
Slovenia				●	
Indonesia				●	
Japan				●	
Thailand				●	

Annex IV: ICP Waters workplan for 2012–2013

- Finalize the report on: Biodiversity changes – effects of air pollution and climate change
  - Draft report finish by 1. December
  - Comments back from Task Force members **by 15. January**
  - Special reviewers: John Stoddard, Jens Følster
  - **Finalize before 15. February 2013**
- Finalize the report on Ecosystem services of acid sensitive surface waters in Europe and North America
  - Draft report finish by 15. February
  - Comments back from Task Force members **by 15. March**
  - Special reviewers: John Gunn, Martin Forsius
  - **Finalize before 15. May 2013**
- Prepare proceedings from the 28th Task Force meeting
  - abstracts (2-6 pages) **by 1.December**
  - Include all the presentations on LTER with recommendations from the WS
  - Send to Bente Wathne : bmw@niva.no
- Arrange and report chemical intercomparison 1226
  - in collaboration with all ICPs
  - Samples will be sent out **by approx. 1. May**
  - Responsible person: Ivar Dahl, NIVA
- Arrange and report biological intercalibration 1612
  - in collaboration with all ICPs
  - Samples will be sent out approx.
  - Responsible person: Arne Fjellheim, UNI Miljø
- Arrange twenty-ninth meeting of the Programme Task Force, tentatively scheduled to be held in autumn 2013, and its reports
- Run the Programme Centre in Oslo and the Subcentre in Bergen, including:

  → Maintenance of web-pages
  - All presentations from the 28th TF meeting on the web-page
  - All papers using data from ICP Waters sites shall be listed on our web on your request – one limitation: the word ICP Waters has to be mentioned in the paper somewhere.

  → Maintenance of database
  - All Focal centres should submit data to the Programme Centre **by June 15th 2013** to Bente Wathne: bmw@niva.no
- Participating in meetings of relevance for the programme and reporting to WGE
- Contribute to the Common Workplan items of the Working Group on Effects
  - In particular to the joint WGE-report on Ecosystem services
- Cooperation with other bodies within and outside the Convention such as the LTER-network, EU-projects, and other relevant organisations.
- Increase the Cooperation with ECCCA countries (East Central Caucasus and Central Asian countries)
- **New items (suggestions):**
  - **2013:** Start a new trend assessment (chemistry and biology) up to 2012 picking up some of the threads from the work on the biodiversity report.
  - **2014:** What is happening with Nitrogen in the waters and the catchments?? or

  A review of old and new policy relevant indicators?

10. Reports and publications from the ICP Waters Programme

All reports from the ICP Waters programme from 2000 up to present are listed below. Reports before year 2000 can be listed on requet. All reports are available from the Programme Centre. Reports and recent publications are also accessible through the ICP-Waters website; http://www.icp-waters.no/

Fjellheim, A., Johannessen, A., Svanevik Landås, T. 2012. Biological intercalibration: Invertebrates 1612. NIVA-report SNO 6454-2012,**ICP Waters report 111/2012.**

Skjelkvåle, B.L., Wathne B. M. and Moiseenko, T. (eds.) 2010. Proceedings of the 27th meeting of the ICP Waters Programme Task Force in Sochi, Russia, October 19 – 21, 2011. **ICP Waters report 110/2012**

Fjellheim, A., Johannessen, A., Svanevik Landås, T. 2011. Biological intercalibration: Invertebrates 1511. NIVA-report SNO 6264-2011,**ICP Waters report 109/2011.**

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.**

Dahl, I and Hagebø, E. 2011. Intercomparison 1125: pH, Cond, HCO3, NO3-N, Cl, SO4, Ca, Mg, Na, K, TOC, Al, Fe, Mn, Cd, Pb, Cu, Ni, and Zn. NIVA-report SNO 6222-2011. **ICP Waters report 107/2011.**

Skjelkvåle B.L. and de Wit, H. (Eds). 2011. Trends in precipitation chemistry, surface water chemistry and aquatic biota in acidified areas in Europe and North America from 1990 to 2008. NIVA-report SNO 6218-2011 **ICP Waters report 106/2011.**

ICP Waters Programme Centre 2010. ICP Waters Programme manual. NIVA SNO 6074-2010.**ICP Waters report 105/2010**. 91 s. ISBN 978-82-577-5953-7,

Skjelkvåle, B.L., Wathne B. M. and Vuorenmaa J. (eds.) 2010. Proceedings of the 26th meeting of the ICP Waters Programme Task Force in Helsinki, Finland, October 4 – 6, 2010. **ICP Waters report 104/2010**

Fjellheim, A. 2010. Biological intercalibration: Invertebrates 1410. NIVA-report SNO 6087-2010, **ICP Waters report 103/2010.**

Hovind, H. 2010. Intercomparison 1024: pH, Cond, HCO_3, NO_3-N, Cl, SO_4, Ca, Mg, Na, K, TOC, Al, Fe, Mn, Cd, Pb, Cu, Ni, and Zn. NIVA-report SNO 6029-2010. **ICP Waters report 102/2010.**

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**

Skjelkvåle, B.L., De Wit, H and and Jeffries, D. (eds.) 2010. Proceedings of presentations of national activities to the 25th meeting of the ICP Waters Programme Task Force in Burlington, Canada, October 19-21 2009. NIVA-report SNO 5995 - 2010. **ICP Waters report 100/2010.**

Fjellheim, A. 2009. Biological intercalibration: Invertebrates 1309. NIVA-report SNO 5883-2009, **ICP Waters report 99/2009.**

Hovind, H. 2009. Intercomparison 0923: pH, Cond, HCO_3, NO_3-N, Cl, SO_4, Ca, Mg, Na, K, TOC, Al, Fe, Mn, Cd, Pb, Cu, Ni, and Zn. NIVA-report SNO 5845-2009. **ICP Waters report 98/2009.**

Ranneklev, S.B., De Wit, H., Jenssen, M. T. S. and Skjelkvåle, B.L., 2009. An assessment of Hg in the freshwater aquatic environment related to long-range transported air pollution in Europe and North America. NIVA-report SNO 5844-2009. **ICP Waters report 97/2009.**

Skjelkvåle, B.L., Jenssen, M. T. S. and De Wit, H (eds.) 2009. Proceedings of the 24th meeting of the ICP Waters Programme Task Force in Budapest, Hungary, October 6 – 8, 2008. NIVA-report SNO 5770-2009. **ICP Waters report 96/2008.**

Fjellheim, A and Raddum, G.G. 2008. Biological intercalibration: Invertebrates 1208. NIVA-report SNO 5706-2008, **ICP Waters report 95/2008**

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.**

Hovind, H. 2008. Intercomparison 0822: pH, Cond, HCO_3, NO_3-N, Cl, SO_4, Ca, Mg, Na, K, Fe, Mn, Cd, Pb, Cu, Ni, and Zn. NIVA-report SNO 5660-2008. **ICP Waters report 93/2008.**

De Wit, H. Jenssen, M. T. S. and Skjelkvåle, B.L. (eds.) 2008. Proceedings of the 23rd meeting of the ICP Waters Programme Task Force in Nancy, France, October 8 – 10 , 2007. NIVA-report SNO 5567-2008. **ICP Waters report 92/2008.**

Fjellheim, A and Raddum, G.G. 2008. Biological intercalibration: Invertebrates 1107. NIVA-report SNO 5551 – 2008, **ICP Waters report 91/2008**

Hovind, H. 2007. Intercomparison 0721: pH, Cond, HCO3, NO3-N, Cl, SO4, Ca, Mg, Na, K, Fe, Mn, Cd, Pb, Cu, Ni, and Zn. NIVA-report SNO 5486-2007. **ICP Waters report 90/2007**

Wright, R.F., Posch, M., Cosby, B. J., Forsius, M., and Skjelkvåle, B. L. 2007. Review of the Gothenburg Protocol: Chemical and biological responses in surface waters and soils. NIVA-report SNO 5475-2007. **ICP Waters report 89/2007**

Skjelkvåle, B.L., Forsius, M., Wright, R.F., de Wit, H., Raddum, G.G., and Sjøeng, A.S.M. 2006. Joint Workshop on Confounding Factors in Recovery from Acid Deposition in Surface Waters, 9-10 October 2006, Bergen, Norway; Summary and Abstracts. NIVA-report SNO 5310-2006. **ICP Waters report 88/2006.**

De Wit, H. and Skjelkvåle, B.L. (eds). 2007. Trends in surface water chemistry and biota; The importance of confounding factors. NIVA-report SNO 5385-2007. **ICP Waters report 87/2007.**

Hovind, H. 2006. Intercomparison 0620. pH, K25, HCO3, $NO_3 + NO_2$, Cl, SO_4, Ca, Mg, Na, K, total aluminium, aluminium - reactive and nonlabile, TOC, COD-Mn. Fe, Mn, Cd, Pb, Cu, Ni and Zn. NIVA-report SNO 5285-2006. **ICP Waters report 86/2006.**

Raddum, G.G. and Fjellheim, A. 2006. Biological intercalibration 1006: Invertebrate fauna. NIVA-report SNO 5314-2006, **ICP Waters report 85/2006.**

De Wit, H. and Skjelkvåle, B.L. (eds.) 2006. Proceedings of the 21th meeting of the ICP Waters Programme Task Force in Tallinn, Estonia, October 17-19, 2005. NIVA-report SNO 5204-2006, **ICP Waters report 84/2006.**

Wright, R.F., Cosby, B.J., Høgåsen, T., Larssen, T., Posch, M. 2005. Critical Loads, Target Load Functions and Dynamic Modelling for Surface Waters and ICP Waters Sites. NIVA-report SNO 5166-2005. **ICP Waters report 83/2006.**

Hovind, H. 2005. Intercomparison 0317. pH, K25, HCO3, NO3 + NO2, Cl, SO4, Ca, Mg, Na, K, total aluminium, aluminium - reactive and nonlabile, TOC, COD-Mn. Fe, Mn, Cd, Pb, Cu, Ni and Zn. NIVA-report SNO 5068-2005. **ICP Waters report 82/2005**

Raddum, G.G. 2005. Intercalibration 0307: Invertebrate fauna. NIVA-report SNO 5067-2005. **ICP Waters report 81/2005**

De Wit, H. and Skjelkvåle, B.L (eds.). 2005. Proceedings of the 20th meeting of the ICP Waters Programme Task Force in Falun, Sweden, October 18-20, 2004. NIVA-report SNO 5018-2005, **ICP Waters report 80/2005.**

Fjeld, E., Le Gall, A.-C. and Skjelkvåle, B.L. 2005. An assessment of POPs related to long-range air pollution in the aquatic environment. NIVA-report SNO 5107-2005, **ICP Waters report 79/2005.**

Skjelkvåle et al 2005. Regional scale evidence for improvements in surface water chemistry 1990-2001. *Environmental Pollution, 137: 165-176*

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